ANATOMICAL SIGNIFICANCE OF CERVICAL SPINE IN *MANYĀSTAMBHA*.

A thesis submitted to

TILAK MAHARASHTRA VIDYAPEETH, PUNE.

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Annexure III

Tilak Maharashtra Vidyapeeth, Pune

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I **Vd. Dinesh Balkrishna Naik** is the Ph. D Scholar of the Tilak Maharashtra Vidyapeeth in **Rachana Sharir** subject. Thesis entitled **Anatomical Significance of Cervical Spine in *manyāstambha*** under the supervision of **Prof. Vd. Prashant Anant Suru**, solemnly affirm that the thesis submitted by me is my own work. I have not copied it from any source. I have gone through extensive review of literature of the related published / unpublished research works and the use of such references made has been acknowledged in my thesis. The title and the content of research is original.

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It is certified that work entitled- **ANATOMICAL SIGNIFICANCE OF CERVICAL SPINE IN *MANYĀSTAMBHA*.**
is an original research work done by **VD. DINESH BALKRISHNA NAIK**
Under my supervision for the degree of Doctor of Philosophy in **RACHANA SHARIRA**
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-Vd. Dinesh Balkrishna Naik

ANATOMICAL SIGNIFICANCE OF CERVICAL SPINE IN *MANYĀSTAMBHA*.

Abstract

Key Words- *racanā śārīra, manyāstambha, vāta dosha, vatavikāra, cervical spine.*

Introduction

Normal physiological activities occur within anatomically normal organs. Hence structural abnormalities of an organ with respect to either structural involvement or abnormal structural modification or both as a result of the action of vitiated *dosha* are responsible to develop many diseases. The neck is a multipart structure. As far as *manyāstambha* is concerned the anatomy of cervical spine formed by the vertebrae, their joints, attached ligaments, muscles, spinal cord, nerves, blood vessels play a significant role. Functionally cervical spine is a very dynamic region of the body for the movement of the head and neck.

The degeneration starts much earlier in the neck. It is very much essential to find out structural involvement and changes in the cervical spine before deciding Ayurvedic line of treatment.

Various principles in *Āyurveda* like *mahābhūtas and dosha-dushya* as well as concepts of *sārira* e.g. *asthi, sandhi, snāyu, māmsa, peśī, kalā, srotas, sirā, dhamanī, avayava* etc.as well as *samprāpti* of certain diseases which produce symptoms found in *manyāstambha e.g. shūla, sraṉsa, swāpa, harsha etc.* are very important and useful to understand *manyāstambha.*

Aim

To find the significance of anatomical structures of cervical spine in the signs and symptoms of *manyāstambha.*

Objectives

To find the involvement and abnormal structural changes of cervical spine in *manyāstambha* with the help of MRI reports.

Study design

Observational and cross-sectional study.

Literature study

From the literature study the effort has been made to border the possible progression of affections to the cervical spine by the actions of vitiated *dosha* in its various parts. The factors vitiating *vāta* produce degeneration in the cervical spine.

According to the concept of *āṣraya āsrayi* relationship; when *vāta* gets contaminated it causes *asthi* related diseases. *Vāyu* finds favourable environment in *asthi* and *majjā. Vāyu* gets aggravated and filling up the channels and *vātavaha sirā* of cervical spine produces disorders.

Morbid affection of *asthi* and *majjā* in cervical spine develops- *adhyasthi, asthibheda, asthiṣūla, parva rujā, bhrama, mūrchā, tamo darśana* etc. The affection of many joints in the spine can also be caused due to loss of normal functions of *kapha dosha* i.e. *sneha, bandha, sthiratva, sandhisanṣleshaṇa.*

The muscles, ligaments, tendons, blood vessels, nerves in the neck get affected by vitiated *vāta dosha* predominantly with accompanying *kapha* and *pitta* and develop *manyāstambha* and other symptoms.

Here alternate *samprāpti* can also be considered. In the state of reduced *kapha, vāta* emigrates the normally located *pitta.* It develops *bheda, dāha, śrama* and *daurbalya*. In other form *pitta* produces *dāha* and *śūla* obstructing *vāta*.

Manyāstambha and its symptoms are found in various diseases described in *Āyurveda.* Their study helps us to understand the pathology of *manyāstambha* and its symptoms. *Manyāstambha* in the present study is a chronic disease.

Study of these symptoms helps us to understand the pathology for the development of various symptoms of *manyāstambha.* These are *ardhāvabhedaka, vātaj shiroroga, hasta- pāda dāha, hasta- pāda harsha, ekaṅgavāta, sarvāṅgavāta, antarāyām and bahirāyām.*

We get structural details of cervical spine from the modern anatomy is the first step in the comprehensive study of *manyāstambha.* Various disorders of cervical spine are sorted out from the modern medicine text according to our inclusion criteria e.g. cervical spondylosis, spondylosis deformans etc. From that we get the detail description of anatomical structural involvement, affections and structural changes in each part of the cervical spine.

Understanding of the pathological processes and their effects developed in the anatomical structures helps to correlate them with Ayurvedic concepts of *samprāpti*. It

helps us to understand contributory factors, which properties of *dosha* and *dhātu* have affected and suffered modifications, how actions of vitiated *doshas* have taken place in *dhātu* and the structures. Thus, it produces symptoms of *manyāstambha* i.e. *stambha, vyathā, toda, supti, harsha* etc.

Various parts of the cervical spine suffer affections of vitiated *vāta* and undergo structural changes these are vertebral body, articular processes, intervertebral foramina zygapophyseal joint (facet joint), synovial folds (meniscus) of zygapophyseal joint intervertebral joints between the laminae, spines and transverse processes the ligaments of the spine, intervertebral discs, curvatures of the vertebral column, vertebral canal, spinal cord, vertebral artery, neck muscles and spinal nerves.

The modern science of medicine has described many diseases of cervical spine. Most of these spinal diseases are developed due to degeneration of the spine i.e. intervertebral disc, articular processes, body etc. These are cervical spondylosis, disc herniation, spondylosis deformans, osteochondrosis, degenerative spondylolisthesis, spinal canal stenosis, cervical spondylotic myelopathy and neuropathic (charcot) spine. Few inflammatory disorders of spine are also described i.e. sero-negative inflammatory spondylitis, ankylosing spondylitis and ankylosing hyperostosis of the spine. Metabolic disorders of spine are described like osteoporosis of the spine, deposition diseases affecting the spine and ochronosis.

Various causes to bring about the degeneration of the spine are described in the above listed diseases. Certain parts of the cervical spine get involved and undergo structural changes is very well elaborated by the modern science. Cervical pain is the main symptom in all these diseases along with neck stiffness, cervical radiculopathy and so on. Using the clinical history, clinical examination, laboratorial investigation and imaging technics one can very well understand and diagnose these conditions in the patient.

This description of spinal disorder helps us to understand *manyāstambha* and correlate it with the various Ayurvedic aspects like *racanā* and *kriyā śārir*, activities of *dosha* and *dhātu* to produce *manyāstambha* (in the form of *samprāpti*), other symptoms of *mañyastambha*, *upadrava* and *sādhyāsadhyatva* (prognosis).

The main symptom of *manyāstambha* is the neck stiffness which is found in all the above diseases together with cervical pain referred pain in head, radiating pain in upper limbs etc. The peculiar anatomical structure of cervical spine is the definite source to develop these diseases. Hence the anatomy of cervical spine must be given at

most importance while considering all aspects of *manyāstambha.* There are limits for radiological investigations to find minute changes in many parts of the cervical spine precisely in the patients of *manyāstambha*. But the physician should always consider whole anatomical structure of cervical spine in the patients suffering from *manyāstambha.*

Degeneration in the cervical spine may take place due to genetic factors also. Family history is found in scoliosis, spondylolisthesis, Schmorl's nodes etc.

Materials and Methods

150 Patients suffering from chronic *manyāstambha* as the cardinal symptom were selected considering inclusion exclusion criteria. They were examined and the findings from their cervical spine MRI were recorded in the Case Record Form.

Goniometer reading was an objective parameter to observe the restriction in the various neck movements i.e. flexion, extension and rotation. The reading is recorded at the comfortable range of neck movement. The accuracy of reading depends on the patient's ability to identify exact demarcation point between comfortable Goniometric measurements and neck stiffness causing discomfort. It has a limited significance to represent neck stiffness in the present study for diagnosis purpose only.

Some other symptoms were also found in the patients while taking the history. These are referred pain in head, neck, shoulder and upper limbs, burning and tingling sensation in hands etc.

Assessment of *manyāstambh* with the help of MRI of the cervical spine-

MRI is a very useful investigation in the patients of *manyāstambha* to find out anatomical involvement and structural changes in the cervical spine. With some limitations it gives a fair idea of the condition of the cervical spine in *manyāstambha.* All the findings are helpful to understand the disease better. It will help to decide the direction of treatment. For example, MRI can detect reduction in the water contents of disc confirming the disc desiccation. This finding can be helpful to understand the disc degeneration and the precise Ayurvedic treatment can be given.

Observations and results

Cervical spine straightening due to loss of normal lordosis is found in maximum patients. This most affected parameter is developed due to cervical muscle spasm and modification in the shape of disc. Then comes the place of degenerated disc. The

degenerative changes in the disc are observed in the form of various stages of disc herniation posteriorly. The disc between C5-C6 vertebrae is found to be herniated in maximum patient as compared to the other cervical intervertebral discs. The vertebrae near the skull and thorax are comparatively express less movements than the vertebrae between them hence their disc might be suffering degeneration less frequently. Postero-central bulging of intervertebral disc indents anterior meningeal covering around the spinal cord. Postero-lateral bulging narrows intervertebral foramens abutting nerve roots. Both these conditions are developed due to the disc herniation hence found at the levels where there is severe disc herniation. This structural change is affecting severely the intervertebral foramen at C5- C6 level bilaterally and compressing bilateral roots of C6 nerves.

Fourth major structural change affecting the vertebral body is the osteophyte formation found in the patients of *manyāstambha.* Osteophytes represent the degeneration of cervical spine. These osteophytes are also found compressing the nerve roots.

Other important structural affections found in decreasing order are spinal cord compression, scoliosis, spinal canal stenosis, intervertebral space reduction, ligament affections, facet joint affection, vertebral body affection, change in vertebral alignment and atlanto occipital joint affection. No affections were found in bilateral intervertebral foramen at C1, C1-C2 level in any patient. Nerve root compression was not found for bilateral nerve roots at C1, C2, T1 and left C3 nerves.

With the Chi-square Test P value is determined. These indicate highly susceptible structures, moderately susceptible structures etc. to produce *manyāstambha*. This sorting provides presumption to a clinician about the structural involvement and changes in the cervical spine in the case of *manyāstambha.* This helps the clinician to evaluate the severity of the disease.

Discussion

The degeneration starts early in the neck. The spinal structures show not only involvement in the diseases but also express structural changes. The cervical spine is affected by genetic factors, age, nutrition, life style, occupation, other systemic disorders etc.

Āyurveda has emphasized the study of human anatomy described under the topic *śārira* in ancient texts. The importance of anatomy is certainly for the seamless diagnosis and treatment. From the literature study it is possible to frame the probable

process of affections to the cervical spine by the actions of vitiated *dosha* in its various parts. It is also important to understand *Manyāstambha* and its symptoms from various diseases in *Āyurveda* and its correlation with degenerative spinal diseases e.g. *vātaj shiroroga, hasta- pāda dāha etc.*

Assessment of manyā*stambha* with the help of goniometer reading provides a broad idea about the restriction in the various neck movements. Assessment of *manyāstambha* with the help of MRI of the cervical spine is a very useful modality in the patients of *manyāstambha* to find out anatomical involvement and structural changes in the cervical spine. This finding can be helpful to understand the degeneration and the precise Ayurvedic treatment can be given.

Findings of the clinical study reflects many affected anatomical structures i.e. cervical spine straightening, intervertebral disc herniation, thecal sac indentation, osteophyte formation, intervertebral foramen and nerve root compression, spinal cord compression, scoliosis, spinal canal stenosis, intervertebral space reduction, ligament affections, facet joint affection, vertebral body affection, change in vertebral alignment and atlanto-occipital joint affection.

Conclusions

Degenerated intervertebral disc herniating significantly at the level of C5-C6 is found along with indentation of thecal sac, intervertebral foramen compression and nerve roots compression. These structural modifications accompanied by cervical muscle spasm leading to loss of cervical lordosis develop signs and symptoms of *manyāstambha*.

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ANATOMICAL SIGNIFICANCE OF CERVICAL SPINE IN *MANYĀSTAMBHA*

Introduction

The metabolism of body is achieved by maintenance of natural state of *dosha, dhātu, agni, mala*. This is also dependent on normal anatomy. Healthy physiological activities take place within anatomically normal organs. The structural abnormalities of an organ with respect to either structural involvement or abnormal structural modification or both due to the action of vitiated *dosha* are responsible to develop many diseases. Precise anatomical structure is provided for certain physiological activity to take place. But at many places some structural provision can develop disease due to the process of vitiated *dosha,* inherited causes, normal aging process etc. In the earlier stage of disease there may be only involvement of the anatomical structure but progressively there may be alteration in the anatomy of that structure that makes the disease complex.

Therefore, a physician needs meticulous knowledge of anatomy for understanding a disease and deciding the treatment. In *Āyurveda*, there is brief description of *śārīra* as well as involvement of various organs or their parts in a particular disease. Therefore, understanding the severity of the disease becomes difficult. To overcome this problem, we have to find out the anatomical structures affected in the diseases mentioned in *Āyurvediya* texts. For this; we should observe signs and symptoms of the disease mentioned in *Āyurvediya* texts and find out the affected anatomical structures with the help of modern laboratorial investigation methods like USG, CT scan, MRI etc.

Ācarya Caraka has mentioned symptoms of '***vātavikāra****'* at *c. su*. 20/12, like *sraṇsa, bhranśa, vyāsa* etc. These symptoms are produced by vitiated *vāta dosha* alone (unaccompanied by any other *dosha*). These symptoms; themselves are independent diseases and described as ***vātavikāra***. This vitiated *vata dosh* can affect any organ or region of the body and produce *sraṇsa, bhransh, vyasa* etc. If *vāta dosh* is affecting *manyā* (back of neck), *manyāgat vātavikār* will be produced. *Stambha* is one of *vātavikār* in this list of *vātavikār*. This is considered for the present study with respect to the cervical spine and related structures.

If we demonstrate the involvement and abnormal changes; precisely in cervical spine (main structure of *manyā*), along with musculature and allied structures; it will be supportive to the principals of *Āyurveda*.

Keeping this view in mind the present study has been designed with respect to 'cervical spine' as an anatomical structure and '*manyāstambha'* as a disorder.

Outline of Human Anatomy

Human anatomy is one of the important basic subjects that are useful in medical science. The Anatomy (Greek words 'ana' means up and 'tome' means cutting) is the branch concerned with the bodily structure of living things including their systems, organs and tissues. It includes thorough description of the organs along with their position, appearance, their relationships with other parts, coverings, the tissues from which they are composed and the blood, lymphatic and nerve supply.

The history of anatomy is characterized by a progressive understanding of the organs and structures of the human body. In *Atharva Veda* various organs are mentioned e.g. *sirā, dhamani, asthi, stana, grīvā, twacā, udara, āntra* and so on. The knowledge of anatomy was based on the observation of internal organs of animals which were sacrificed.

In ancient time; *Suśruta* has described the method of dissection and emphasized the significance of human cadaveric dissection along with the theoretical study, as it provides knowledge of anatomy by direct perception. Especially, for surgeons the knowledge of anatomy is a must. *Āyurveda* has its own way of describing anatomy (*śārira*). *Srotas*, *marma*, *kalā* etc. are very distinctive topics described only in *Āyurveda*, thousands of years back! We can consider that era, when a simple magnifying lens was not available. *Caraka*, *Suśruta* and the other scientist of *Āyurveda* conducted scientific research to get advance knowledge of human body in the non-existence of the instruments and equipment.

Methods have improved dramatically, with the advancement of physics, chemistry and other branches of modern science. With the availability of research instruments, the microstructure was available to us and many physiological aspects were discovered by the modern scientists.

The 20th century medical imaging techniques including X-ray, ultrasound, magnetic resonance imaging and endoscopes have added the knowledge of anatomy. And today comprehensive knowledge of anatomy is available, which is essential for the treatment of the patients.

Assortment of the present research topic

We find many patients having long-lasting problems of neck in the form of stiffness, pain, referred pain in upper limbs etc. There is no single disease described in *Āyurveda* which will include all these symptoms. There is also deficiency of knowledge regarding the structural affections in this regard. Hence there is no uniformity in the line of treatment among Ayurvedic physicians. To overcome this problem, it is necessary to framework this disease condition in Ayurvedic terms and find out what happens in the cervical spine so as to produce these symptoms.

Therefore, this thought-provoking research topic has been selected. If this disorder is considered with Ayurvedic interpretations, we find *manyāstambha* as an appropriate term to be used to describe this disorder of neck. MRI of cervical spine is a better modality by means of which we can detect various structural affections in the patients of *manyāstambha.* We get advanced knowledge of diseases of cervical spine in modern medical science. They have categorized and described many cervical spine disease conditions in which above symptoms are found e.g. cervical spondylosis, cervical spondylolisthesis etc.

Acquiring this knowledge from modern medical science will invigorate our concepts and science. This research work will provide Ayurvedic physicians a new insight concerning *manyāstambha;* as it emphasizes the importance of considering anatomical involvement and structural modifications while treating these patients. Similarly, this will help to decide severity and prognosis of the disease. This will also encourage the patients of *manyāstambha* as they can now expect more precise and specific condition oriented Ayurvedic treatment.

Therefore, this research topic is **Interesting, Informative** and having **Practical Utility** in the field of *Āyurveda***.**

Previous work done

1) Anatomical study of structural changes in *pristhavansha*- gata pratara sandhi with special reference to prolapsed intervertebral disc. (Maharashtra University of health sciences, nashik 2012-13)

2) Establish the concept of *prushthavamsha* as described in *samhitā*. (Maharashtra University of health sciences, nashik.2012-13)

3) A study of *pratara sandhi* of *grīvhā kasherukā* (cervical vertebrae) w.s.r. to cervical spondylosis. (Maharashtra University of health sciences, nashik 2010-2011)

4) Study of *manyāsharīra* with special reference to anatomical changes in *grivākasherukā* in *manyāstambha* (cervical spondylosis) (Maharashtra University of health sciences, nashik 2014-15)

Works have been done on cervical vertebrae, cervical spondylosis however anatomical significance, comprehensive structural involvement and abnormal modifications of cervical spine in *manyāstambha* with the MRI assessment has not been a research topic as yet.

Research Question

Are there any anatomical structures of cervical spine involved with abnormal changes in *manyāstambha*?

Aim

To find the significance of anatomical structures of cervical spine in the signs and symptoms of *manyāstambha.*

Objectives

To find the involvement and abnormal structural changes of cervical spine in *manyāstambha* with the help of MRI reports.

Study Design

Observational and cross-sectional study.

Review of Literature

Āyurveda perceptive

From ancient time anatomy and physiology have been considered as essential basic knowledge. Doubtless knowledge of human body and its embryological development has been given prime importance to become *prāṇābhisara vaidya* (a *vaidya* who cures the diseases and saves the life of patients).

तथाविधा हि केवले शरीरज्ञाने शरीराभिनिर्वृत्तिज्ञाने

प्रकृतिविकारज्ञाने च निःसंशयाः । –च.सू.२९/७

The description of anatomy in *Āyurveda* is peculiar. *Marma, srotas, kala* etc. are described only in *Āyurveda*. One should have a thorough knowledge of basic principles in *Āyurveda*, for the successful use of Ayurvedic way of treatment. The modern science of medicine has developed anatomy by continuous research in this subject. Hence an Ayurvedic physician must know modern anatomy and its applied aspects. He must study how the anatomical structure has been involved and modified in a particular disease. Considering involvement and changes of structures he should decide the line of treatment to get the complete success in the treatment.

शरीरविचयः शरीरोपकारार्थमिष्यते ।

ज्ञात्वाहिशरीरतत्त्वं शरीरोपकारकरेषु भावेषु ज्ञानमुत्पद्यते ।

तस्माच्छरीरविचयं प्रशंसन्ति कुशलाः ॥ –च.शा. ६/३

Detailed study of the human body is essential for the maintenance of health of body. After getting the knowledge about the anatomy and physiology of the body we can find out the factors suitable to the body. Therefore, the detailed knowledge of the body is praised by the experts.

इति सर्वावयवशो यो जानाति कलेवरम्।

अहितेषु स मोहेन न कदाचित् प्रवर्तते॥ –अ.सं.शा.५/९८

The physician who studies the whole human body along with its all parts and organs always avoids mistakes while treating the patients.

त्वक्पर्यन्तस्य देहस्य योऽयमङ्गविनिश्चयः ॥

शल्यज्ञानादृते नैष वर्ण्यतेऽङ्गेषु केषुचित् ॥ –सु.शा.५/४६

The various parts and organs of the body up to the skin are described only in *shalya tantra*. It is not described by any one who is not a surgeon. In other wards surgeon has a thorough knowledge of anatomy.

यतोऽप्रतिपन्नेऽशेषविशेषतः शरीरे न
शरीरविज्ञानाधीना चिकित्सा साध्वी भवति । –चक्र. च.शा.१/१

The place of treatment is body. Therefore, the knowledge of human body is very much essential. The success of treatment depends on the knowledge of human body.

While considering the pathology/ etiology of any disease by Ayurvedic method, *Āyurvediya racanā śārira* must be considered first but beyond that; knowledge of modern anatomy must be applied for the thorough understanding of the disease because it is said that-

एकं शास्त्रमधीयानो न विद्याच्छास्त्रनिश्चयम् ।
तस्माद्बहुश्रुतः शास्त्रं विजानीयाच्चिकित्सकः ॥ –सु.सू.४/७

The physician who studies only one science will not be able to arrive at a correct decision. Therefore, the physician should study many sciences.

In brief modern anatomy must be studied in details by a physician and structural involved must be examined. Now days advanced diagnostic imaging techniques help us in this regard.

History of human anatomy

The description of Ayurvedic human anatomy is found in *samhitās* like *Caraka*, *Suśruta* etc. But it is also found in *Vedās*, which are prepared before these *Samhitā*. Study of anatomy was started right from the very antient time of *Veda*.

Āyurveda derived from *Atharvaveda*-

तत्र भिषजा पृष्टेनैवं चतुर्णामृक्सामयजुरथर्ववेदानामात्मनोऽथर्ववेदे भक्तिरादेश्या,
वेदो ह्याथर्वणो दानस्वस्त्ययन बलिमङ्गल होमनियम प्रायश्चित्तोपवास
मन्त्रादिपरिग्रहाच्चिकिसां प्राह; चिकित्सा चायुषो हितायोपदिश्यते॥
–च.सू.३०/२१

Experts of *Āyurveda* should mention their devotion to *Atharvaveda* among four *Vedās*- Ṛk, *Sāma*, *Yajus* and *Atharva.* Because *Atharvaveda* describes treatment of diseases by way of donation, propitiatory rites, offerings, auspicious rites, oblations,

observance rules, expiations, fasting and incantations. It has been described for benefits of life.

We find names of many organs such as *sirā, dhamanī, asthi, mānsa, majjā, janghā, pāda, stana, grīvā, tvacā, kloma, udara, āntra* etc. We also get many diseases and disorders of various organs in *Atharvaveda*. We will find some examples here.

यदान्त्रेषु गवीन्योर्यद्वस्तावधि संश्रुतम् ।
एवा ते मूत्रं मुच्यतां बहिर्बालिति सर्वकम् ॥

–अथर्ववेद, काण्ड–१,सूक्त–३,सूत्र–६

Due to disease the obstructed urine in the channels of abdomen, ureters and bladder should come out suddenly.

शतस्य धमनीनां सहस्त्रस्य हिराणाम् ।
अस्थुरिन्मध्यमा इमाः साकमन्ता अरंसत ॥३॥

–अथर्ववेद, काण्ड–१,सूक्त–१७,सूत्र–३

The diseased bleeding vessels among the major hundred vessels of heart and their thousands of branches should stop bleeding under the influence of *mantra*.

After that empty vessels due to bleeding terminal nonspecific vessels should work usually.

Śārīra

The details of human body are mentioned mainly under *śārīra* in *sanhitā* and we get various references regarding *śārīra* in *sutra sthāna, cikitsā sthāna.* In *samhitā* various terms like *śarīra, śārīra, śarīra vicaya, śarīra tatva, dehasya aṇgaviniścaya* etc. represent anatomy as well as physiology.

शरीरमधिकृत्य कृतो ग्रन्थः शारीरः । –अरुणदत्त, अ.ह्र.शा.१/१

The book describing *śarīra* (anatomy and physiology of body) is called *śārīra*.

शरीरं चिन्त्यते सर्वं दैवमानुषसंपदा ।
सर्वभावैर्यतस्तस्मात्छारीरं स्थानमुच्यते ॥ –च.शा.८/६९

In this section the whole human body is studied in all aspects and also for knowing the godly and manly excellence of it, hence this section is called *śārīra*.

इत्यत्र जन्ममरणं यतः सम्यगुदाहृतम्।
शरीरस्य ततः स्थानं शारीरमिदमुच्यते ॥ –अ.सं.शा.१२/३७

In this section we get the entire description of human body right from birth to the death, hence this section is called *śārīra*.

The study of human body is considered as the initial step in the understanding of *Āyurveda.*

शरीरं सर्वथा सर्वं सर्वदा वेद यो भिषक् ।
आयुर्वेदं स कार्त्स्येन वेद लोकसुखप्रदम् ॥ –च.शा.६/१९
केवलं विदितं यस्य शरीरं सर्वभावतः ।
शारीराः सर्वरोगाश्च स कर्मसु न मुह्यति ॥ –च.वि.५/३१

The physician who knows the entire human body will never get failure in the treatment of any disease of body.

Methodology to obtain knowledge of human body without any doubt

शरीरे चैव शास्त्रे व दृष्टार्थः स्याद्विशारदः ॥
दृष्टश्रुताभ्यां संदेहमवापोह्याचरेत् क्रिया ॥ –सु.शा.५/५१

The doctor should study the whole human body theoretically as well as practically. He should carefully observe and listen the patient so that there should not be any doubt in his mind. Acquiring confidence, he should treat the patient.

The important fact is mentioned by *Caraka-*

एतावद्दृश्यं शक्यमपि निर्देष्टुम् ॥ –च.शा.७/१३

The visible organs only can be demonstrated.

न शक्यश्चक्षुषा द्रष्टुं देहे सूक्ष्मतमो विभुः ॥
दृश्यते ज्ञानचक्षुर्भिस्तपश्चक्षुर्भिरेव च ॥ –सु.शा.५/५०

Very minute Soul can not be seen by our eyes. It can only be seen with the eyes of knowledge or with the eyes of penance.

Very minute structures of body are also not visible by eyes. Hence to describe some minute structures *Āyurveda* has used *anumāna pramāna (*conjecture*)* and

dṛishṭānta (exemplification) (means of obtaining true knowledge). For example, *anumāna pramāna* is used to describe minute *sirā, srotas* etc. For describing urine formation *dṛishṭānta* (instance) has been used. Hence, we can't get description of microscopic structures in *samhitās*. Hence anatomical and physiological description of endocrine glands is also not available in our science. This weakness has been overcome by various principles i.e. *dosha, dhātu, mala, oja, indriya, srotas*. These basic concepts are very useful to treat the patients.

The science grows on the support of its own laws and principles. *Āyurveda* has been developed as a science which contains many laws and principles. *Caraka* has defined the principle in *Āyurveda-*

सिद्धान्तो नाम स यः परीक्षकैर्बहुविधं परीक्ष्य

हेतुभिश्च साधयित्वा स्थाप्यते निर्णयः । –च.वि.८/३७

The principle or theory is the conclusion drawn by the scientists after testing in several ways and thus proving the concept.

In this way observing the human body carefully and scientifically, *Ācāryas* have established many principles of *śarīra*.

प्रत्यक्षतो हि यदृष्टं शास्त्रदृष्टं च यद्भवेत् ॥

समासतस्तदुभयं भूयो ज्ञानविवर्धनम् ॥ –सु.शा.५/४७–४८

A comprehensive knowledge of anatomy is obtained by both theoretical and practical study of human body.

Śarīra

Caraka has defined *śarīra* as following

तत्र शरीरं नाम चेतनाधिष्ठानभूतं पञ्चमहाभूतविकार

समुदायात्मकं समयोगवाहि । –च.शा.६/४

The body is defined as the seat of consciousness, composed of the combined products of five *mahābhūtas*, maintaining equilibrium of all *dhātūs* and continues state of health.

Divisions of the human body

तत्रायं शरीरस्याग्ङ्गविभागः, तद्यथा– द्वौ बाहू,

द्वे सक्थिनी, शिरोग्रीवम्, अन्तराधिः, इति षडग्ङ्गम् ॥ –च.शा.७/५

The human body is divided into six parts- two *bāhu*, two *sakthi*, *śira*, *grīvā* and *antarādhi* (thorax and abdomen)

This division of body is convenient to study and describe a particular region of the body. *Āyurveda* has used this division while describing some concepts from anatomy such as *marma* in limbs, places of *dosha* e.g. *uraḥ* is location of *kapha*.

Formation of body by five great elements

The body of organism is composed of the combined products of five *mahābhūtas*.

तस्य पुरुषस्य पृथिवी मूर्तिः, आपः क्लेदः, तेजोऽभिसन्तापः,

वायुः प्राणः, वियत् सुषिराणि, ब्रह्म अन्तरात्मा । –च.शा.५/५

In the person *pṛithvī*, *āpa*, *teja*, *vāyu*, *ākāśa* and *brahman* from universe are represented by *mūrti*, *kleda*, *abhisantāpa*, *prāṅa* and *sushiratā* and *antarātmā* respectively.

Various body parts have predominance in certain *mahābhūta* which have been listed in the following lines-

तत्र यद्विशेषतः स्थूलं स्थिरं मूर्तिमदुरुखरकठिनमग्ङ्गं

नखास्थिदन्तमांसचर्मवर्चः केशश्मश्रुलोमकण्डरादि

तत् पार्थिवं गन्धो घ्राणं च, यद्द्रवसरमन्दस्निग्धमृदु

पिच्छिलं रसरुधिरवसाकफपित्तमूत्रस्वेदादि तदाप्यं

रसो रसनं च, यत् पित्तमूष्मा च यो या च भाः

शरीरे तत् सर्वमाग्नेयं रूपं दर्शनं च, यदुच्छ्वास

प्रश्वासोन्मेष निमेषाकुञ्चन प्रसारण गमन प्रेरण

धारणादि तद्वायवीयं स्पर्शः स्पर्शनं च, यद्विविक्तं

यदुच्यते महान्ति चाणूनि स्रोतांसि तदान्तरीक्षं शब्दः

श्रोत्रं च, यत् प्रयोक्तृ तत्तु प्रधानं बुद्धिर्मनश्च ।

इति शरीरावयवसंख्या यथास्थूल भेदेनावयवानां निर्दिष्टा ॥ –च.शा.७/१६

Predominant in *pṛthvī*- *sthūla, sthira, mūrtiman, gurū, khara, kaṭhina* and *nakha, asthi, danta, mansa, carma, warca, keśa, smaśru, loma, kaṇdarā, gandha, ghrāna.*

Predominant in *āpa*- *drava, sara, manda, snigdha, mṛidu, picchila* and *rasa, rudhira, vasā, kapha, pitta, mūtra, sveda, rasa, rasanā.*

Predominant in *teja*- *pitta, ushma, bhāh, rūpa, darśana*.

Predominant in *vāyu*- *ucchvāsa, praśvasa, unmesha, nimesha, akuñcana, prasāraṇa, gamana, preraṇa, dharaṇa* etc. and *sparśa, sparśana*.

Predominant in *ākāśa*- *vivikta, mahā srotas, aṇu srotas, śabda,* and *śrotra*.

Suṣruta has described *grīvā* as *pratyaṅga-*

अतः परं प्रत्यङ्गानि वक्ष्यन्ते– मस्तकोदरपृष्ठनाभिललाटनासाचिबुक

बस्तिग्रीवा इत्येता एकैकाः ॥ –सु.शा.५/४

चतुरङ्गुलानि ग्रीवोच्छ्राय–––––चतुर्विंशतिविस्तार परिणाहं मुखग्रीवं ।

–सु.सू.३५/१२

The neck is four fingers long and its girth is twenty fingers.

The neck is formed by *asthi, sandhi, mānsa, snāyu, sirā, dhamanī* etc. hence their description is given here.

1) ***Asthi***

Asthi is fifth *dhātu* among the seven *dhātus* described in *Āyurveda.* Many bones join together to form skeleton. This bony skeleton offers strength to the body. Muscles, tendons get support of bones. Soft organs e.g. brain, liver, kidneys etc. are placed in the cavities supported by the bones.

Importance of bones-

अभन्तरगतैः सारैर्यथा तिष्ठन्ति भूरुहाः ॥

अस्थिसारैस्तथा देहा श्रियन्ते देहिनां ध्रुवम् ॥२१॥

तस्माच्चिरविनष्टेषु त्वग्ङ्मांसेषु शरीरिणाम् ॥

अस्थीनि न विनश्यन्ति साराण्येतानि देहिनाम् ॥२२॥

मांसान्यत्र निबद्धानि सिराभिः स्नायुभिस्तथा ॥

अस्थीन्यालम्बनं कृत्वा न शीर्यन्ते पतन्ति वा ॥२३॥

–सु.शा.५/२१–२३

The trees get supported by the strong core inside the trunks. Likewise, human body is supported by the skeleton of firm bones. (If the dead body is buried in the soil) the attached *māmsa*, *tvak* etc. are destroyed but *asthi* are retained for a very long time. Therefore, they are called pith of human body. The bones provide support to the various structures of body. The *māmsa* is attached strongly to the bones with the help of *sirā* and *snāyu*. Hence, they never fall off.

Embryological expression of bones-

षष्ठे केशरोमनखास्थिस्नाय्वादीन्यभिव्यक्तानि

बलवर्णोपचयश्च । –अ.सं.शा.२/२३

Embryological expression of *asthi* takes place in the sixth month of pregnancy.

Formation of bone-

पृथिव्यग्न्यनिलादीनां संघातः स्वोष्मणा कृतः ॥

खरत्वं प्रकरोत्यस्य जायतेऽस्थि ततो नृणाम् । –च.चि.१५/३०

Action of own *agni* of *meda* and combination of *pṛithvī, teja* and *vāyu* together gives rise to hardness and produces *asthi* in humans.

ग्रीवां प्रत्यूर्ध्वं त्रिषष्टिः .....॥ –सु.शा.५/१८

There are 63 bones above the clavicles.

ग्रीवायां नव.....॥ –सु.शा.५/१९

There are 9 bones in the neck.

Types of bones

Suśruta has classified bones as *mahat asthi* and *aṇu asthi*. These respectively contain *majja dhatu* and *meda*.

मेदो हि सर्वभूतानामुदरस्थमण्वस्थिषु च,

महत्सु च मज्जा भवति ॥ –सु.शा.४/१२

Fat is located in the abdomen of all organisms and in the small bones. And the large bones contain *majja dhatu* (bone marrow).

Five types of bones-

एतानि पञ्चविधानि भवन्ति; तद्यथा–

कपालरुचकतरुणवलयनलकसंज्ञानि । –सु.शा.५/२०

These bones are classified into five types such as *kapāla* (flat bones), *rucaka* (teeth), *taruna* (cartilages), *valaya* (curved or irregular) and *nalaka* (long bones).

The type of vertebrae is *valaya asthi.*

Functions of bones-

धारणं–ऊर्ध्वधारणम् ,अस्थिकर्म । –अरुणदत्त,अ.ह्र.सू.११/४

धारणं–अवलम्बनम्, अस्थ्न्यः । –हेमाद्रि,अ.ह्र.सू.११/४

Providing support and firmness is the main function of bones.

मज्जवहानां स्रोतसामस्थीनि मूलं सन्धयश्च । –च.वि.५/८

majjāvaha srotas have their *mūla* in *asthi* and *sandhi*.

करोति तत्र सौषिर्यमस्थ्नां मध्ये समीरणः ॥

मेदसस्तानि पूर्यन्ते स्नेहो मज्जा ततः स्मृतः । –च.चि.१५/३१

Vāyu develops hollowness within the bone which is filled up by the essence of *meda* called *majjā* (marrow).

Asthi is an important place of *vāyu*. This is stated in the following lines.

पक्वाशय कटी सक्थि श्रोत्र <u>अस्थि</u> स्पर्शनेन्द्रियम् ।

स्थानं वातस्य । –अ.ह्र.सू.१२/१

There is mutual interdependence of *asthi* and *vāyu*.

तत्रास्थिनि स्थितो वायुः ..... ।

..... आश्रयाश्रयिणां मिथः । – अ.ह्र.सू.११/२६

Excretion of *asthi*-

स्यात्किट्टं केशलोमास्थ्नो । –च.चि.१५/१८

Kiṭṭa of *asthi* is hairs of head and body.

Manifestation of *asthi vṛiddhi*

अस्थ्यध्यस्थीन्यधिदन्तांश्च । –सु.सू.१५/१४

Asthi vṛiddhi causes development of *adhyasthi* (osteophytes) and *adhidanta* (hyperdontia).

Manifestation of *asthi kshaya*

अस्थिक्षयेऽस्थिशूलं दन्तनखभङ्गो रौक्ष्यं च। --सु.सू.१५/९

Caraka has mentioned *sandhi shithilatā* (weakness) as one of the symptoms of *asthi kshaya.*

ज्ञेयमस्थिक्षये लिङ्गं सन्धिशैथिल्यमेव च । –च.सू. १७/६७

Majjā dhātu

Manifestation of *majjā kshaya*

अस्थ्नां मज्जनिसौषिर्यं भ्रमस्तिमिरदर्शनम् । –अ.ह्र.सू.११/१९

It produces *saushirya* porocity in bones, *bhrama* and *timira darśana* (blackout).

मज्जक्षयेऽल्पशुक्रता पर्वभेदोऽस्थिनिस्तोदोऽस्थिशून्यता च । –सु.सू. १५/९

Majjā kshaya causes *alpa śukratā,* pain in joints and bones and feeling of hollowness in the bone.

2) *Sandhi*

Whole body is supported by the skeleton of bones. The skeleton is formed by the articulations among the bones. Movements of various body parts are possible due to these joints.

अस्थीनि स्नायुबद्धानि । –का.शा.पृ.क्र.७७

Bones are joined together by ligaments and tendons.

Fig.1 Various joints in the foot joined together by ligaments and tendons.

The structure of a *sandhi* according to *Caraka*-

अस्थिसन्धयोऽस्थि संयोगास्तन्त्रोपनिबद्धाश्च स्नायुकण्डराः । –च.सू.११/४८

Joints of bones are those where bones articulate together with the ligaments and tendons.

प्रतानवत्यः शाखासु सर्वसन्धिषु चाप्यथ । –सु.शा.५/३०–३४

Pratānavati (branching or ramifying) ligaments are present in four limbs and all joints.

सिरास्नाय्वस्थिपर्वाणि सन्धयश्च शरीरिणाम् ।

पेशीभिः संवृतान्यत्र बलवन्ति भवन्त्यतः ॥ –सु.शा.५/३८

Blood vessels, ligaments, tendons, bones and joints originate strength and support as these are covered with *peshī* (coverings or fascial sheaths).

Features of normal joints should be deep, strong and not observed externally.

- (अ.सं.शा. ८/३८)

Types of joints

सन्धयस्तु द्विविधाश्चेष्टावन्तः, स्थिराश्च ॥२४॥

शाखासु हन्वोः कट्यां च चेष्टावन्तस्तु सन्धयः ॥

शेषास्तु सन्धयः सर्वे विज्ञेया हि स्थिरा बुधैः ॥२५॥

–सु.शा.५/२४–२५

कट्यां चेति चकाराद्ग्रीवायामपि चलाः ॥ –डल्हण

The joints are of two types- movable and immovable. The joints of limbs, jaws and waist are movable. Rest of the joints are considered to be immovable. *Dalhana* says that along with waist; joints of **neck** are also movable.

चलेष्वितिशाखाहनुकरग्रीवासुचलाः सन्धयः । –डल्हण, सु.सू.२५/३६–३९

There are movable joints in *shākhā* (limbs), *hanu* (temporomandibular joint), *kara* (hand), *grīvā* (neck).

त एतेसन्धयोऽष्टविधाः– कोरोलूखल सामुग्द प्रतर तुन्नसेवनी

वायसतुण्डमण्डलशङ्खावर्ताः । –सु.शा.५/२७

The joints are of eight types- *kora* (hinge joint), *ulūkhala* (ball and socket), *sāmudga* (joint with a socket like a cup), *pratara* (like a Raft- a collection of timber

fastened together), *tunna sevanī* (suture like), *vāyasa tuṇda* (crow beak), *maṇdala* (circular) and *śaṅkhāvarta* (spiral shaped).

ग्रीवा पृष्ठवंशयोः प्रतराः । –सु.शा.५/२७

Neck and vertebral column are provided with *pratara* type of *sandhi*.

ग्रीवां प्रत्यूर्ध्वं त्र्यशीतिः । –सु.शा.५/२६

There are 83 joints in head and neck.

Proper lubrication is needed in joint to avoid wear and tear. Hence movable joints are provided with *śleshmadharā kala*.

चतुर्थी श्लेष्मधरा सर्वसन्धिषु प्राणभृतां भवति ॥१४॥

स्नेहाभ्यक्ते यथा ह्यक्षे चक्रं साधु प्रवर्तते ॥

सन्धयः साधु वर्तन्ते संश्लिश्टः श्लेष्मणा तथा ॥१५॥ –सु.शा.४/१४–१५

Fourth *kalā* is *śleshmadharā kalā* which is present in the joints. A wheel rotates smoothly around its axle when it is applied with oil. Similarly, *śleshmā* present in the joint facilitate smooth movement of joint.

मज्जवहानां स्रोतसामस्थीनि मूलं सन्धयश्च । –च.वि.५/८

Majjāvaha srotas have their *mūla* in *asthi* and *sandhi*.

उरःकण्ठशिरःक्लोमपर्वाण्यामाशयो रसः।

मेदो घ्राणं च जिव्हा च कफस्य, सुतरामुरः ॥ –अ.हृ.सू.१२/३

Sandhi is place of *kapha*.

सन्धिस्थः श्लेष्मा सर्वस्न्धिसंश्लेषात् सर्वसन्ध्यनुग्रहं करोति ॥

–सु.सू.२१/१४

Symptoms of joint injury-

शोफातिवृद्धिस्तुमुला रुजश्च बलक्षयः पर्वसु भेदशोफौ ॥

क्षतेषु सन्धिष्वचलाचलेषु स्यात् सन्धिकर्मोपरतिश्च लिङ्गम् ॥ –सु.सू.२५/३८

Ati śopha, rujā, balakśaya, parva bheda- śopha, sandhikarmoparati (inoperativeness of joint) mark the injury of the movable or immovable joint.

3) ***Peśī***

There is controversy regarding the confirmation of the term *peśī* among the experts. Some experts consider *peśī* as muscle and some consider *peśī* as covering and fascia. According to *Dalhana* the meaning of the ward *peśī* is-

पेशी मांसखण्डः । –डल्हण, सु.शा.४/२८–२९

Peśī is *mānsakhaṇda.*

पेश्यः पुनः स्नाय्वाकृतयो मांसमय्यः । –इन्दु,अ.सं.शा.५/७१

Peśī is having shape of *snāyu* and formed of *mānsa.*

Significant definition of *peśī* by *Dalhana-*

मांसावयव सङ्घातः परस्परं विभक्तः 'पेशी' इत्युच्यते । –डल्हण, सु.शा.५/३७

Peśī is a structure which separates *māns* (flesh), *avayava* (organs) and *saṅghāta* (conjunction of structures) from each other.

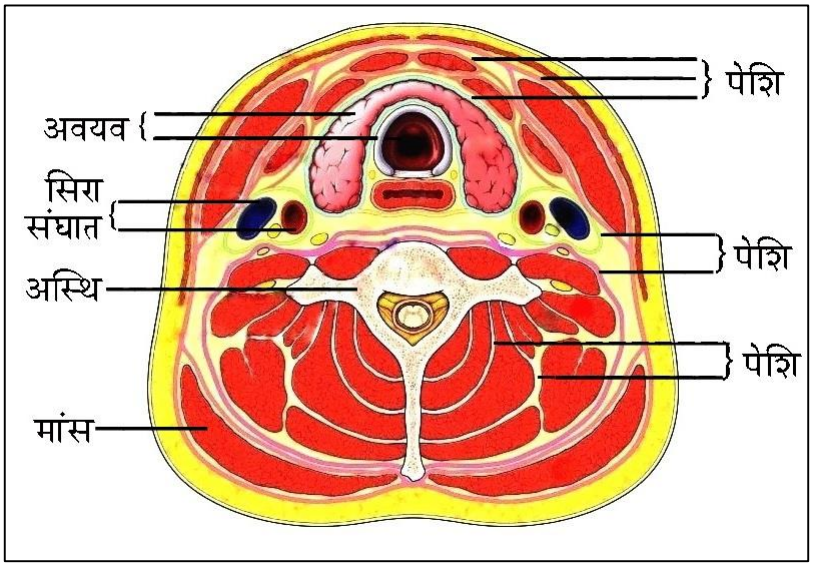


Fig.2 T.S. of neck showing *peṣī,* which separates *māns, avayava* and *saṅghāta* [1]

From the above definition it is clear that *peśī* is nothing but covering and fascia

सिरास्नाय्वस्थिपर्वाणि सन्धयश्च शरीरिणाम् ।

पेशीभिः संवृतान्यत्र बलवन्ति भवन्त्यतः ॥ –सु.शा.५/३८

In the body, *sirā, snāyu, asthi* and *sandhi* get support and strength from the covering of *peśī* (fascia).

Types of *peśī*

तासां बहल पेलव स्थूलाणु पृथु वृत्त ह्रस्व दीर्घ स्थिर मृदु श्लक्ष्ण कर्कशभावाः

सन्ध्यस्थि सिरा स्नायु प्रच्छादका यथाप्रदेशं स्वभावत एव भवन्ति । –सु.शा.५/४०

While covering *sandhi, asthi, sirā* and *snāyu; peśī* (fasciae) become naturally, according to place, *bahala, pelava, sthūla, aṇu, pṛithu, vṛitta, hrasva, dīrgha, sthira, mṛidu, ślakśṇa* and *karkaśa*.

If we observe the fasciae of the neck, they can be included into *pelavā, anavah, vṛitta, rhswa, mṛidu slakśṇa* types of *peśī.*

ग्रीवा प्रत्यूर्ध्वं चतुस्त्रिंशत् । –सु.शा.५/३७

There are 34 *peṣī* of head and neck.

4) *Snāyu*

Development of *snāyu*

मेदसः स्नेहमादाय सिरास्नायुत्वमाप्नुयात् ॥

सिराणां तु मृदुः पाकः स्नायूनां च ततः खरः ॥ –सु.शा.४/२९

Sirā takes off oily principles of fat and transforms them into *snāyu*. *Sirā* are under baked while *snāyu* are over baked.

वाय्वम्बुतेजसा रक्तमूष्मणा चाभिसंयुतम् ।

स्थिरतां प्राप्य मांसं स्यात् स्वोष्मणा पक्वमेव तत् ॥

–च.चि.१५/२९

Vāyu, ambu, rakta and *ushmā* combine together and become mature with the help of their own *ushmā* and produce *mānsa*.

मेदसः स्नायुसंभवः ॥ –च.चि.१५/१७

Snāyu is generated from *meda* in the form of *upadhātu*

गर्भस्य केश श्मश्रुलोमास्थि नखदन्तसिरा

स्नायु धमनीरेतःप्रभृतीनि स्थिराणि पितृजानि । –सु.शा.३/३३

Asthi and *snāyu* in the fetus are developed from the *pitṛija bhāva* (paternal element).

पञ्चमे मासि गर्भस्य मांसशोणितोपचयो

भवत्यधिकमन्येभ्यो मासेभ्यः,----॥ –च.शा.४/२१

Foetal *mānsa* and *rakta* are more developed in fifth month compared to other months.

षष्ठे केशरोमनखास्थिस्नाय्वादीन्यभिव्यक्तानि

बलवर्णोपचयश्च । –अ.सं.शा.२/२३

Mānsa, asthi, snāyu etc. are more expressed in the sixth month of pregnancy.

मांसवहानां च स्रोतसां स्नायुर्मूलं त्वक् च । –च.वि.५/८

Root of *mamsavaha srotas* lies in *snāyu*.

Types of *snāyu*-

स्नायूश्चतुर्विधा विद्यात्तास्तु सर्वा निबोध मे ॥

प्रतानवत्यो वृत्ताश्च पृथ्व्यश्च शुषिरास्तथा ॥ –सु.शा.५/३०

Snāyu are having four types- *pratānavatī* (branching), *vṛtta* (circular), *pṛthu* (broad and thick), *śushira* (sphincter).

If *snāyu* are compared with ligaments and tendons, then *snāyu* related with the cervical spine are of *pratānavatī* and *vṛtta* types.

नौर्यथा फलकास्तीर्णा बन्धनैर्बहुभिर्युता ॥

भारक्षमा भवेदप्सु नृयुक्ता सुसमाहिता ॥३३॥

एवमेवशरीरेऽस्मिन् यावन्तः सन्धयः स्मृताः ॥

स्नायुभिर्बहुभिर्बद्धास्तेन भारसहा नराः ॥३४॥ –सु.शा.५/३३–३४

As a boat made up of planks fastened together by means of large number of bindings, becomes capable of carrying passengers, so the *sandhi* being bound and fastened by *snāyu* make a person capable to bear weight.

षट्त्रिंशद्ग्रीवायां, मूर्ध्नि चतुस्त्रिंशत्,---॥ –सु.शा.५/२९

There are 36 *snāyu* in the neck and 34 *snāyu* in the head.

Significance of ligaments and tendons

न ह्यस्थीनि न वा पेश्यो न सिरा न च सन्धयः ॥

व्यापादितास्तथा हन्युर्यथा स्नायुः शरीरिणम् ॥ –सु.शा.५/३५

The disorders of *asthi*, *pesī*, *sira* and *sandhi* are not so detrimental to the body as is the case if the *snāyu* (ligaments, tendons) are affected.

5) ***Mānsa rajju***

महत्यो मांसरज्जवश्चतस्त्रः– पृष्ठवंशमुभयतः पेशीनिबन्धनार्थं

द्वे बाह्ये, आभ्यन्तरे च द्वे ॥ –सु.शा.५/१४

There are four large *mānsa rajju* on either side of the spine; two outer and two inner, for the purpose of binding *pesī* together.

6) ***Kaṇdarā***

कण्डरा इह तन्त्रे स्थूलस्नायुः । –चक्र. च.सू.११/४८

The meaning of *kaṇdarā* is *sthūla snāyu.*

कण्डराशब्दः स्नायुवाचकः । –डल्हण, सु.उ.१/१९

The word *kaṇdarā* is expressive of *snāyu*.

कण्डरा महास्नायुः। –डल्हण, सु.नि.१/७४

The meaning of *kaṇdarā* is *mahā snāyu.*

Kaṇdarā is developed as *upadhātu* of *rakta.*

असृजः कण्डराः सिराः । –च.चि.१५/१७

Rakta gives rise to *kaṇdarā.*

षोडश कण्डराः – तासां चतस्रः पादयोः,

तावत्यो हस्तग्रीवापृष्ठेषु,---। –सु.शा.५/११

There are 16 *kaṇdarā*, of which four are in legs, four in the hands, four in the neck and four in the back.

7) ***Kalā***

Definition of *kalā*.

कलाः खल्वपि सप्त भवन्ति धात्वाशयान्तरमर्यादाः ॥ –सु.शा.४/५

There are seven *kalā*, which are present between *dhātu* and it's *āṣaya*.

Kalā in relation with joints of spine is *śleshmadharā kalā*.

चतुर्थी श्लेष्मधरा सर्वसन्धिषु प्राणभृतां भवति ॥१४॥

स्नेहाभ्यक्ते यथा ह्यक्षे चक्रं साधु प्रवर्तते ॥

सन्धयः साधु वर्तन्ते संश्लिष्टः श्लेष्मणा तथा ॥१५॥

–सु.शा.४/१४–१५

The fourth *kalā* is called *śleshmadharā kalā*. It is present in about all *sandhi* of the organism. A wheel rotates smoothly around its axle when lubricating oil is applied at their joint. Similarly, a *sandhi* works smoothly when the *sandhi* surfaces are smeared with *śleshma*.

8) *Sīvanī*

सप्त सेवन्यः, शिरसि विभक्ता; पञ्च,

जिह्वाशेफसोरेकैका; ताः परिहर्तव्याः शस्त्रेण ॥ –सु.शा.५/१५

शिरसि द्वें शंखावाश्रित्य प्रवृत्ते द्वे कृकाटिके एका उपरि ऋज्वी इति पञ्च ।

द्वे जिह्वामेढ्रयोरिति सप्त सीवन्यः शस्त्रेण परिहार्याः । –इन्दु, अ.सं.शा.५/५८

sīvanī (raphe and sutures) are seven such as- in head five (at *ṣira* two, at *ṣankh* two and one straight upright at *kṛikātikā*) and one each in tongue and penis. These should be avoided during surgery.

सेवनीच्छेदादृजाप्रादुर्भावः । –सु.शा.९/१२

If *sīvanī* is cut, there occurs pain.

9) *kūrcā*

षट् कूर्चाः, ते हस्तपादग्रीवामेढ्रेषु; हस्तयोर्द्वौ,

पादयोर्द्वौ, ग्रीवामेढ्रयोरेकैकः ॥ –सु.शा.५/१३

kūrcā (brush like structure) are six found in the hands, feet, neck and penis. They are two each in hands and feet while one each in neck and penis.

10) *Sirā*

सप्त सिराशतानि भवन्ति, याभिरिदं शरीरमाराम इव

जलहारिणीभिः केदार इव च कुल्याभिरुपस्निह्यतेऽनुगृह्यते

चाकुञ्चनप्रसारणादिभिर्विशेषैः, द्रुमपत्र सेवनीनामिव

तासां प्रतानाः, तासां नाभिर्मूलं, ततश्च प्रसरन्त्यूर्ध्वमधस्तिर्यक्च ॥

–सु.शा.७/३

There are seven hundred *sirā* by which the body is nourished like garden by water carriers and like field by irrigating channels and also benefitted with activities such as contraction, extension etc. their ramifications are as venation in a leaf, their root is umbilicus wherefrom they spread upwards, downwards and obliquely.

Functions of normal *vātvaha sirā*

क्रियाणामप्रतीघातममोहं बुद्धिकर्मणाम् ।

करोत्यन्यान् गुणांश्चापि स्वाः सिराः पवनश्चरन् । –सु.शा. ७/८

Vāyu in its normal state coursing through its specific *sirā* helps the unobstructed performance of its specific functions i.e. expansion, speech etc. and produces the clearness and non-illusiveness of *buddhi* (intellect) and the sense organs.

Development of diseases by the deranged *vāyu* affecting *vātvaha sirā*

यदा तु कुपितो वायुः स्वाः सिराः प्रतिपद्यते ॥

तदाऽस्य विविधा रोगा जायन्ते वातसंभवाः ॥ –सु.शा.७/९

The deranged *vāyu* affects *vātvaha sirā* and develops such diseases in the body which are produced due to derangement of *vāyu.*

Functions of normal *kaphavaha sirās*

स्नेहमङ्गेषु सन्धीनां स्थैर्यं बलमुदीर्णताम् ॥

करोत्यन्यान् गुणांश्चापि बलासः स्वाः सिराश्चरन् ॥ –सु.शा.७/१२

अन्यान् गुणान् सन्धिश्लेषणादिकान्। –डल्हण

When normal *kapha* is streaming through *kaphavaha sirā*, they produce *sneha* in body, *sandhi sthairya*, *bala* and performs its usual body metabolism.
Other functions like binding the joint together.

***Sirā* in the neck**

तासां चतुर्दश ग्रीवायां---। –सु.शा.७/७

There are *vātvaha, pittavaha, kaphavaha* and *raktavaha sirā*. Fourteen *sirā* of each type are present in *grīva*.

Sirā has important role in the place of *marma* that is explained in the description of *marma.*

10) *Srotas*

मूलात् खादन्तरं देहे प्रसृतं त्वभिवाहि यत् ।

स्रोतस्तदिति विज्ञेयं सिराधमनिवर्जितम् ॥ –सु.शा. ९/१३

Srotas is defined as the channel; apart from *sirā* and *dhamani,* originating from hollow organs and spreading throughout the body which transmits materials.

It has been stated that food and behavior which are similar to *doṣas* and dissimilar to *dhātu* in properties cause morbidity in *srotas* as following.

अतिप्रवृत्तिः सङ्गो वा सिराणां ग्रन्थयोऽपि वा ।

विमार्गगमनं चापि स्रोतसां दुष्टिलक्षणम् ॥ –च.वि.५/२४

Atipravṛitti (Enhanced flow) or *saṅga* (obstruction) or *sirāgranthi* (formation of nodules) and *vimārgagamana* (flow of contents in wrong direction) are the symptoms of morbidity in *srotas.*

The chief *srotas* in relation with the spine are *asthivaha* and *majjavaha.*

Asthivaha Srotas

अस्थिवहानां स्रोतसां मेदो मूलं जघनं च । –च.वि.५/८

Asthivaha srotas have their *mūla* in *meda* and *jaghan*.

Morbid affection of *asthi*

अध्यस्थिदन्तौ दन्तास्थिभेदशूलं विवर्णता ।

केशलोमनखश्मश्रुदोषाश्चास्थिप्रदोषजाः ॥ –च.सू.२८/१६

*Adhyasthi (*osteophytes*), adhidanta, dantabheda, asthibheda, asthiṣūla,* discoloration, abnormality in the hairs of head, body hairs, nails, beards-moustaches these are disorders due to morbid affection of *asthi*.

Majjāvaha Srotas

Majjā is *dhātu* placed inside the bone.

मज्जवहानां स्रोतसामस्थीनि मूलं सन्धयश्च । –च.वि.५/८

Majjāvaha srotas have their *mūla* in *asthi* and *sandhi*.

Morbid affection of *majjā*

रुक् पर्वणां भ्रमो मूर्च्छा दर्शनं तमसस्तथा ।

अरुषां स्थूलमूलानां पर्वजानां च दर्शनम् ॥१७

मज्जप्रदोषात् । –च.सू.२८/१७

Parva rujā (pain in joints), *bhrama, mūrchā, tamo darśana* and *arusha* (appearance of thick based wounds)- these are developed due to morbid affection of *majjā.*

11) Marma

The knowledge of anatomy and physiology is very essential to become good surgeon or physician. Similarly, knowledge of *marma* is contemporary to surgeon and physician. *Marma* is a certain place, when there is an injury death can take place. Hence these places of *marma* should be avoided while doing surgeries.

Definition of *marma* by *Suśruta-*

मर्माणि मांससिरास्नाय्वस्थिसन्धिसन्निपाताः,

तेषु स्वभावत एव विशेषेण प्राणास्तिष्ठन्ति,

तस्मान्मर्मस्वभिहतास्तांस्तान् भावानापद्यन्ते ॥ –सु.शा.६/१५

The collection of *mānsa* (muscles), *sirā* (vessels, nerves), *snāyu* (ligaments, tendon), *asthi* (bones), *sandhi* (joints) is called *marma* (vital part). This is the seat of *prāna* (soul). Therefore, injury to any one of the *marmas* always produces such symptoms as arise from the injury of a specific marma.

Marma in neck

जत्रु ऊर्ध्वं चतस्रो धमन्योऽष्टौ

मातृका द्वे कृकाटिके द्वे । –सु.शा.६/६

Marma present in the neck are *4 dhamanī marma, 8 mātṛkā and 2 kṛkātikā.*

शृङ्गाटकान्यधिपतिः शङ्खौ कण्ठशिरा गुदम् ॥

कुकुन्दरे कक्षधरे विधुरे सकृकाटिके ॥१२॥

अंसांसफलकापाङ्गा नीले मन्ये फणौ तथा ॥

वैकल्यकरणान्याहुरावर्तौ द्वौ तथैव च ॥१३॥ –सु.शा.६/८–१३

8 *kaṇtha sirā* (*mātṛkā*) are *sadyaprāṇhara marma* (fatal). Whereas *2 kṛkātikā, 2 nīlā, 2 manyā* are *vaikalyakara marma* (produce deformity).

गले दश यानि च द्वे ॥

तानि स्वपाणितलकुञ्चितसंमितानि शेषाण्यवेहि

परिविस्तरतोऽङ्गुलार्धम् ॥२९॥ –सु.शा.६/२८–२९

The dimension of *nīlā, manyā* and *mātṛkā* is of 4 fingers. The dimension of *kṛkātikā marma* is of half finger.

नीलधमनीमातृकाशृङ्गाटक---- सिरामर्माणि,---

कृकाटिकाश्चेति सन्धिमर्माणि ॥ –सु.शा.६/७

Nīlā, manyā and *mātṛikā are sirā marmas* and *kṛikātikā* is *sandhi marma.*

The blood vessels, nerves are very significant in the *marma*. How trauma to *marma* produces disease is described in the following lines.

चतुर्विधा यास्तु सिराः शरीरे प्रायेण ता मर्मसु सन्निविष्टाः ॥

स्नाय्वस्थिमांसानि तथैव सन्धीन् सन्तर्प्य देहं प्रतियापयन्ति ॥१८॥

ततः क्षते मर्मणि ताः प्रवृद्धः समन्ततो वायुरभिस्तृणोति ॥
विवर्धमानस्तु स मातरिश्वा रुजः सुतीव्राः प्रतनोति काये ॥ १९॥

–सु.शा.६/१८–१९

Four types of *sirā* are predominant in the place of *marma*; which nourish and strengthen *snāyu* (ligaments and tendon), *asthi (bones), mānsa (muscles)* and *sandhi* (joints) and sustain the body. *Vāyu* aggravated due to injury to the *marma* scatter through the body affecting *sirā*. It gives rise to severe pain, extending all over the body and produce serious disorder.

Effect of trauma on various *marma* in the neck

तत्र कण्ठनाडीम् उभयश्चतस्रो धमन्यो द्वे नीले द्वे
च मन्ये व्यत्यासेन, तत्र मूकता स्वरवैकृतमरसग्राहिता च,
ग्रीवायामुभयतश्चतस्रः सिरा मातृकाः तत्र सद्योमरणं,
शिरोग्रीवयोः सन्धाने कृकाटिके, तत्र चलमूर्धता–––। –सु.शा.६/२७

There are four *dhamani* on each side of the neck- two *nīlā* and two *manyā.* An injury to any of them produces *mūkatā*, *swaravikṛiti* and *arasagrāhitā* (loss of sense of taste). There are four *sirā matṛkā* on each side of neck. If these are injured sudden death will take place. Two *kṛkātikā marma* are located at the junction of head and neck. If these are injured *calamūrdhatā* (shaking movements in the head) takes place.

Spine as a place of *marma*

According to the definition, *marma* is a place where *mānsa, sirā, snāyu, asthi* and *sandhi* come together with the predominance of *prāṇa*. These conditions are fulfilled by the cervical spine The spinal region is very delicate and vital part of the body. Trauma to the cervical region can lead to severe pain, disability, or death. The cervical spine thus can be treated as a place of *marma* and all the general principles of *marma* concept should be applied to this region.

12) *Idā, pinglā* and *sushumnā* and *nāḍicakra*

Idā, pinglā and *sushumnā* and *nāḍicakra* are not described by *Carak*, *Suśrut* etc. Their description is found in *Tantraśāstra*, *Yogaśāstra* and *Upanishada*.

Here the functions of *idā*, *pinglā* and *sushumnā* are more significant. These, with the help of *naḍicakra* carry out the functions of body and mind. *Idā* and *pinglā nāḍī* are called *candra nāḍī and sūrya nāḍī* respectively. *Idā* is related with left nostril and *pinglā* is related with right nostril. Both *nāḍī* are joined with *mūlādhāracakra.*

These two spiral around *sushumnā* and ascend to join *ājñācakra*. Further it separates again to remain in relation with right and left nostrils. *Sushumnā nāḍī ascends* from *mūlādhāracakra* and ends in *brahmarandhra* in the head. *kundalinī* is stable in *mūlādhāracakra* attaining spiral shape. *Kundalinī* gets activated by *brahmanādī* located inside *sushumnā* and ascends superiorly. Activated *kundalinī* joins the soul to *brahmā* by achieving *sahasrāhāra cakra*. This is considered as supreme felicity.

Nāḍī cakra

Nāḍī cakra are six; but occasionally they are described as seven or eight. Each *cakra* has been compared with the flower of lotus having different numbers of petals. The petals represent *nāḍī* and *ṣakti*. Activated *Kundalinī* by the diligent practice of *yoga* ascends superiorly travelling through *cakra.*

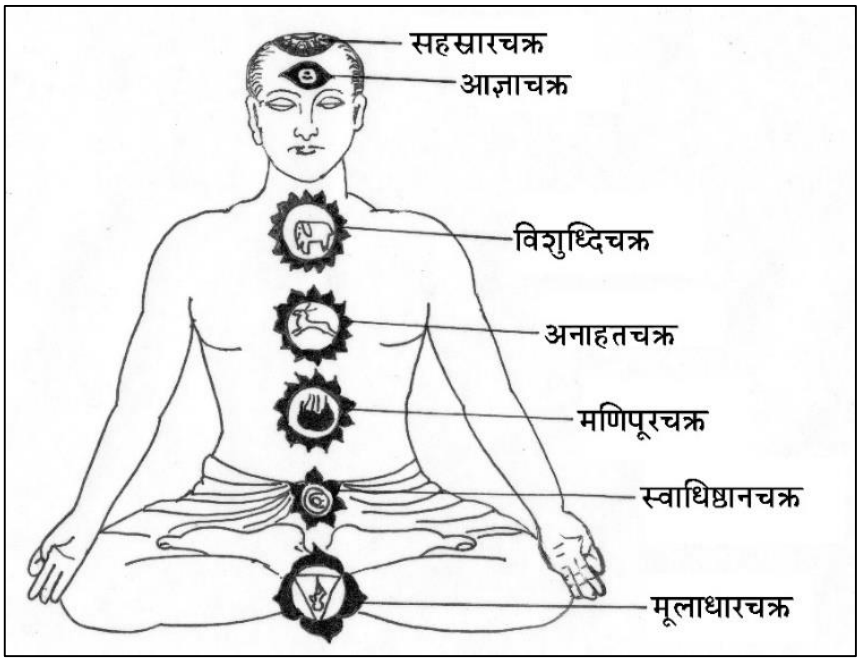


Fig. 3 ***Nāḍī cakra***

Sr. no.	Name	Location	*Pancama hābhūta*	Petals	Colour	Letters on petals	*Yantra*	*Bīja-akṣara*	*Bīja vāhak*	God	Goddess	*Loka*	Result of concentration
1	Mūlādhara	End of spinal cord	Pṛithvi	Four	Blood red	Vam, Sam, Shams Ssam	Square	Lam	Airāvata	Ganeṣa, Brahma	Dākinī	Bhū	Health and Vidyā
2	Svādhishṭhāna	Base of genitalia	Jala	Six	Vermillion	Bam, Bham, Mam, Yam, Ram, Lam	Crescent moon	Vam	Makara	Brahma, Vishnu, Hara	Rākinī, Varuṇa	Bhuvar	Poetic power
3	Maṇipūra	Level of umbilicus	Agni	Twelve	Blue	Damm, Dhamm, Namm, Tam, Tham, Dam, Dham, Nam,Pam, Pham	Triangle	Ram	Mesha	Vishnu, Ṣankar	Lakṣmi (Lākinī)	Swarg	Vidyā, capacity enhances
4	Anāhata	Heart	Vāyu	Twelve	Red	Kam, Kham, Gam, Gham, Nnam, Cam, Cham, Jam, Jham, Jnam, Ttam, Tham	Hexagonal	Yam	Deer	Rudra	Kākinī	Mahar	Achievement of rationality and godliness

Sr. no.	Name	Location	*Pancam ahābhūta*	Petals	Colour	Letters on petals	*Yantra*	*Bīja-akṣara*	*Bīja vāhak*	God	Goddess	*Loka*	Result of concentration
5	viṣuddha	Level of throat	Ākāṣa	Sixteen	Dark smoke	Am, Aam, Im, Iim, Um, Uum, Rm, Rrm, Lm, Llm, Em, Alm, Om, Aum, Aam, Ahm.	Round	Ham	Elephant	Maheṣvara	Ṣākinī	Janar	Speech, knowledge
6	Ājñā	In between eyebrows		Two	White	Ham, kṣam	Oval	Aum	Nāda	Linga Ṣambhu	Hākinī	Tapah	Perfection of speech
7	Sahasrahār	Brain		One thousand	Colourless	A to kṣa	Formless, fulmoon	Visarga	Vindu	Para Brahma	Mahā Sakti	Satya	Emancipation

Table no.1 Description of *Nāḍī cakra*

Consideration of *dosha* and *dūshya* in *manyāstambha*

Vāta dosha

Properties of *Vāta dosha*

रूक्षलघुशीतदारुणखरविशदाः षडिमे वातगुणा भवन्ति ॥ –च.सू.१२/४

The six properties of *vāta* are- *rūksha, laghu, śīta, dāruṇa, khara, viśada*.

Functions of *vāyu*

उत्साहोच्छ्वासनिःश्वासचेष्टा धातुगतिः समा ।

समो मोक्षो गतिमतां वायोः कर्माविकारजम् ॥ –च.सू.१८/४९

utsāha, ucchvāsa, nihśvāsa, ceshṭā normal functioning of *dhatus* and normal elimination of *mala*. These are the normal functions of *vāyu*.

सर्वा हि चेष्टा वातेन स प्राणः प्राणिनां स्मृतः ।

तेनैव रोगा जायन्ते तेन चैवोपरुध्यते ॥ –च.सू.१७/११८

All the movements are due to normal *vāta* and *vāta* is considered as *prāṇa* of the organism. But in abnormal state it produces disorders obstructing *prāṇa*.

वातप्रकोपणानि खलु रूक्षलघु शीतदारुणखरविशदशुषिरकराणि

शरीराणां, तथाविधेषु शरीरेषु वायुराश्रयं गत्वाऽऽप्यायमानः प्रकोपमापद्यते;

वातप्रशमनानि पुनः स्निग्धगुरूष्णश्लक्ष्णमृदुपिच्छिलघनकराणि

शरीराणां तथाविधेषु शरीरेषु वायुरसज्यमानश्चरन् प्रशान्तिमापद्यते ॥ –च.सू.१२/७

the *vāta* vitiating factors produce *rūkśatā, laghutā, śītatā, dāruṇatā, kharatā, viśadatā,* and *śushiratā* in the body parts. *Vāyu* finds favorable environment and gets located and vitiated in those body parts. On the contrary, *vāta* pacifying factors produce *snigdhatā, gurūtā, ushṇtā, ślakśṇatā, mṛidutā, picchilatā* and *ghanatā. Vāyu* moving in such body parts finds no place and gets pacified.

Pitta

दर्शनं पक्तिरूष्मा च क्षुत्तृष्णा देहमार्दवम् ।

प्रभा प्रसादो मेधा च पित्तकर्माविकारजम् ॥ –च.सू.१८/५०

Darśana, pacana, ushmā, ksudhā, tṛishṇā, dehamārdava, prabhā, prasāda and *medhā* are the normal functions of *pitta*.

Kapha

Locations of *kapha*

उरः शिरो ग्रीवा पर्वाण्यामाशयो मेदश्च श्लेष्मस्थानानि । –च.सू.२०/८

Urah, śira, grīvā, sandhi, āmāśaya and *meda* are the locations of *kapha* particularly the chest.

Functions of *Kapha*

स्नेहो बन्धः स्थिरत्वं च गौरवं वृषता बलम् ।

क्षमा धृतिरलोभश्च कफकर्माविकारजम् ॥ –च.सू.१८/५१

Sneha, bandha, sthiratva, gaurava, vṛishata, bala, kśamā, dhṛiti and *alobha*. These are the normal functions of *kapha*.

सन्धिसंश्लेषणस्नेहनरोपणपूरणबलस्थैर्यकृच्छ्लेष्मा

पञ्चधा प्रविभक्त उदककर्मणाऽनुग्रहं करोति ॥ –सु.सू.१५/६

Śleshmā divided into five divisions supports the body by functions such as *sandhisanśleshaṇa, snehana, ropaṇa, pūraṇa, bala, sthairya* and such other functions of water. (These functions are very much significant in the intervertebral disc (symphysis joint) as well as in the facet joints.)

Dhātu

Constituents of the body which support, nourish and help the body to grow are called *dhātu.* These are developed from *pancamahābhūta.* The structures in the neck are formed of various *dhātu* i.e. *asthi, majjā, māṉsa* etc.

Healthy condition of *dhātu* depends on balanced state of *dosha*.

स्वधातुवैषमानिमित्तजा ये विकारसंघा बहवः शरीरे ।

न ते पृथक् पित्तकफानिलेभ्य आगन्तवस्त्वेव ततो विशिष्टाः ॥ –च.सू.१९/६

The group of diseases in the body which are caused by the disequilibrium of *dhātu* are not independent of *vāta, pitta* and *kapha*. Only *āgantu* (exogenous diseases) are different from them.

Significance of *vāyu* in the development of *manyāstambha*

Vāyu has a very important role in the development of *manyāstambha. Vāyu* becomes vitiated by various means. The structure of the neck especially the spine is very much prone to be affected by *vāyu* and development of *manyāstambha.* Hence here *vāyu* has been considered meticulously with respect to its vitiation.

Process by which vitiated *vāyu* affects the body

Due to various aggravating causes *vāyu* develops various disorders. An important basic principle regarding this has been stated below-

देहे स्रोतांसि रिक्तानि पूरयित्वाऽनिलो बली ।

करोति विविधान् व्याधीन् सर्वाङ्गैकाङ्गसंश्रयान् ॥ –च.चि.२८/१८

Vāyu gets aggravated and filling up *rikta srotas* vacant channels in the body produces various disorders pertaining to the entire body and one of the parts.

Two ways for *vāyu* to become vitiated

वायोर्धातुक्षयात् कोपो मार्गस्यावरणेन च (वा) । –च.चि.२८/५९

धातुक्षयादिति सारक्षयात् । मार्गावरणेन वेगप्रतिबन्धादेव कुपितो भवति ।

–चक्र.च.चि.२८/५९

Vitiation of *vāyu* takes place from either wasting of *dhātus* or obstruction in passage.

Ekāṅgavāta* and *sarvāṅgavāta

In *ekaṅgavāta*, *vāyu* affects only a certain region of the body. If it is left untreated it affects many regions of the body producing the condition *sarvāṅgavāta*.

हस्तपादशिरोधातूंस्तथा संचरति क्रमात् ॥

व्याप्नुयाद्वाऽखिलं देहं वायुः सर्वगतो नृणाम् ॥

स्तम्भनाक्षेपणस्वापशोफशूलानि सर्वगः ॥ –सु.नि.१/३०

वायुस्तथा हस्तपादशिरः क्रमात् संचरति यथा उपेक्षितः

सन्नखिलं देहं व्याप्नुयात्, तथा धातून् क्रमात् संचरति यथा

सर्वगतो वा भवति सर्वधातुगतो वा भवतीत्यर्थः ।

व्याप्नुयाद्वेति वाशब्दो भिन्नक्रमे, सर्वगतो वेत्यत्र द्रष्टव्यः ॥ –ड.सु.नि.१/३०

हस्तावस्तम्भनादिभिरेकाङ्गगतैरेकाङ्गत एवानुमेयः । –ड.सु.नि.१/३१

सर्वाङ्गसंन्नयस्तोदभेदस्फुरणभञ्जनम् ।

स्तम्भनाक्षेपणस्वापसन्ध्याकुञ्चनकम्पनम् ॥ –अ.सं.नि.१५/१७

Aggravated *vāyu* affects the arms, legs, head and tissues, one after the other successively and affects the entire body when all the tissues are invaded. Aggravated *vāta* moving the whole body produces *stambhana*, *ākṡepaṇa*, *svāpa*, *ṡopha* and *ṡūla*.

kṡaya (Wasting) of *dhātus* is the probable cause of *sarvāṅgavāta*.

सर्वाङ्गगो वातप्रकोपः प्रायोः धातुक्षयनिमित्तः.....। –डल्हण.सु.चि.४/११

Basic principles to diagnose *vātika* disorders

सर्वेष्वपि खल्वेतेषु वातविकारेषूक्तेष्वन्येषु चानुक्तेषु

वायोरिदमात्मरूपमपरिणामि कर्मणश्च स्वलक्षणं, यदुपलभ्य

तदवयवं वा विमुक्तसंदेहा वातविकारमेवाध्यवस्यन्ति कुशलाः,

तद्यथा– रौक्ष्यं शैत्यं लाघवं वैशद्यं गतिरमूर्तत्वमनवस्थितत्वं

चेति वायोरात्मरूपाणिः एवंविधत्वाच्च वायोः कर्मणः स्वलक्षणमिदमस्य

भवति तं तं शरीरावयवमाविशतः; तद्यथा– –च.सू.२०/१२

In all these *vātika* disorders, said or unsaid-the following natural and specific characters are observed, finding which wholly or partly, the expert physicians undoubtedly diagnose them as the disorders of *vāta dosha* alone. They are- *raukṡya*, *ṡyaitya*, *lāghava*, *vaiṡadyatva*, *gati*, *mūrtatva* and *anavasthitatva* are the specific characters of *vāta*. *Vāta dosha* having these characters produces the following actions in respective organs when enters into them.

Disorders produced by vitiated *vāta dosh*

स्रंसभ्रंसव्याससङ्गभेदसादहर्षतर्षकम्पवर्त

चालतोद व्यथाचेष्टादीनि, तथा खरपरुषविशदसुषिरारुणवर्ण

कषायविरसमुखत्व शोषशूलसुप्तिसङ्कोचन स्तम्भनखञ्जतादीनि च

वायोः कर्माणि, तैरन्वितं वातविकारमेवाध्यवस्येत्॥ –च.सू.२०/१२

स्रंसः किंचित्स्वस्थानचलनम्, भ्रंशस्तु दूरगतिः। व्यासः विस्तरणम् ।

हर्षः वायोरनवस्थितत्वेन प्रभावाद्वा क्रियते । वर्तुलीकरणं वर्तः ।

चालः स्पन्दः । रसवर्णौ वायुना रसवर्णरहितेनापि प्रभावात् क्रियते ॥

–चक्र.

Vitiated *vāta dosha* having this characters produces the following actions in respective organs when enters into them such as *sraṉsa, bhraṉsa, vyāsa, saṅga, bheda, sāda, harsha, tarsha, kampa, varta, cāla, toda, vyathā, ceshṭā* etc. and also *khara, parusha, viśada, sushira, aruṇavarṇa, kashāyavirasamukhatva, śosha, śūla, sūpti, saṅgkocana, stambhana, khaⁿjatā* etc. are the actions of *vāyu*. These diseases should be diagnosed as *vātic* one.

These *sraṉsa, bhraṉsa* are considered as '*vāta vikār'*; produced by *vitiated vāta dosha* alone. In the same *shloka; Caraka* has emphasized the importance of anatomical structures. Because vitiated *vāta dosha* affects certain regions, organs, structures of body. And the effect of vitiated *vāta dosha* is observed in the form of involvement, and abnormal structural changes in the anatomical structures of body themselves.

Amūrtatva (formlessness) is the character of *vāyu*. Hence *raukshya, shaitya, laghava, vishadatā, gati, anavasthitva* these characters of *vāyu* are observed with respect to anatomical and physiological elements only.

वर्णः श्यावोऽरुणोऽपि वा ॥ –अ.हृ.सू.१२/४९

According to *ashtāng hṛidaya, shyāva* and *aruṇa* discoloration is developed in the structures due to *vitiated vāta dosh.*

In the list of diseases developed by *vāta, Caraka* has mentioned stiffness of neck-

तत्रादौ वातविकाराननुव्याख्यास्यामः.....ग्रीवास्तम्भश्च,

मन्यास्तम्भश्च.....इत्यशीतिर्वातविकारा । –च.सू.२०/११

Therefore, the only way for perception of vitiated *vāta dosha* is to study the effect of it on anatomy and physiology (*shārira*) of body region or organs. This fact is described by *Caraka* in the following *shloka*-

रोगमादौ परीक्षेत ततोऽनन्तरमौषधम् ।

ततः कर्म भिषक् पश्चाज्ज्ञानपूर्वं समाचरेत् ॥

यस्तु रोगमविज्ञाय कर्माण्यारभते भिषक् ।

अप्यौषधविधानज्ञस्तस्य सिद्धिर्यदृच्छया ॥

यस्तु रोगविशेषज्ञः सर्वभैषज्यकोविदः ।

देशकालप्रमाणज्ञस्तस्य सिद्धिरसंशयम् ॥ –च.सू.२०/२०–२२

The physician should examine the disorder first then the medicine and finally give the treatment. He should treat the patient with prior knowledge. The physician who without knowing the disease starts the treatment may get success coincidentally even if he is skillful in the management with drugs. The physician who knows the characters of disease, is accomplished in all therapeutic measures and is familiar with the appropriate measure of place and time; succeeds certainly.

The diseases produced by aggravated *vāyu* in *māṉsa* and *meda*

गुर्वङ्गं तुद्यते स्तब्धं दण्डमुष्टिहतं यथा ।

सरुक् स्तिमितमत्यर्थं मांसमेदोगतेऽनिले ॥ –च.चि.२८/३२

Vitiated *vāta* affecting *māmsa* and *meda* produces *gurūtā* in organs, severe *toda* as if beaten with sticks or fists, *ruk* and *stimitatā*.

The diseases produced by aggravated *vāyu* in *asthi* and *majjā*

भेदोऽस्थिपर्वणां सन्धिशूलं मांसबलक्षयः ।

अस्वप्नं सन्तता रुक् च मज्जास्थिकुपितेऽनिले ॥ –च.चि.२८/३३

Vitiated *vāta* affecting *asthi* and *majjā* produces *bheda* (breaking pain in bones and joints), loss of *māmsa* and *bala*, *asvapna* and *santatā ruk* (continuous pain).

मज्जस्थोऽस्थिशु सौषिर्यम् अस्वप्नं स्तब्धतां रुजम् । –अ.हृ.नि.१५/१०

Aggravated *vāta* residing in *majjā* causes *sushirata* (porosity in the bones), *asvapna*, *stabdhatā* and *rujā*.

अस्थिशोषं च प्रभेदं च कुर्याच्छूलं च तच्छ्रितः ॥ –सु.नि.१/२८

Affecting the bones *vāyu* produces *asthi śosha* (degeneration), and *prabheda* (their fractures) and causes *śūla* (bone ache).

तथा मज्जगते रुक् च न कदाचित् प्रशाम्यति ॥ –सु.नि.१/२७–२९

Affecting *majja dhātu*, *vāyu* produces pain which may not be pacified or soothed.

The diseases produced by aggravated *vāyu* in muscles, tendons

स्नायुप्राप्तः स्तम्भकम्पौ शूलमाक्षेपणं तथा ॥ –सु.नि.१/२७

In *snāyu* (tendons and ligaments) *vāyu* produces *stambha*, *kampa*, *śūla* and *ākśepaṇa*.

बाह्याभ्यंतरमायामं खल्लिं कुब्जत्वम् एव च ॥

सर्वाङ्ग एकांङ्ग रोगांश्च कुर्यात् स्नायुगतोऽनिलः ॥ –च.चि.२८/३५

Vāyu located in *snāyu*, produces *bāhyāyāma* (opisthotonus), *abhyantara āyama* (emprosthotonus), *khalli* (cramps), *kubjatva* (humpedness) and general and other generalized or localized disorders.

The diseases produced by aggravated *vāyu* in the joints

हन्ति सन्धिगतः सन्धीन् शूलशोफौ करोती च ॥ –सु.नि.१/२८

In the joints *vāyu* produces painful inflammatory swelling affecting joint movements.

सन्धिगतः सन्धीन् हन्ति प्रसारणाकुञ्चनयोरसामर्थ्यं करोति । –डल्हण, सु.नि.१/२८

Aggravated *vāta* residing in joints destroys the movements of the joints and produces pain and swelling in them.

प्रसारणाकुञ्चनयोः प्रवृत्तिश्च सवेदना । –च.चि.२८/३७

Pain is felt during contraction and extension.

The diseases produced by aggravated *vāyu* in *tvak*

वैवर्ण्यं स्फुरणं रौक्ष्यं सुप्तिं चुमुचुमायनम्॥

त्वक्स्थो निस्तोदनं कुर्यात् त्वग्भेदं परिपोटनम् ॥ –सु.नि.१/२५

Aggravated *vāta* residing in *tvak* (*rasa dhātu*) produces *vaivarṇya, sphuraṇa, raukśya, supti, cumucumāyana, nistoda, tvakbheda* and *paripoṭana*.

The symptoms *supti, cumucumāyana, nistoda* mentioned above are similar to that found in cervical spine diseases producing radiculopathy.

Combined effect of *vata, pitta and kapha dosha*

These are few conditions which are produced by means of various combinations of *dosha*. These include symptoms produced in *manyāstambha* and its various stages. The following lines emphasizes the importance of *vāta, pitta* and *kapha dosha* in the process of developing disease.

सर्व एव निजा विकारा नान्यत्र वातपित्तकफेभ्यो निर्वर्तन्ते,
यथाहि–शकुनिः सर्वं दिवसमपि परिपतन् स्वां छायां
नातिवर्तते, तथा स्वधातुवैषम्यनिमित्ताः सर्वे विकारा
वातपित्तकफान्नातिवर्तन्ते । वातपित्तश्लेष्मणां पुनः
स्थानसंस्थानप्रकृति विशेषानभिसमीक्ष्य तदात्मकानपि च
सर्वविकारांस्तानेवोपदिशन्ति बुद्धिमन्तः ॥ –च.सू.१९/५

All the innate illnesses do not arise except from *vāta, pitta* and *kapha*. A bird flying over all the day does not get free from its shadow. Similarly, all the diseases due to disequilibrium of *dhātu* do not go beyond the causation of *vāta, pitta* and *kapha*. The expert physicians observe *vāta, pitta* and *kapha* with respect to location, characters and functions and define the disease caused by them.

प्रकृतिस्थं यदा पित्तं मारुतः श्लेष्मणः क्षये ।
स्थानादादाय गात्रेषु यत्र यत्र विसर्पति ॥
तदा भेदश्च दाहश्च तत्र तत्रानवस्थितः ।
गात्रदेशे भवत्यस्य श्रमो दौर्बल्यमेव च ॥ – च.सू.१७/४५–४६

In the event of diminution of *kapha, vāta* moves away the normal *pitta* from its location. This produces *bheda* (severe tearing pain), *dāha* (burning sensation) in those organs wherever it spreads; along with *śrama* (fatigue) and *daurbalya* (debility).

यदाऽनिलं प्रकृतिगं पित्तं कफपरिक्षये। संरुणद्धि
तदा दाहः शूलं चास्योपजायते ॥ –च.सू.१७/४८

When *pitta*, in diminution of *kapha*, obstructs the normal *vāta*, *dāha* and *śūla* are developed.

मारुतस्तु कफे हीने पित्तं च कुपितं द्वयम् ।
करोति यानि लिङ्गानि शृणु तानि समासतः ॥
भ्रममुद्वेष्टनं तोदं दाहं स्फुटनवेपने ।
अङ्गमर्दं परीशोषं दूयनं धूपनं तथा ॥ –च.सू.१७/५८

When *kapha* is diminished and both *vāta* and *pitta* are aggravated, it produces *bhrama, udveshṭana, toda, dāha, sphuṭana, vepana, aṅgamarda, parīśosha, dūyana* and *dhūpana*.

These symptoms i.e. *daurbalya, toda, dāha, bhrama* are observed in *manyāstambha* and in severe cases of radiculopathy.

दाहसन्तापमूर्च्छाः स्युर्वायौ पित्तसमन्विते ॥३२॥
शैत्यशोफगुरुत्वानि तस्मिन्नेव कफावृते ।
सूचीभिरिव निस्तोदः स्पर्शद्वेषः प्रसुप्तता ॥३३॥
शेषाः पित्तविकाराः स्युर्मारुते शोणितान्विते ।
प्राणे पित्तावृते छर्दिर्दाहश्चैवोपजायते ॥३४॥
दौर्बल्यं सदनं तन्द्रा वैवर्ण्यं च कफावृते ।
उदाने पित्तसंयुक्ते मूर्च्छादाहभ्रमक्लमाः ॥३५॥
अस्वेदहर्षौ मन्दोऽग्निः शीतस्तम्भौ कफावृते ।
समाने पित्तसंयुक्ते स्वेददाहौष्ण्यमूर्च्छनम् ॥३६॥
कफाधिकं च विण्मूत्रं रोमहर्षः कफवृते ।
अपाने पित्तसंयुक्ते दाहौष्ण्ये स्यादसृग्दरः ॥३७॥
अधः कायगुरुत्वं च तसिन्नेव कफावृते ।
व्याने पित्तावृते दाहो गात्रविक्षेपणं क्लमः ॥३८॥
गुरूणि सर्वगात्राणि स्तम्भनं चास्थिपर्वणाम् ।
लिङ्गं कफावृते व्याने चेष्टा–स्तम्भस्तथैव च ॥३९॥ –सु.नि.१/३३–३९

Vāta mixed with *pitta* gives rise to *dāha, santāpa* and *mūrchā*. Getting covered with *kapha* it produces *śaitya, śopha* and *gurūtva*.

Vāta mixed with *śoṇita* produces pain as though pricked by needles, *sparśadvesha*, *prasuptatā* and other symptoms of *pitta* aggravation.

Prāna vāyu when covered by *pitta* gives rise to *chardi* and *dāha*. When covered by *kapha* it produces *daurbalya, sadana, tandrā* and *vaivarṇya*.

Udāna vāyu when mixed with *pitta* produces *mūrchā, dāha, bhrama* and *klama*.

When it is covered by *kapha*, it causes *asweda, harsha, mandoagni*, feeling of *śītatā* and *stambha*.

Samāna vāyu when mixed with *pitta* produces *sveda, dāha, ushṇatā* and *mūrchā*.

When covered by *kapha*, it causes increase of *kapha*, more of *viṇ* (faeces), *mūtra* and *romaharsha*.

Apāna vāyu mixed with *pitta* produces *dāha, ushṇatā* and *asṛigdara*.

When covered by *kapha*, it gives rise to feeling of heaviness of the lower body.

Vyāna vāyu when covered by *pitta* causes *dāha, gātravikśepaṇa, klama*, feeling of heaviness of the entire body and *stambha* of the bony joints.

When covered by *kapha*, it gives rise to loss of movements.

***Manyāstambha*, as a disease**

Manyāstambha, the disease condition of present study is not being described as a disease in *Samhitā* but we get many patients of it with certain symptoms. We get these symptoms scattered in various references as stated above. Therefore, it is the necessity that we should offer rank of a disease to *Manyāstambha*. Following are the guidelines with this respect-

त एवापरिसंख्येया भिद्यमाना भवन्ति हि ।
रुजावर्णसमुत्थानस्थानसंस्थाननामभिः ॥
व्यवस्थाकारणं तेषां यथास्थूलेषु संग्रहः ।
तथा प्रकृतिसामान्यं विकारेषूपदिश्यते ॥ –च.सू.१८/४२–४३

In fact, the diseases are innumerable being divided on the basis of disorder, color, etiology, symptoms and name. Their systematization has been attempted in the form of some gross diseases. However, in other cases general principle may be followed.

विकारानामाकुशलो न जिन्हियात् कदाचन ।
न हि सर्वविकाराणां नामतोऽस्ति ध्रुवास्थितिः ॥४४॥

स एव कुपितो दोषः समुत्थानविशेषतः ।
स्थानान्तरगतश्चैव जनयत्यामयान् बहून् ॥४५॥
तस्माद्विकारप्रकृतीरधिष्ठानान्तराणि च ।
समुत्थानविशेषांश्च बुध्द्वा कर्म समाचरेत् ॥ ४६॥
यो ह्येतत्त्रितयं ज्ञात्वा कर्माण्यारभते भिषक् ।
ज्ञानपूर्वं यथान्यायं स कर्मसु न मुह्यति ॥४७॥

–च.सू.१८/४४–४७

The one who cannot label a disorder with some name should not feel ashamed because all disorders have no established footing by name. The reason is that the same vitiated *dosha* causes various disorders according to variations in etiology and location. Hence one should initiate treatment after having complete knowledge about the nature of the disorder (pathogenesis), locations and etiological factors. The one who initiates treatments after knowing these three, rationally and according to prescribed procedure does not get confused in actions.

वृद्धिस्थानक्षयावस्थां रोगाणामुपलक्षयेत् ।
सुसूक्ष्मामपि च प्राज्ञो देहाग्निबलचेतसाम् ॥३६॥
व्याध्यवस्थाविशेषान् हि ज्ञात्वा ज्ञात्वा विचक्षणः ।
तस्यां तस्यामवस्थायां चतुःश्रेयः प्रपद्यते ॥३७॥ –च.नि.८/३६–३७

The intelligent physician should observe the states of aggravation, normalcy and diminution of diseases even if they are subtle along with the condition of *dehāgni*, strength and mind. The expert physician continuously observing the conditions of the disease and managing the treatment accordingly obtains the valuable fours i.e. virtue, wealth, enjoyment and emancipation.

दोषभेषजदेशकालबलशरीरसाराहार सात्म्यसत्त्वप्रकृतिवयसां मानमवहितमनसा
यथावज्ज्ञेयं भवति भिषजा, दोषादिमानज्ञानायत्तत्वात् क्रियायाः ।
न ह्यमानज्ञो दोषादीनां भिषग् व्याधिनिग्रहसमर्थो भवति । –च.वि.१/३

The physician should observe wisely the features of *doshas*, drugs, place, time, strength, body (anatomy), constitutional dominance of *dhātu*, diet, suitability, psyche

constitution and age. Because the line of treatment depends on these features. The physician unaware of these features fails to treat the disease.

Patient of *manyāstambha* may become symptomless occasionally in spite of involvement of structures and their changes. How this is possible is explained in the following low of *swabhāvoparamh*.

जायन्ते हेतुवैषम्याद्विषमा देहधातवः।

हेतुसाम्यात् समास्तेषां स्वभावोपरमः सदा ॥ –च.सू.१६/२७

Dhātus of the body suffer disequilibrium due to imbalance of the cause and they remain in equilibrium when the cause is in balance. Their termination is always natural.

Manyāstambha **and certain other disorders related with it**

The study of pathology and etiology of some following disorders helps to understand many symptoms developed in *manyāstambha* i.e. stiffness, pain, tingling sensation etc. as these are not explained in it. These disorders are also considered under differential diagnosis.

Manyāstambha

Etymology-

The word *manyāstambha* is composed of two words- मन्या + स्तम्भ

मन्या–

मन्या= ग्रीवायाः पश्चात शिरा। इत्यमरः ॥

मन् + करणे क्यप्। स्त्रियां टाप्।

मन्यते ज्ञायते स्तम्भदुःखादिकमनया ।

– शब्दकल्पद्रुम भाग क्र.३, पृ.क्र.६३०

Manyā is synonym of *grīvā* (nape of the neck) which experiences stiffness, pain and so on.

स्तम्भ–

स्तम्भो जडीभावस्तत्करणञ्च ।

स्तम्भ इह क्रियानिरोधः इति भीमः ।

स्तम्भ, रोधने । इति कविकल्पद्रुमः ।

स्तम्भः स्थूनजडत्वहोरिति विश्वः । इति त ीका

– शब्दकल्पद्रुम भाग क्र.५, पृ.क्र.४३२

Stambha stands for stiffness, rigidity; which confines the activity. Therefore, *manyāstambha* is stiffness or rigidity of the neck in the form of reduced movements.

Manyāstambha described by *Suṣruta*-

दिवास्वप्नासनस्थानविकृतोर्ध्वनिरीक्षणैः ।

मन्यास्तम्भं प्रकुरुते स एव श्लेष्मणाऽऽवृतः ॥ –सु.नि.१/६७

Sleeping during day, improper sitting, standing and gazing upwards, *vāta* gets aggravated and covered by *śleshmā* produces *manyāstambha*.

This is an acute condition produced by the muscular and ligamental involvement.

There are certain diseases described in Ayurvedic texts in which symptoms of *manyāstambha* are found along with referred pain in head, upper limbs, symptoms of nerve roots compression etc. These are described below-

Ardhāvabhedaka

अर्धावभेदको वा स्यात्सर्वं वा स्यात् सर्वं वा रुज्यते शिरः।

प्रतिश्यामुखनासाक्षिकर्णरोगशिरोभ्रमाः ॥

अर्दितं शिरसः कम्पो गलमन्याहनुग्रहः ।

विविधाश्चापरे रोगा वातादिक्रिमिसंभवः ॥ – च.सू.१७/१४

Pain in half or entire head, *pratiśyāya*, disorder of mouth, nose, eyes and ear, *bhrama*, *ardita*, *śrakampa*, stiffness in throat, neck and jaws and other various disorders are due to *vāta* etc. and *krimis*.

पृथग्दिष्टास्तु ये पञ्च संग्रहे परिमर्षिभिः ।

शिरोगदांस्ताञ्छृणु मे यथास्वैर्हेतुलक्षणैः ॥१५॥

उच्चैर्भाष्यातिभाष्याभ्यां तीक्ष्णपानात् प्रजागरात् ।

शीतमारुतसंस्पर्शाद्व्यवायाद्वेगनिग्रहात् ॥१६॥

उपवासादभीघाताद्विरेकाद्वमनादति ।

बाष्पशोकभयत्रासाद्धारमार्गातिकर्शनात् ॥१७॥

शिरोगताः सिरा वृद्धो वायुराविश्य कुप्यति ।
ततः शूलं महत्तस्य वातात् समुपजायते ॥१८॥
निस्तुद्येते भृशं शङ्खौ घाटा संभिद्यते तथा ।
सभ्रूमध्यं ललाटं च तपतीवातिवेदनम् ॥१९॥
वध्यते स्वनतः श्रोत्रे निष्कृष्येते इवाक्षिणी ।
घूर्णतीव शिरः सर्वं संधिभ्य इव मुच्यते ॥२०॥
स्फुरत्यतिसिराजालं स्तभ्यते च शिरोधरा ।
स्निग्धोष्णमुपशेते च शिरोरोगेऽनिलात्मके ॥२१॥

–च.सू.१७/१५–२१

Now listen about the five head diseases along with causes and symptoms as said earlier by the great sages. Due to loud and too much speech, sharp drinks, vigil, contact with cold wind, sexual intercourse, suppression of urges, fasting, injury, excessive vomiting and purgation, tears, grief, fear and anxiety excessive exhaustion due to weight-carrying and travelling on foot *vāyu* gets aggravated and vitiated and entering into the *śirogata sirā* and produces these symptoms.

There is intense *śūla* due to *vāta* particularly in temporal regions and nape, middle of the eyebrow and forehead have *dāha* and *ativedanā*. There is dizziness and pain in the ears, eyes seem to be coming out (due to pain), the entire head reels about and seems to be broken on sutures, *sirājāla* have excessive throbbing and neck becomes stiff the patient gets relief from unctuous and hot applications. This is about head diseases caused by *vāta*.

In *manyastambha*, in the advance stages of disease the exiting nerve roots through the intervertebral foramen get compressed by the herniation of the intervertebral disc called radiculopathy which produces tingling and burning sensation in the upper limb. The pathology of these symptoms developed in the legs is described in the following lines. It will be helpful if the same pathology can be applicable for the hands.

पादयोः कुरुते दाहं पित्तासृक्सहितोऽनिलः ॥
विशेषतश्चङ्क्रमणात् पाददाहं तमादिशेत् ॥ सु.नि.१/८०

The *dāha* in the soles of the feet caused by the enraged local *vāyu* in conjunction with the deranged *pitta* and *asṛik* is called *pāda dāha*.

हृष्यतश्चरणौ यस्य भवतश्च प्रसुप्तवत् ॥

पादहर्षः स विज्ञेयः कफवातप्रकोपजः॥ सु.नि.१/८१

पादहर्षमाह–हृष्यत इत्यादि । हृषत इति हर्षो रोमाञ्चप्रायो
वेदनाविशेषोऽन्तःशीतकरः । भवतश्च प्रसुप्तवदिति
स्पर्शाज्ञानात् सुप्ताविव भवत इत्यर्थः ॥ –नि.सं.

पादहर्षः कफान्वितेन वातेन। हर्षो रोमाञ्चप्रायोऽन्तःशीतकरो
वेदनाविशेषः । सुप्तकौ स्पर्शस्यावेदनात् सुप्ताविव ।
अयं पाददाहविपरीतः पादहर्षो वातकफाभ्यां
चिरविषमपादन्यासादिना; परः पाददाहः खलु
सिरामुखपीडनावृतेन वायुना, सोऽस्माद् भिन्नः;
सिरामुखावृतत्वेन तद्विवृतौ स्वयमेव प्रशमते॥ –न्या.च.

When the legs are deprived of all sensibility of touch and a sort of tingling sensation is experienced in them it is called *pādaharsha*. Which is due to deranged action of *vāyu* and *kapha*.

Antarāyāma

मन्ये संश्रित्य वातोऽन्तर्यदा नाडीः प्रपद्यते ।
मन्यास्तम्भं तदा कुर्यादन्तरायामसंज्ञितम् ॥ ४३
अन्तरायम्यते ग्रीवा मन्या च स्तभ्यते भृशम् ।
दन्तानां दशनं लाला पृष्ठायामः शिरोग्रहः ॥४४॥
जृम्भा वदन सङ्गश्चाप्यन्तरायामलक्षणम् ।
इत्युक्तस्त्वन्तरायामो ----------॥ –च.चि.२८/४३–४५

मन्ये इत्यादिना अन्तरायाममाह । अन्तर्यदा नाडीः
प्रपद्यते इति अन्यासंबद्धा एव अन्तर्गताः सिराः
प्रपद्यत इत्यर्थः । अन्तरायामसंज्ञितमिति एवंविधो मन्यास्तम्भ
अन्तरायाम उच्यते; अपरस्तु मन्यास्तम्भो अक्ष्यमाणबहिरायाम
इति वक्तव्यः। तन्त्रान्तरे तु मन्यास्तम्भ आयामयोः पूर्वरूपत्वेनोक्तः ।
अन्तरायम्यत इति अन्तः आकृष्यते । पृष्ठायाम इति पृष्ठबहिर्निर्गतिः।

–चक्र.

When the aggravated *vāyu* located in the neck area afflicts *nādi* (internal channels, vessels or nerves) of this region, it causes *manyā stambha* (neck stiffness) which is called *antarāyāma*. The neck bends forward and the sternomastoid region becomes excessively stiff. There is clenching of the teeth, *lālāsrāva*, contraction of the back, *śirograha*, *jṛimbhā* and rigidity of the face. This condition is called *antarāyāma*.

-Caraka

Bahirāyāma

----------बहिरायाम उच्यते ॥४५॥

पृष्ठमन्याश्रिता बाह्याः शोषयित्वा सिरा बली ।

वायुः कुर्याद्धनुस्तम्भं बहिरायामसंज्ञकम् ॥४६॥

चापवन्नाम्यमानस्य पृष्ठतो नीयते शिरः ।

उर उत्क्षिप्यते मन्या स्तब्धा ग्रीवाऽवमृद्यते ॥४७॥

दन्तानां दशनं जृम्भा लालास्रावश्च वाग्ग्रहः ।

जातवेगो निहन्त्येष वैकल्यं वा प्रयच्छति ॥४८॥

–च.चि.२८/४५–४८

पृष्ठेत्यादि बहिरायामलक्षणम् । पृष्ठमन्याश्रिता इति पृष्ठानुगतमन्यासंबद्धाः । बाह्या इति सिराविशेषणम् । बाह्याश्च सिराः पृष्ठगता एव । केचित्तु पृष्ठमन्याश्रित इति वातविशेषणं पठन्ति । पृष्ठतो नीयते इति पृष्ठं प्रति आकृष्यते । जातवेग इति उद्वेगः । एतौ चायामौ "बाह्याभ्यन्तरमायामंखल्लीं कुब्जत्वमेव च । सर्वैकाङ्गरोगांश्च कुर्यात् स्नायुगतोऽनिलः" इत्यनेन स्नायुगतानिलजन्यावुक्तौ, इह च सिरागतवातजन्यत्वेनोक्तौ, तेनोभयवचनात् सिरास्नायुगतवातजन्यावेव भवतः । उक्तं ह्यन्यत्र– महाहेतुर्बली वायुः सिराः सस्नायुकण्डराः । मन्यापृष्ठाश्रिता बाह्याः संशोष्यायामयेद्बहिः" इत्यादि । –चक्र.

Bahirāyāma is now being described. The aggravated *vāyu* located in the back side of the neck causes shrinking of the external *sirā.* As a result of which the body bends backwards like a bow which is called *bahirāyāma.* While bending backwards like a bow, the head moves towards the back, the chest gates protruded, the neck becomes stiff and squeezed and the teeth become clenched. In addition, there is *jṛimbhā*, *lālāsrāva* and *vāggraha*. When the attack becomes acute, it either leads to death of the patient or causes serious deformity in the body *-Charaka*

Both of these *antarāyāma* and *bahirāyāma* are developed due to vitiated *vāyu* affecting *snāyu* of this region. Here affection of *sirā* by *vāyu* is also mentioned. In another place it is mentioned that due to causative factors *vāyu* becomes severely vitiated and degenerates *sirā*, *snāyu* and *kandarā* located in the neck and back to produce *bahirāyām.* *-Cakrapāṇi*

Antarāyāma and *bahirāyāma* are included here only to understand how *vāyu* can produce *manyāstambha.*

Disorders of *snāyu, sirā and kaṇḍarā*

स्नायौ सिराकण्डराभ्यो दुष्टाः क्लिश्नन्ति मानवम् ।
स्तम्भसंकोचखल्लीभिर्ग्रन्थिस्फुरणसुप्तिभिः ॥ –च.सू.२८/२१
खल्ली करपदावमोटनम् । ग्रन्थिः स्नाय्वादिग्रन्थिरेव॥ –चक्र.

Doshas vitiated in *snāyu*, *sirā* and *kaṇḍarā* afflict the person with *stambha* (stiffness), *samkoca* (contraction or compression), *khallī* (shooting pain in the extremities- dictionary meaning) (*khallī- avamotana* of extremities), *granthi* (protuberance in *snāyu*, *sirā* etc.), *sphuraṇa* (throbbing), *supti* (numbness)

Three passages of diseases

त्रयो रोगमार्गा इति –शाखा, मर्मास्थिसन्धयः, कोष्ठश्च ।
तत्र शाखा रक्तादयो धातवस्त्वक् च, स बाह्यो रोगमार्गः ;
मर्माणि पुनर्बस्तिहृदयमूर्धादीनि, अस्थिसन्धयोऽस्थि
संयोगास्तत्रोपनिबद्धाश्च स्नायुकण्डराः, स मध्यमो रोगमार्गः,
कोष्ठः पुनरुच्यते महास्रोतः शरीरमध्यं महानिम्नमाम्प्क्वाशयश्चेति
पर्यायशब्दैस्तन्त्रे, स रोगमार्ग आभ्यन्तरः॥ –च.सू.११/४८

There are three passages of diseases- *śākhā* (periphery), *marmāsthisandhi* (vital parts) and *koshṭha* (trunk) (where internal organs of the body are located). Periphery consists of *dhatus- rakta* etc. and skin. It is the external passage of disease. *Marma* are *basti*, *hṛidaya*, *mūrdhā* etc. *asthi sandhi* are those where bones meet along with the attached *snāyukaṇḍrā*. It is the middle passage of diseases. *Koshṭha* is usually called *mahāsrot* in the middle of the body extending from above downwards. It includes *āmāśaya* and *pakwāśaya*. It is the internal passage of diseases.

पक्षवधग्रहापतानकार्दितशोषराजयक्ष्मास्थिसन्धिशूल

गुदभ्रंशादयः शिरोहृद्बस्तिरोगादयश्च मध्यममार्गानुसारिणो भवन्ति रोगाः ।

–च.सू.११/४९

pakśavadha, graha, apatānaka, ardita, śosha, rājayakśmā, asthisandhiśūla, gūdabhranśa etc. and the diseases of *śira, hṛidaya* and *basti* are the diseases of *madhyama mārga*.

From the above description it can be determined that *manyāstambha* is the disease of *madhyama mārga*.

***Anuvānṣika siddhānta* (laws of heredity)**

Āyurveda has proved that *bīja* (seed) of each organism carry normal as well as abnormal factors producing physical and mental properties. It has also been proved that disease producing factors are also transferred from the parents to their offspring. Many hereditary diseases are identified in *Āyurveda*. In the patients of *manyāstambha* family history may found.

A very important law has been stated by *Caraka* in this respect.

यस्य यस्य ह्यङ्गावयवस्य बीजे बीजभाग उपतप्तो भवति,

तस्य तस्याङ्गावयवस्य विकृतिरुपजायते, नोपजायते चानुपतापात् ॥ –च.शा.३/१७

In *bīja* of organism, the part of the body which is affected in its genetic source gets abnormality otherwise not.

It has been also stated that these inherited diseases are usually incurable.

असाध्यान्येवमाख्याताः सर्वे रोगाः कुलोद्भवाः॥ –अ.हृ.नि.७/७

Literature review from modern perceptive

The cervical spine is mainly a bony structure. Hence the study is started with description of bone.

The skeletal system in the neck

The human skeleton is an endoskeleton formed by bones. It provides attachment to the muscles and takes part in the body movements. It is also protective in function in the vault of the skull and vertebral column.

Bone

It is a firm structure which provides support and shape to the body and facilitate the mobility. In addition, bones protect the delicate organs of the body, produce red and white blood cells, store and release calcium, phosphate and other minerals. It regulates extracellular calcium concentration. The bone is constantly formed, resorbed and remodeled in response to mechanical stress, physiologic and biochemical demands.

The cervical spine is the most distinct part of the spine. Many anatomical structures are compactly arranged in a small area. It is believed that the cervical spine is the most complicated articular system in the body. The spinal movement is maximum in this region. It is surrounded by numerous nerves, vessels, muscles and ligaments etc. which are vital structures. Understanding the neck anatomy in detailed helps physician to make very precise assessment of the patients. This helps to establish effective line of treatment.

Structure of bone [2]

The **compact bone** (hard outer shell of all bones) consists of numerous cylindrical units, called *Haversian systems*. These have variable numbers of irregularly arranged interstitial lamellae. Each system (*osteone*) has a *Haversian* **(**or central) *canal* of 0.05 mm in diameter. It is surrounded by about ten concentric *lamellae* of bony tissue. The central canal contains artery, vein, nerves, areolar tissue and osteoblasts. Between the lamellae are numerous minute spaces called *lacunae*, connected with each other and with the central canal by fine *canaliculi*.

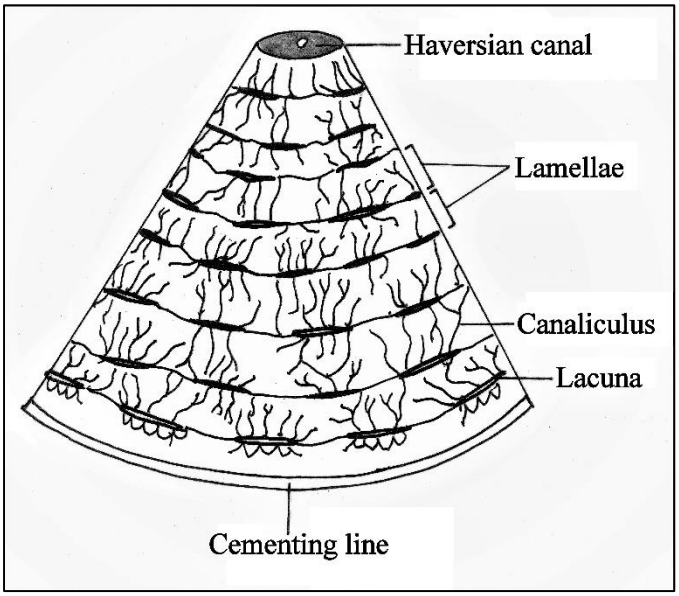


Fig.4 Haversian system

Cells of bone

Various cells are found in the bone these are-

1) **Osteoblast**- A cell that makes bone. It produces a matrix that becomes mineralized. They are active in protein synthesis and secret unmineralized bone matrix known as osteoid. They also help to control the transport of calcium and phosphate in and out of bone cells. The high concentrations of alkaline phosphatase can provide type I collagen and osteocalcin. They have surface receptors for PTH and 1, 25-dihydroxyvitamin D3. Osteoblasts respond to these cells and in turn regulate both phages of bone remodeling by inhibiting osteoclastic resorption and by controlling bone formation.

2) **Osteocyte**- It is a bone cell, formed when an osteoblast becomes embedded in the bone matrix (extracellular mineralized bone material).

3) **Osteoclast**- It is a large multinucleated bone cell, which breaks down bone tissue and absorbs it during growth and healing. They release protons that lower the local pH, activate acid proteases and degrade the extracellular matrix of bone. They have surface receptors for and act in response to calcitonin, colchicine, interlukin-1, interlukin-6, prostaglandin E2 and γ-Interferon. Osteoclasts do not have receptors for parathyroid hormone. Instead the osteoclasts act in a train paracrine response to these cells. Through inhibition of resorption by osteoblastic cells.

The extracellular matrix of bone is composed of water, collagen and hydroxyapatite crystals formed from calcium and phosphate. The hydroxyapatite provides the rigidity and compressive strength to bone [3]

Parathyroid Hormone plays an active role in the bone metabolism and acts in response to serum calcium levels. If the serum calcium levels are low, parathyroid hormone acts on osteoblasts, as well as the kidneys to increase the flow of calcium back into the serum partially through increased bone resorption.

Vitamin D is converted to 25-hydroxyvitamin D3 in the liver and subsequently to 1, 25- dihydroxy vitamin D3 in the kidneys. This is the active form of Vitamin D, and it plays a role in the synthesis of calcium- binding proteins that increase the ability to absorb calcium during digestion. The conversion to its active form in the kidney is regulated by parathyroid hormone.

Calcitonin is a hormone secreted by the thyroid gland in response to elevated serum calcium levels and acts to inhibit osteoclasts to prevent further release of calcium [4].

Cartilage

It is a type of connective tissue. It is softer and much more flexible than bone. It is present in the walls of larynx, trachea, bronchi, nose etc. It is covered by *perichondrium*. The matrix of the cartilage contains *chondroblasts* and *chondrocytes*. The intercellular matrix is composed of collagen, lipids, proteins and proteoglycan filaments. The ground substance is a gel. The matrix is created by the *chondrocytes*.

Types of cartilage- hyaline (e.g. costal, nasal, articular), white fibrocartilage (e.g. intervertebral disc), yellow elastic cartilage (e.g. external ear, epiglottis).

Development of bone

Ossification [5]

It is the process by which bone is formed. Bones are developed by the *mesoderm*. There are two types of bone development-

Endochondral ossification- In this type the process of calcification and ossification occurs in the model of cartilage with following steps-

1) The mesenchymal cells become aggregated and become chondroblast at the site of bone.

2) The chondroblast lay down hyaline cartilage surrounded by perichondrium.

3) The intercellular substance between the enlarged chondroblast increases. The lime salts are deposited in this substance and it becomes calcified.

4) The chondroblast degenerate to leave cavities called primary areolae.

5) Perichondrium is now called periosteum. The osteoclasts from the periosteum, absorb much of the calcified matrix creating larger cavities called secondary areolae.

6) Blood vessels with osteoblasts follow into the cavities.

7) The osteoblasts start formation of bones on the surfaces of the matrix between the secondary areolae to form lamellus.

8) Another layer of lamellus is formed over the first lamellus. Some osteoblasts become embedded in these two lamellae and form osteocytes. Many lamellae are formed to create bony trabeculae.

9) Ossifying cartilage gradually increases in size.

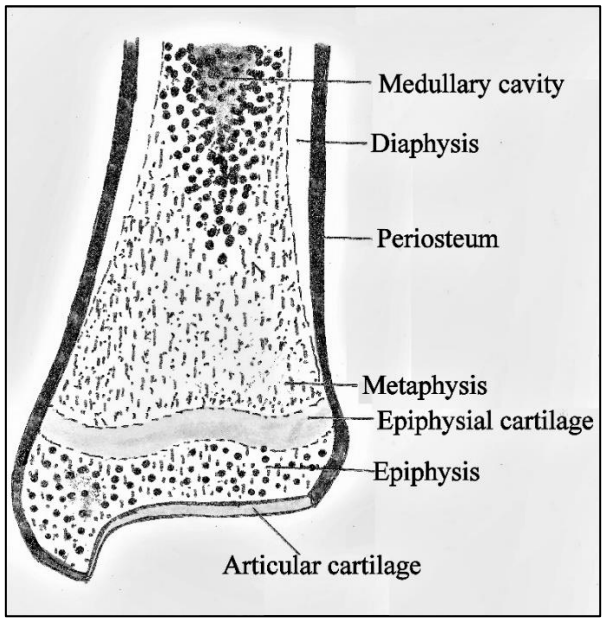


Fig.5 Growing long bone: longitudinal section.

10) In long bone endochondral ossification starts in the part of the shaft which is called the *primary center of ossification*. This developing shaft is called *diaphysis*. After birth *secondary centers of ossification* develop in the cartilage which form the ends of the bone. The part of the bone developed from one secondary centre is called *epiphysis*. The diaphysis and epiphysis are separated by a plate of cartilage called the *epiphyseal cartilage*. It has major role in the growth of the bone. The region of diaphysis adjacent to the epiphyseal cartilage is called the *metaphysis*. It is the main site of bone growth.

11) The osteoclasts destroy bony trabeculae in the centre of the bone to create *marrow cavity*.

Intramembranous ossification- In this type the process of calcification and ossification occurs in the fibrous tissue. It occurs in certain skull bone, mandible and in clavicle. It is the process in which the bone is laid down in connective tissue other than cartilage. The osteoblasts lay down bone tissue and the trabeculae are formed concentrically. The vascular connective tissue occupies the spaces between the trabeculae.

Types of bones

1) **Long bones**- Are longer than their width. They consist of a shaft (which is the main long part) and two ends. e.g. femur, tibia, fibula.

2) **Miniature long bones**- These bones have a small appearance. e.g. metacarpals, metatarsals.

3) **Short Bones**- Are about cube shaped. e.g. carpal and tarsal bones.

4) **Flat bones**- Have a thin and plane shape e.g. cranial bones, scapula, ribs.

5) **Irregular bones**- Have complicated shapes. e.g. vertebrae, hyoid bone.

6) **Sesamoid bones**- Develop in some tendons in locations where there is significant friction and physical stress. e.g. patella. Other sesamoid bones are un-named.

7) **Pneumatic bone**- A bone that is hollow or contains many air cells. e.g. sphenoid bone, maxilla.

Skeleton

The bones and cartilages together provide support to the body, called the skeleton.

The division of the skeleton-

1) **Axial skeleton**- It includes vertebral column, sternum, twelve pairs of ribs and skull together with mandible, hyoid bone and ear ossicles.

2) **Appendicular skeleton**- It includes the bones of the upper and lower limbs.

The skeleton of an adult consists of 206 bones.

Bones of Axial Skeleton= 80
Skull Bones- 22
Vertebrae- 26
Ribs- 24
Sternum- 01
Ear ossicles- 06
Hyoid- 01

Bones of the appendicular skeleton=126
upper limb bones- 64
lower limb bones- 62

Total number of bones= 206

Vertebrae

The spine is composed of 33 individual vertebrae, interlocking bones that form the vertebral column. The vertebral column consists of seven cervical, twelve thoracic, and five lumbar vertebrae in addition to five fused vertebrae of the sacral region and four fused vertebrae forming the coccyx. The vertebrae in each region have specific features that help them to perform their functions. Vertebrae are interconnected by facet joints that allow mobility in the spine. Intervertebral discs separate the individual bones providing additional weight-bearing support.

General features of the vertebra [6]

A vertebra is formed by an anterior body and a posterior arch (neural arch). The bone is composed of an outer layer of compact bone and a core of trabecular (cancellous) bone.

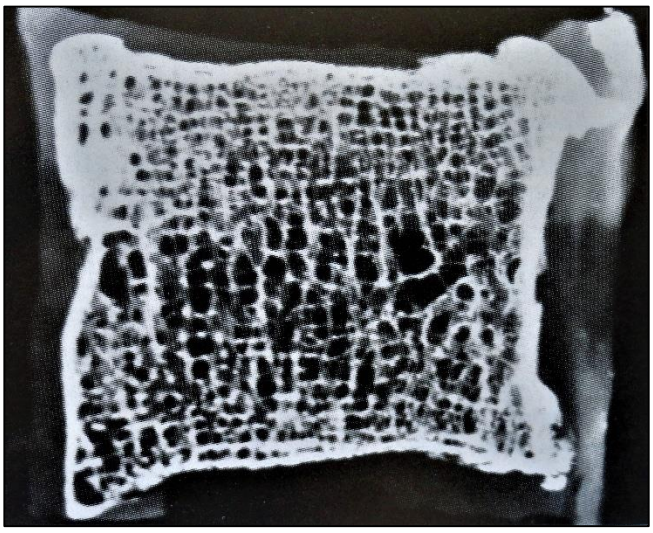


Fig. 6 Normal cancellous bone distribution in the body of vertebra.

Externally it is covered by a thin layer of periosteum which is innervated by nerve endings which transmit both nociception and proprioception. The outer compact bone contains small foramina for the passage of nutrient arteries and veins. The trabecular bone contains red marrow and large canals for the basivertebral veins. Two bodies are joined together by intervertebral disc. Thus, the bodies and discs arranged one above another form the vertebral column, which serves as support of the trunk and head in the form of central axis. The body and the arch together form vertebral foramen and all foramina constitute vertebral canal and between the adjoining neural arches, intervertebral foramina are created.

Body- It acts to support the weight of the trunk and head. It is cylindrical. The anterior surface is convex transversely and concave longitudinally. Whereas posterior surface is concave transversely and flat longitudinally. The transverse diameter of the vertebral bodies increases from C2 to L3. The width of the last two lumbar vertebrae is variable. The width decreases from the first sacral segment to the apex. The upper and lower surfaces are rough and attached to the intervertebral disc. A raised smooth region around the edge of the vertebral body is formed by the annular epiphysis. The part of vertebral body inside the annular epiphysis is rough. The vertebral bodies are mostly concave posteriorly to form the vertebral foramina.

Arch- It has following parts-

Pedicles- The pedicles and laminae protect the spinal cord. The pedicles are narrow and thick bones extending from the upper part of the vertebral body. They are connected to the lamina to form the vertebral arch. Their superior and inferior borders are curved and form superior and inferior vertebral notches. The adjacent vertebral notches form the intervertebral foramen.

Laminae- These are bony plates, vertically flattened and curve dorso-medially. These extend from the pedicles postero-medially. Posteriorly they join with the spine.

These are bony plates. These extend from the pedicles postero-medially. Posteriorly they join with the spine.

Processes- 1) Transverse processes- Extend laterally from the joint of pedicle and lamina. These work as levers for muscles and ligaments especially for rotation and lateral flexion.

2) Articular processes (zygapophyses)- These are superior and inferior articular processes arising from the joint of pedicle and lamina (pediculolaminar junction). They help to determine spinal movement by the facing of their facets. They bear articular facets. The superior process bears dorsal facet with lateral or medial inclination. The inferior process bears facet directed anteriorly with lateral or medial inclination. Articular processes of adjoining vertebrae form zygapophyseal joint which forms posterior part of intervertebral foramina.

3) Spinous process (vertebral spine)- It arises from the junction of the laminae and extends dorsally. These are having variable size, shape and direction. They provide place for the attachment of muscles which are essential for various movements of vertebral column like flexion, extension, rotation etc.

Vertebral foramen- The body of the vertebra, pedicles and laminae form the vertebral foramen. It is larger, central opening that forms the spinal canal, enclosing the spinal cord.

Intervertebral foramina- These are present in the form of canal between the adjacent vertebrae from C2 to the sacrum. The sacrum has paired dorsal and ventral foramina. The foramina are smallest in the cervical region and there is a regular increase in intervertebral foramina dimensions to the L4 vertebra. The width of canals ranges from 5mm in the cervical region to 18 mm at the L5-S1 level.

The boundaries of intervertebral foramen are-

Anteriorly- from above downwards, periosteum of the posterolateral aspect of the superior vertebral body, posterolateral aspect of the intervertebral symphysis including the disc and posterolateral part of body of the inferior vertebra; covered with periosteum.

Superiorly- compact bone of the deep arched inferior vertebral notch of the vertebra above.

Inferiorly- compact bone of the shallow superior vertebral notch of the vertebra below.

Posteriorly- anterior part of the fibrous capsule of the zygapophyseal joint.

The walls of each foramen are covered all over by collagen tissue.

The intervertebral foramen becomes larger in the flexion of the spine and smaller in the extension.

Contents of intervertebral foramen- segmental mixed spinal nerve with its sheaths, two to four recurrent meningeal nerves, variable spinal arteries and plexiform venous connections between internal and external vertebral venous plexuses, lymph vessels.

Arrangement of contents of intervertebral foramen

The contents are surrounded by the adipose tissue. In the intervertebral foramen, dorsal and ventral nerve roots unite to form the mixed spinal nerve. It is surrounded by the dural root sleeve. The dural root sleeve is attached to the borders of the intervertebral foramen by fibrous connective tissue and becomes continuous with the epineurium of the mixed spinal nerve at the lateral border of the intervertebral foramen. The arachnoid fuses with the perineurium proximal to the dorsal root ganglion and also at corresponding region of the ventral root. The subarachnoid space outspreads to the lateral one third of the intervertebral foramen.

Each recurrent meningeal nerve originates from the most proximal part of the ventral ramus. It receives a branch from the nearest gray communicating ramus of the

sympathetic chain before passing through the intervertebral foramen. This nerve provides sensory innervation including nociception to

1) Posterior aspect of the anulus fibrosus
2) Posterior longitudinal ligament
3) Anterior epidural veins
4) Periosteum of the posterior aspect of the vertebral bodies
5) Anterior aspect of the spinal dura mater

Clinical significance of intervertebral foramen

1) The nerves present in this foramen may be affected by trauma or diseases of the tissues forming the borders of the foramen i.e. a) fibrocartilage of annulus fibrosus b) nucleus pulposus c) vascular red bone marrow occupying the cancellous bone of the vertebral bodies d) compact bone of the pedicles e) capsules f) synovial membranes g) articular cartilages of synovial zygapophyseal joints. [7]

2) Disorders of intervertebral foramen (mainly due to intervertebral disc protrusion and intervertebral foramen (stenosis) affects- a) nerve root b) arteries c) veins d) lymphatics The spinal structures responsible for the affection of these structures are-

a) Fibrocartilage of the anulus fibrosus
b) Nucleus pulposus
c) Red bone marrow of the vertebral bodies
d) Compact bone of the pedicles
e) Facet joints
f) Capsules
g) Synovial membranes
h) Articular cartilage
i) Fibroadipose meniscoids
j) Fat pads
k) Connective tissue rim
l) Costovertebral joints (in the thoracic region)

3) The stenosis of intervertebral foramen occurs due to- a) disc degeneration b) ligamentum flavum hypertrophy c) facet joint arthrosis (increased bone formation due to increased weight bearing)

4) Bony tissue can compress the exiting spinal nerves and other contents. It is the cause of back pain and pain radiating into the extremities.

5) Conditions in which intervertebral foramen is enlarged- a) presence of a neurofibroma.

b) meningioma c) fibroma d) lipoma e) herniated meningocele f) tortious vertebral artery g) congenital absence of pedicle with malformation of transverse process h) chordoma.

Accessory ligaments of the intervertebral foramen [8]

This is a transforaminal ligament (extraforaminal ligament). It is a ligamentous band that crosses the intervertebral foramen. These are having variable size, shape and location.

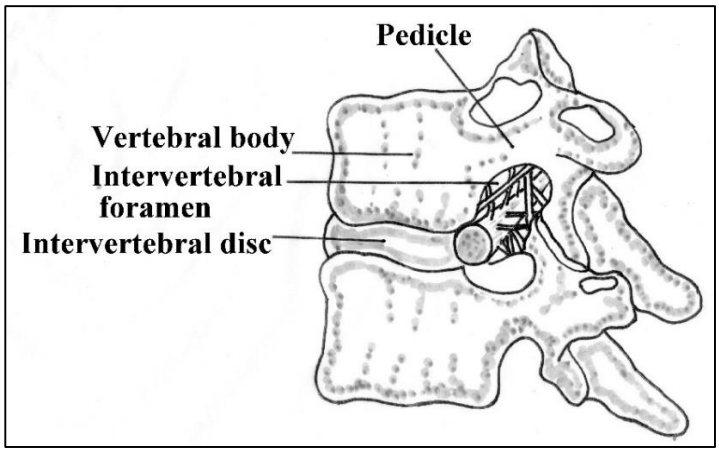


Fig. 7 The intervertebral foramen with the nerve coming out through it.

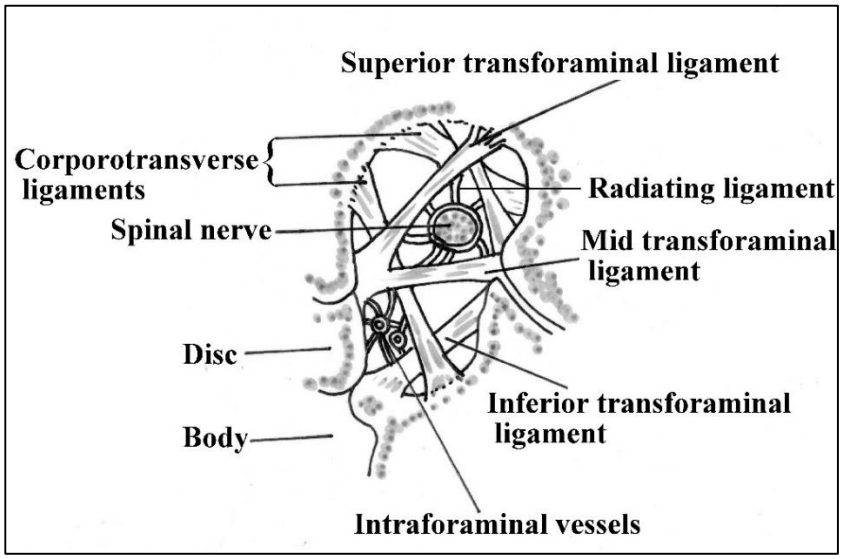


Fig.8 Accessory ligaments of the intervertebral foramen in relations with its contents.

Extraforaminal ligaments in the cervical spine can be divided into two types-

1) **Transforaminal ligaments-** During their course, transforaminal ligaments cross the intervertebral foramen ventrally. They usually originate from the anteroinferior margin of the anterior tubercle of the cranial transverse process and insert into the superior margin of the anterior tubercle of the caudal transverse process. The dorsal aspect of the transforaminal ligaments adhere loosely to the spinal nerve sheath. The length, width and thickness of these ligaments increases from the cranial to the caudal direction. A single intervertebral foramen contained at least one transforaminal ligament.

2) **Radiating ligaments-** The spinal nerves are extraforaminally attached to neighboring anterior and posterior tubercle of the cervical transverse process by the radiating ligaments. The radiating ligaments consisted of the ventral superior, ventral, ventral inferior, dorsal superior and dorsal inferior radiating ligaments. Radiating ligaments originates from the adjacent transverse processes and inserts into the nerve root sheath. The spinal nerve is held like the hub of a wheel by a series of radiating ligaments. The dorsal ligaments are the thickest. From C2-3 to C6-7 at the cervical spine, radiating ligaments are observed. They developed particularly at the level of the C5-C6 intervertebral foramen.

It is found that the spinal arteries and veins run superior to the ligament and the anterior primary nerve division runs below it.

Corporotransverse ligament- It is transforaminal ligament which runs between the vertebral body and the transverse processes at the L5-S1 junction

Cervical vertebrae [9]

There are seven cervical vertebrae.

Typical- third to sixth. **Atypical**- first, second and seventh vertebrae.

Features of typical cervical vertebra

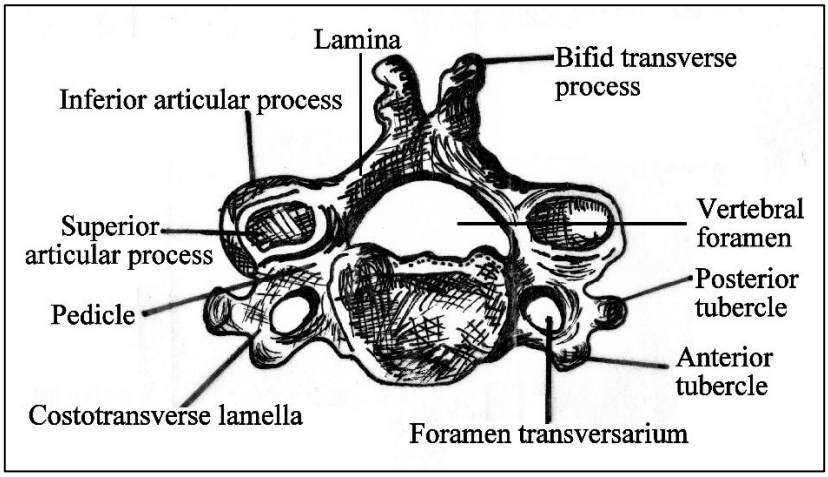


Fig. 9 Typical cervical vertebra (C5) seen from above.

Body- It is cylindrical in shape. It's size and shape are variable in different regions of vertebral column. It is small and broad. The superior surface is concave from side to side (saddle shaped), formed by flange-like lips which arise from most of the lateral circumference of the upper margin of the vertebral body these are called *uncus* or *uncinate* or *neurocentral lips* or *processes* which are derived from the annular epiphyseal disc.

The uncus is not found in quadrupeds. It is found only those who have to support their head. The uncus forms a joint with the lower surface of upper vertebral body called the *uncovertebral joint* or *neurocentral joint of Luschka*[10]. The surface within which is rough.

In the transverse plane bodies are convex anteriorly and concave posteriorly. The central part of posterior surface has several vascular foramina. The two larger foramina are known as *basivertebral foramina*; these transmit basivertebral veins to the anterior internal vertebral veins. The inferior surface is convex from side to side and concave antero-posteriorly. Its anterior border extends downwards and partly overlaps the anterior surface of the intervertebral disc. The shapes of the discal surfaces of the body help to limit the lateral and antero-posterior gliding movements during articulation.

Clinical significance of body - Bony spurs (osteophytes) may be developed on the anterior aspects of the vertebral bodies. These can press anteriorly located oesophagus or trachea resulting difficulty with swallowing and difficulty with speech.

Vertebral arch- On each side it has a pedicle which is vertical and narrow and a dorsal lamina which is broader. A paired superior and inferior articular processes arise from their junction.

1) **Pedicles**- these act to transfer weight from the posterior arch to the vertebral body, and vice versa. These are directed postero-laterally. Its superior and inferior vertebral notches are of same size. The dorsal root ganglion of each cervical spinal nerve lies between he superior and inferior vertebral notches of adjacent vertebrae.

2) **Laminae**- These are directed postero-medially thin and long. The laminae of C2 and C7 are much thicker than those of their neighbors and help to support weight.

3) **Spine**- It is short and bifid with two tubercles. The spinous process of sixth cervical vertebra is larger and usually not bifid.

4) **Superior and inferior articular process**- These are present at the junction of the pedicle and lamina with oval articular facet. These form two (left and right) separate pillars that bear weight. The superior articular facet is flat and oval. It is directed supero-posteriorly. The inferior facet is directed anteriorly.

Clinical significance of superior and inferior articular process-

Hypertrophy of the superior and inferior articular processes secondary to degeneration (osteoarthritis) of the zygapophyseal joints may result in compression of the dorsal nerve rootlets, dorsal root or dorsal root ganglion.

5) **Transverse process**- It has a foramen called the *foramen transversarium*. This foramen is bounded anteriorly and posteriorly by the ventral and dorsal roots. These roots end in anterior and posterior tubercles. The anterior tubercle of sixth cervical vertebra is longest called *carotid tubercle*. Here the carotid artery can be immobilized and compressed in the groove formed by the vertebral bodies and the prominent anterior tubercles. Lateral to the foramen these tubercles are connected with each other by the *intertubercular lamella*.

Vertebral foramen- It is triangular and large.

Intervertebral foramen- It has superior and inferior vertebral notches of nearly equal depth which faces antero-laterally according the direction of the pedicle. External to it is the transverse process with foramen transversarium.

Table no. 2 Attachments on typical cervical vertebrae

No.	Region of bone	Part of bone	Attached structure	Attachment
1	Body	Upper and lower borders	Anterior and posterior longitudinal ligaments.	Attachment
		Anterior surface	Longus colli (vertical part)	Attachment
		Upper borders and lower parts of the	Ligamenta flava	Attachment

		anterior surfaces of the laminae		
2	Transverse process	Anterior tubercle	Scalenus anterior, longus capitis and longus colli.	Origin
		Posterior tubercle	Scalenus medius, Scalenus posterior and levator scapulae.	Origin
			splenius cervicis, longissimus cervicis and iliocostalis cervicis.	Insertion
3	Spinous process		spinalis cervicis and	origin
			Semispinalis cervicis, semispinalis thoracis and multifidus.	Insertion
			Interspinales	Attachment

Atypical cervical vertebrae

First cervical vertebra (Atlas)

It gives support to the head.

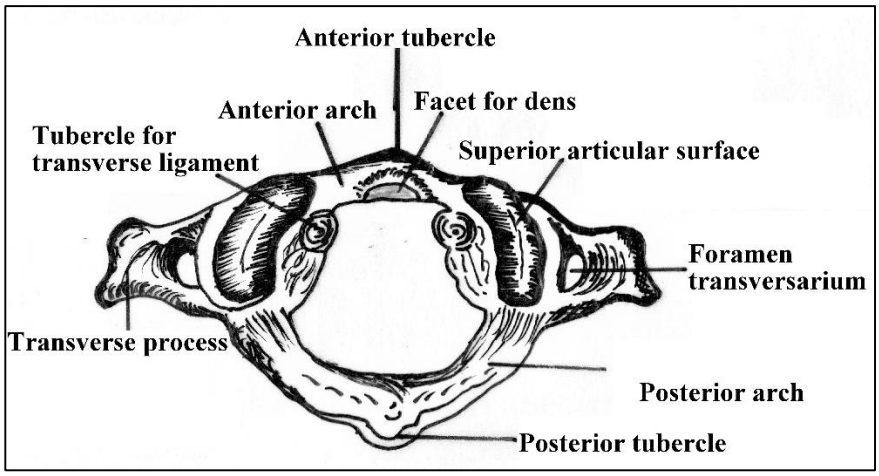


Fig.10 Atlas seen from above.

The peculiarities of atlas are- It has no body; spine and it is ring like. It has short anterior and long posterior arches and two lateral masses.

1) Anterior arch- It has a small convexity anteriorly with an *anterior tubercle*. The posterior surface has a concave and circular facet for the dens.

2) Posterior arch- It forms three-fifth of the circumference of the ring of the atlas. It has *posterior tubercle* representing the spinous process. The superior surface has prominent grooves behind the lateral masses for the vertebral artery and venous plexus.

3) Lateral masses- They are oval in shape with their long axes converging anteriorly. They have following features-

a) Superior articular facet- It is long, oval, kidney-shaped and concave for the articulation with occipital condyle.

b) Inferior articular facet- It is small, circular and flat for the axis vertebra.

c) Medial surface- It is rough with vascular foramina. It has a tubercle to which the transverse ligament is attached.

d) Anterior surface- It is flat.

e) Transverse process- It is long. Its tip is broad and flat. The process has a foramen transversarium.

Table no. 3 Attachments on Atlas vertebra

No.	Region of bone	Part of bone	Attached structure	Attachment
1	Anterior arch	Anterior tubercle	Anterior longitudinal ligament	Attachment
			Longus colli	Insertion
		Upper border	Anterior atlanto-occipital membrane	Attachment
		Lower border	Anterior longitudinal ligament	Attachment
2	Posterior arch	Posterior tubercle	Ligamentum nuchae	Attachment
			Rectus capitis posterior minor	Origin
		Upper border	Posterior atlanto-occipital membrane	Attachment
		Lower border	Ligamenta flava	Attachment
3	Lateral mass	Medial tubercle	Transverse ligament	Attachment
		Anterior surface	Rectus capitis anterior	Origin
4	Transverse process	Upper surface	Rectus capitis lateralis	Origin
		Lateral margin	Levator scapulae	Origin
		Posterior tubercle	Splenius cervicis	Insertion

Second cervical vertebra (Axis)

The characteristic of this vertebra is the strong *odontoid process* which rises upwards from the upper surface of the body. It forms the atlanto-axial joint with the first cervical vertebra, upon which the head rotates.

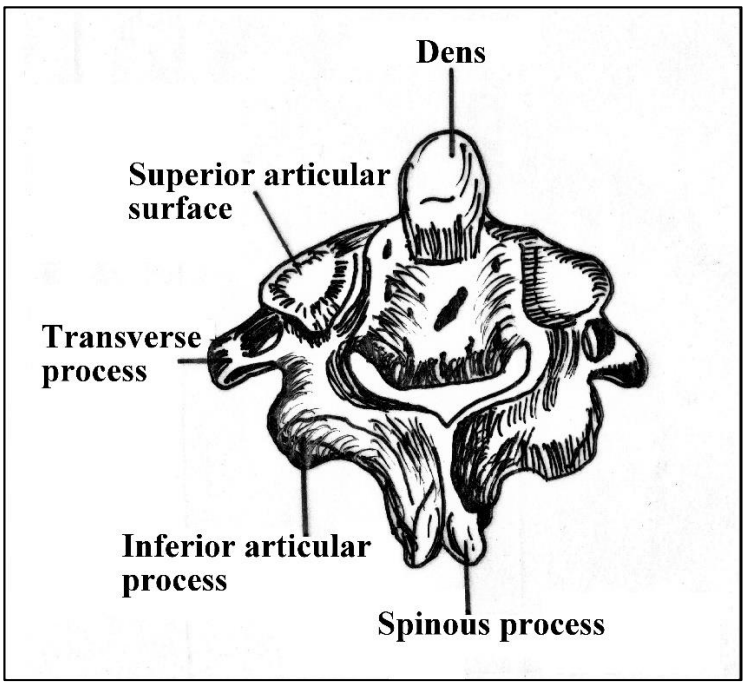


Fig. 11 Axis seen from above.

The axis has following parts-

1) **Body**- The upper surface gives rise to the dens. Large, oval and flat superior facets for atlas are present on the both sides of the dens at the junction of the body and the pedicle. The anterior surface of the body has deep depressions on either side for longus colli muscle.

2) **Dens**- It is conical in shape with pointed apex. The anterior surface of the dens has an oval facet for the atlas. The posterior surface is grooved for the transverse ligament. Arteries to the dens enter from the base as well as from the apex and anterior surface of the dens. Hence vascular necrosis does not occur even after the fracture of the base of the dens.

3) **Pedicles**- These are bulky. The superior surface bears the superior facet. The antero-lateral surface of the pedicle has groove for the vertebral artery. The inferior surface has a deep inferior intervertebral notch containing root sheath of the third cervical nerve.

4) **Transverse process**- It arises from the pediculolaminar junction and the lateral aspect of the interarticular area of the pedicle. It tapers downwards and laterally. The foramen transversarium is directed laterally.

5) **Laminae**- These are thick.

6) **Spinous process**- It is large. Its base is broad and the tip is bifid. Inferiorly it is concave.

Table no. 4 Attachments of axis vertebra

No.	Region of bone	Part of bone	Attached structure	Attachment
1	Dens	Apex	Apical ligament	Attachment
			Alar ligament	Attachment
2	Body	Anterior surface	Longus colli- vertical part	Insertion
			Anterior longitudinal ligament	Attachment
		Posterior surface	Posterior longitudinal ligament, membrana tectoria and cruciate ligament	Attachment
3	Laminae		Ligamenta flava	Attachment
4	Transverse process		Levator scapulae, scalenus medius,	Origin
			Splenius cervicis	Insertion
			Intertransverse muscles	Attachment
5	Spinous process		Ligamentum nuchae, interspinales and	Attachment
			Rectus capitis posterior major	Origin
			Semispinalis cervicis, spinalis cervicis, multifidus.	Insertion

Seventh cervical vertebra (vertebra prominens)

It has a long and non-bifid spinous process with prominent tubercle. It produces protuberance at the back of the root of the neck. The transverse process is thick and

prominent. The anterior root of the transverse process is slender and the anterior tubercle is small or absent. Occasionally it may be large called *cervical rib.* The posterior tubercle is prominent. The costal lamella is slightly thin and may be partly deficient.

Table no. 5 Attachments on seventh cervical vertebra

No.	Region of bone	Attached structure	Attachment
1	Spinous process	Ligamentum nuchae, interspinales	Attachment
		Trapezius, rhomboid minor, serratus posterior superior, splenius capitis, spinalis cervicis	Origin
		Semispinalis thoracis, multifidus	Insertion
2	Transverse process	Suprapleural membrane and	Attachment
		Levatores costarum	Origin

Occipital bone [11]

The first cervical vertebra (atlas) is joined with the occipital bone of the skull. Hence it should be studied in details in contest with the cervical spine. The occipital bone is a trapezoid flat bone. It is the main bone of the occiput (back and base of the skull). It is trapezoidal in shape and curved on itself like a shallow dish. At the base of skull in the occipital bone, there is a large oval opening called the foramen magnum.

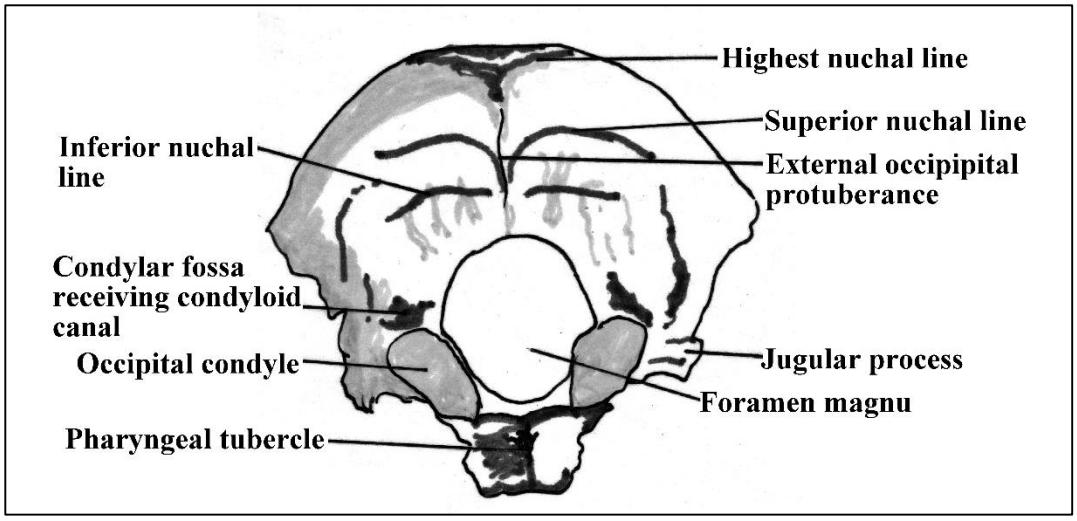


Fig. 12 Occipital bone: External aspect.

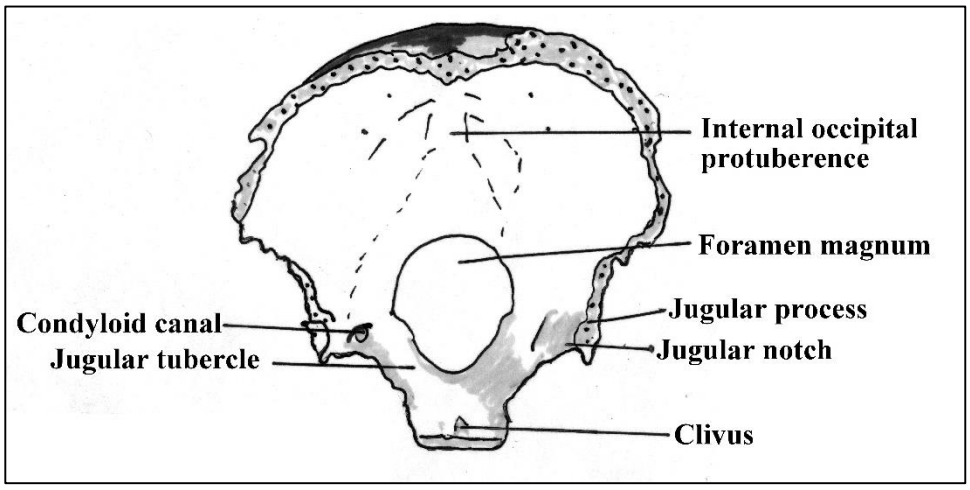


Fig. 13 Occipital bone: internal aspect.

Angles

Superior angle- of the occipital bone joins with the occipital angles of the parietal bones and, in the fetal skull, corresponds in position with the posterior fontanelle.

Lateral angles- are situated at the extremities of the groove for the transverse sinuses. Each is received into the interval between the mastoid angle of the parietal bone, and the mastoid portion of the temporal bone.

Inferior angle- is fused with the body of the sphenoid bone.

Borders

Superior borders- extend from the superior to the lateral angles. They are deeply serrated for articulation with the occipital borders of the parietals, and form the lambdoidal suture.

Inferior borders- extend from the lateral angles to the inferior angle; the upper half of each articulates with the mastoid portion of the corresponding temporal, the lower half with the petrous part of the same bone.

Sutures

Lambdoid suture- joins the occipital bone to the parietal bones.

Occipitomastoid suture- joins the occipital bone and mastoid portion of the temporal bone.

Sphenobasilar suture- joins the basilar part of the occipital bone and the back of the sphenoid bone body.

Petrous-basilar suture- joins the side edge of the basilar part of the occipital bone to the petrous-part of the temporal bone.

The occipital bone is described in the following parts-

1) Front of the foramen magnum is the basilar part (basioccipital)

2) At the sides of the foramen magnum are the lateral parts (exoccipitals)

3) At the back of the foramen magnum is the squamous part.

Basilar part

It is quadrilateral in shape. The inferior surface of the basilar part has a small pharyngeal tubercle for attachment of the fibrous pharyngeal raphe. The superior surface of the basilar part is a broad groove part of the clivus, which ascends anteriorly from the foramen magnum. On its lateral margins are sulci of the inferior petrosal sinuses. Below this the lateral margins articulate with the petrous temporal bones.

Lateral parts

These are lateral to the foramen magnum. On the inferior surfaces are occipital condyles for articulation with the superior atlantal facets. They are oval in shape with long axes converging anteromedially. Their articular surfaces are convex. Medial to each facet a tubercle gives attachment to an alar ligament. Anteriorly above each condyle is a hypoglossal canal. A condylar fossa behind each condyle fits the posterior margin of the superior atlantal facet in full extension. The jugular processes are postero-lateral to each condyle is a quadrilateral plate depressed anteriorly by a jugular notch. On the superior condylar surface an oval jugular tubercle overlies the hypoglossal canal. Its posterior part bears a shallow furrow for the glossopharyngeal, vagus and accessory nerves. On the superior surface of jugular process, a deep groove, curving anteromedially around a hook-shaped process, ends the jugular notch. It contains the end of the sigmoid sinus.

Squamous part

It is convex externally and concave internally. The external surface has a prominence, the external occipital protuberance midway between its summit and the foramen magnum. On each side two curved lines extend laterally from it. The upper faintly marked is the highest nuchal line. The lower is the superior nuchal line. The surface above the highest nuchal lines is smooth below this it is rough and irregular for the attachment of muscles. From the external occipital protuberance, the median external occipital crest, descends to the foramen magnum. On each side an inferior nuchal line spreads laterally from the crest's midpoint.

The squama's internal surface is divided into four deep fossae by an irregular internal occipital protuberance and by ridged sagittal and horizontal extensions from it. The two superior fossae are triangular and modified to the cerebral occipital poles, the inferior fossae are quadrilateral and shaped to lodge the cerebellar hemispheres. A wide groove with raised margins ascends from the protuberance to the squama's superior angle called the superior sagittal sulcus. A prominent internal occipital crest descends from the protuberance and bifurcates near the foramen magnum. On each side a wide sulcus for the transverse sinus extends laterally from the protuberance.

Foramen magnum

It is a large oval foramen longest front to back; it is wider behind where it is encroached upon by the occipital condyles. The clivus, a smooth bony section, travels upwards on the front surface of the foramen, and the median internal occipital crest extends behind it.

Through the foramen passes the medulla oblongata and its meninges, the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, the tectorial membrane and alar ligaments.

Table no. 6 Muscle and ligament attachment on the occipital bone.

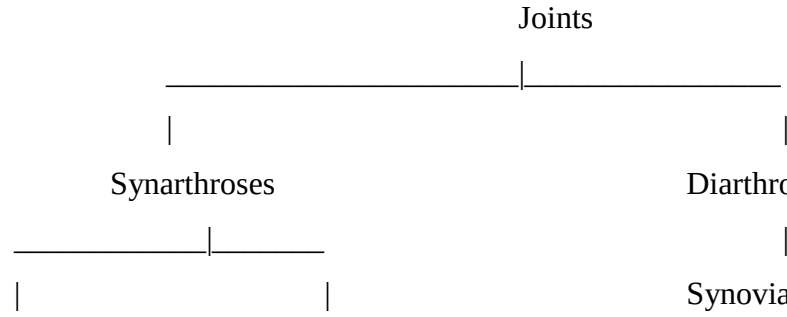
Part	Muscle and ligament attachment
Squamous	Trapezius, sternocleidomastoid, occipital belly of Occipitofrontalis, splenius capitis, semispinalis capitis, obliquus capitis superior, rectus capitis posterior major and minor, posterior atlanto occipital membrane.
Lateral	Rectus capitis lateralis
Basilar	Rectus capitis anterior, longus capitis, superior constrictor, anterior atlanto occipital membrane, apical ligament of the odontoid process, superior band of the cruciform ligament, tectorial membrane.

General consideration of joints [12]

The bones are joined to one another to form the joints which are essential for the movements. The movement of the bones takes place at the joints due to the contractions of the muscles. All joints are not movable; some fixed joints are also useful

to provide stability. Prefix “arthro” refers to joints. Arthroses means a joint between bones. Arthrology is the study concerned with the joints.

Classification of joints



Fibrous joint	Cartilaginous joint	1) Plane
1) Sutures	1) Synchondroses	2) Spheroid (ball and socket)
2) Gomphoses	2) Symphyses	3) Ellipsoid
3) Syndesmoses		4) Ginglymus (hinge)
		5) Bicondylar
		6) Trochoid (pivot)
		7) Sellar (saddle)

Different types of joints

Synarthroses- It is an immovable fixed joint. The bones are connected by connective tissue.

Fibrous joint- These joints have no joint cavity and are connected by fibrous connective tissue.

Sutures- It occurs only in the skull. The bones are bound together by fibres. No active movement is permitted at sutures.

Gomphoses- It is a fibrous peg-and-socket joint. The roots of the teeth (pegs) fit into their sockets in the mandible and maxilla and are the only examples of this type of joint.

Syndesmosis- It is a fibrous joint in which opposing bone surfaces are comparatively far apart and are united by ligaments or interosseous membrane; which allows little movement between them. e.g. inferior tibiofibular joint.

Cartilaginous joint- The bones are connected by fibrocartilage or hyaline cartilage. They allow more movement than fibrous joints but less than that of synovial joints.

Synchondroses- The joint in which the cartilage is usually converted into bone during early adult life and that serves to allow growth, e.g. between epiphyses and diaphysis of long bones, first sternocostal joint.

Symphyses- It is a fibrocartilaginous fusion between two bones. A fibrocartilaginous disc is present between two bones e.g. pubic symphysis, joints between the bodies of the vertebrae.

Diarthroses- The joint between two or more bones which allow wide ranges and different motions.

Synovial joint- This is a movable joint. It is provided with a fibrous joint capsule which surrounds the articulating surfaces of bones. It forms a synovial cavity which is filled with synovial fluid. e.g. shoulder joint, knee joint.

Plane joint- In which the opposing joint surfaces are nearly flat and in which there is only a slight, sliding motion. e.g. joints between the metatarsal bones, between the cuneiform bones of the foot.

Spheroid (ball and socket) joint- In which a sphere-like head of one bone fits into a rounded cavity in the other bone. e.g. hip joint, *shoulder joint.*

Ellipsoid joint- In this, one bone has an oval and convex surface while the other bone has an elliptical concavity. e.g. radiocarpal joint, metacarpophalangeal joints.

Ginglymus (hinge) joint- The shape of this joint allows the movement only in one plane and around one axis like a hinge. e.g. interphalangeal joint, humeroulnar joint.

Bicondylar (or condylar) joint- Has an ovoid articular surface, or condyle that fits into an elliptical cavity. This permits movement in two planes, allowing flexion, extension, adduction, abduction and circumduction. e.g. temporomandibular joint.

Trochoid (pivot) joint- It allows only rotary movement around a single axis. The moving bone rotates within a ring; formed by a second bone and adjoining ligament. e.g. proximal radio-ulnar joint, joint of dens and atlas.

Sellar (saddle) joint- In a this joint the opposing surfaces are reciprocally concave-convex. e.g. carpometacarpal joint of the thumb

Table no.7 Anatomical terms for movements at the joints

Term	Movement at the joint.
Flexion	Decreasing the angle between two bones.
Dorsiflexion	Decreasing the angle between the foot and leg (movement of foot upwards).

Plantar flexion	Increasing the angle between the foot and leg (movement of foot downwards).
Extension	Increasing the angle between two bones.
Abduction	Moving a body part away from the midline.
Adduction	Moving a body part towards the midline.
Circumduction	Movement in a circular or cone-shaped motion.
Rotation	Turning movement of a bone about its long axis.
Supination	Rotation of the forearm or foot so that the palm or sole is moved to face anteriorly.
Pronation	Rotation of the forearm or foot so that the palm or sole is moved to face posteriorly.
Inversion	Sole of the foot moved to face medially.
Eversion	Sole of the foot moved to face laterally.
Retraction	Movement in the backward direction.
Protraction	Movement in the forward direction.
Elevation	Lifting a body part.
Depression	Returning a body part to pre-elevated position.

Structures of synovial joints

Many joints of the neck are of synovial type. Their features are described below.

Articular surfaces- These are the surfaces of bones; in contact with each other in a synovial joint. The bony articular surfaces are smooth and covered with articular cartilage.

Fibrous capsule- It is a cuff of white fibrous and elastic tissue surrounding a synovial joint. It is attached to the periosteum of the articulating bones.

Ligaments- At the region of high tensile stress, the fibrous capsule has dense fibres arranged in parallel bundles called ligaments.

Accessory ligaments- Moreover, separate ligaments may unite the bones called accessory ligaments. These are of following types-

Extracapsular ligament - These are present external to the fibrous capsule e.g. costoclavicular ligament of sternoclavicular joint.

Intracapsular ligament - These are present inside the fibrous capsule e.g. cruciate ligaments in knee joint.

Articular disc- It is a pad of fibrocartilage present between the articular surfaces. The complete articular disc divides the joint cavity into two separate compartments e.g. sternoclavicular joint.

Synovial membrane- It lines the inner surface of joint capsule, bursae and covers tendon sheath, intracapsular ligaments and exposed osseous surfaces. It is composed of two layers- a cellular intima on a subintimal lamina. The synovial intima consists of synoviocytes of two types, type A and type B cells. These cells remove debris from the joint cavity and produce some components of synovial fluid.

Synovial fluid- It is a viscous, clear and colorless fluid found in the cavities of synovial joints. It is useful to reduce friction between the joint cartilages during movement, to maintain proper joint function by providing the structural support and supply of the necessary nutrients to the surrounding cartilage.

Articulations in the cervical spine

Craniovertebral joints

The joint between the cranium and vertebral column is specific to provide a wide range of movement than in the rest of the axial skeleton. It consists of the occipital condyles, atlas and axis. It permits horizontal and vertical scanning movements of the head. It is useful for eye-head co-ordination.

Atlanto-occipital joint [13]

The atlanto-occipital joint includes a pair of joints that connect the skull to the first cervical vertebra (atlas). The bones are connected by articular capsules and the anterior and posterior atlanto-occipital membranes.

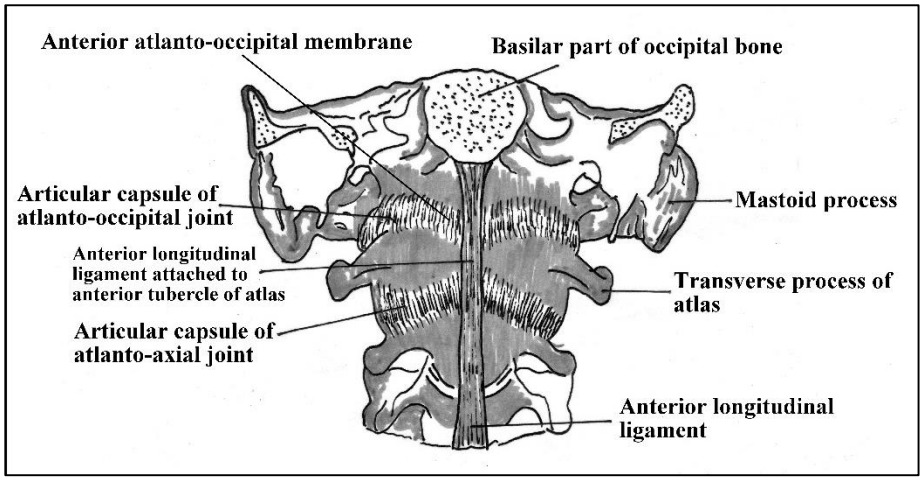


Fig. 14 Atlanto-occipital and atlanto-axial joints in anterior aspect

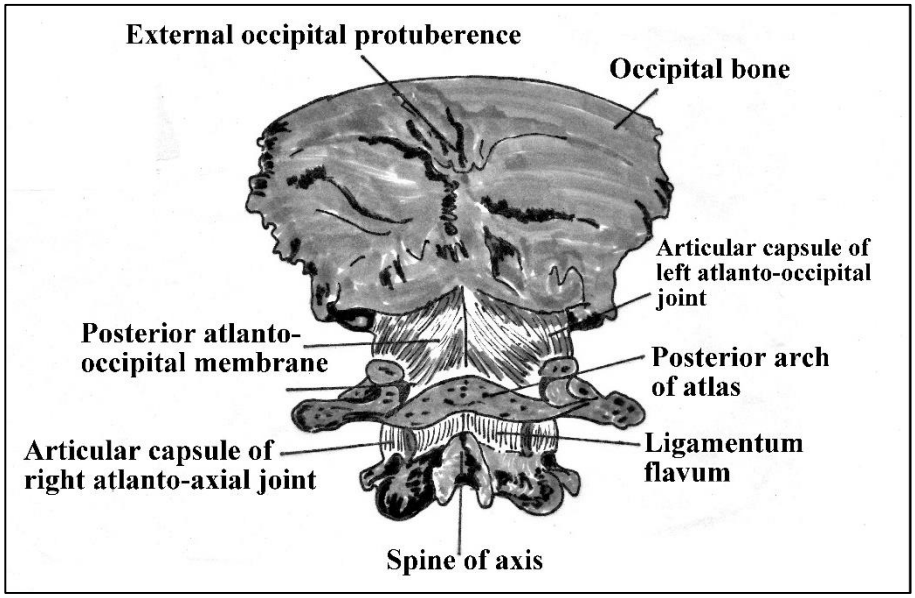


Fig. 15 Atlanto-occipital and atlanto-axial joints in posterior aspect

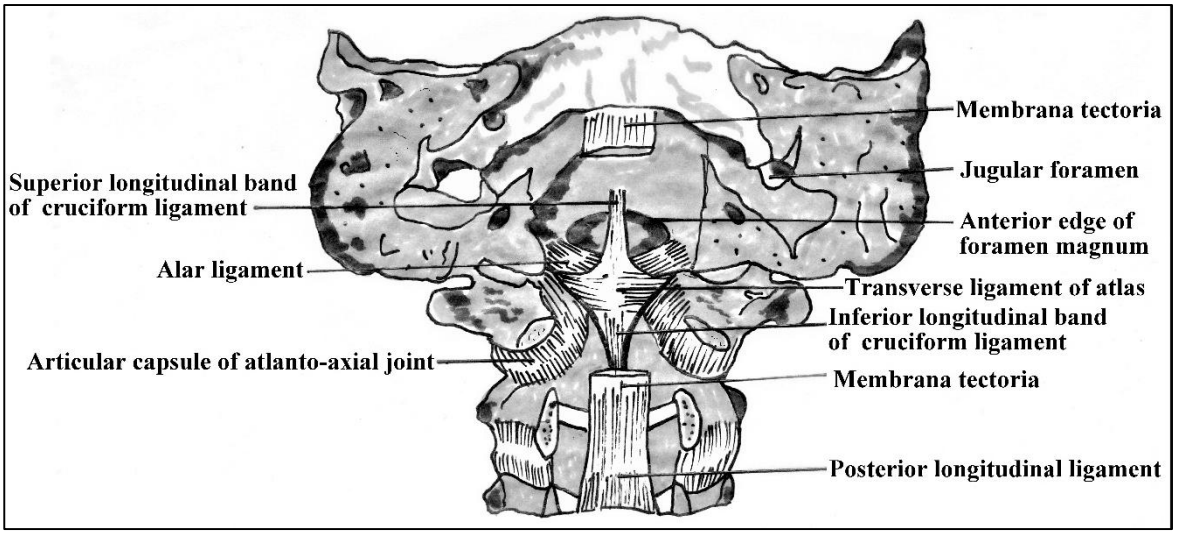


Fig. 16 Anterior aspect of the vertebral canal and foramen magnum as seen from behind

Classification- Synovial joint, condyloid variety.

Parts of bones forming the joint- Concave articular surface on the superior aspect of the lateral mass of atlas which articulates with a convex surface on the occipital condyle.

Ligaments- 1) Fibrous capsule- It surrounds the articular parts i.e. occipital condyle and superior atlantal articular facet. It is thicker posteriorly and laterally.

2) Anterior atlanto-occipital membrane- It is dense, thin, broad fibrous structure which joins the upper border of the anterior arch of the atlas to the anterior margin of the foramen magnum. Laterally, it is fused with the capsular ligaments and medially it is strengthened by a median cord called anterior longitudinal ligament. It is stretched between the basilar occipital bone and anterior atlantal tubercle.

3) Posterior atlanto-occipital membrane- It is broad but thin fibrous membrane. It attaches the upper border of the posterior arch of the atlas to the posterior margin of the foramen magnum. Laterally, it is fused with the capsular ligaments.

Synovial membrane- It lines fibrous capsule.

Movement- flexion, extension and rotation.

Table no. 8 Muscles producing movements at the atlanto-occipital joints.

Movement	Muscles producing movements
Flexion	Longus capitis, rectus capitis anterior
Lateral flexion	Rectus capitis lateralis, semispinalis capitis, splenius capitis, sternocleidomastoid and trapezius
Extension	Recti capitis posteriors major and minor, obliquus capitis superior, semispinalis capitis, splenius capitis and trapezius.
Rotation	obliquus capitis superior, Rectus capitis posterior minor, splenius capitis and sternocleidomastoid

Ligaments connecting axis and occipital bones.

1) **Membrana tectoria**- It is present inside the vertebral canal. It is a broad strong band as a continuation of the posterior longitudinal ligament and attaches to the posterior surface of the body of axis and foramen magnum. Here it fuses with the cranial dura mater. The membrane is separated from the cruciform ligament of the atlas by a thin layer of loose areolar tissue and occasionally by a bursa.

2) **Alar ligaments**- These are cord like bands. They connect the oval flattenings on the posterolateral aspect of the apex of the dens to rough parts on the medial side of the occipital condyle. The alar ligaments limit the atlantoaxial rotation.

3) **Apical ligament of the dens**- It extends from the tip of the *odontoid* process to the anterior margin of the foramen magnum.

4) **Ligamentum nuchae**- It connects cervical vertebrae with the cranium. It is described below.

Atlanto-axial joints [14]

There are three synovial joints between the atlas and axis-

Lateral atlanto-axial joints

Classification – synovial, plane.

Parts of bones forming the joint- lateral masses of atlas and axis.

Ligaments- 1) Fibrous capsule- It is attached to the margins of the articular surfaces.

2) Accessory ligament- It is attached to the body of axis and lateral mass of the atlas.

Anteriorly, the vertebral bodies are connected by the anterior longitudinal ligament. posteriorly the vertebral bodies are joined by the ligamenta flava attaching to the lower border of the atlantal arch above and the upper borders of the axial laminae.

Synovial membrane- It lines the fibrous capsule.

Median atlanto-axial joint

Classification – synovial, pivot.

Parts of bones forming the joint- The dens of axis and the ring formed by the anterior arch and transverse ligament of the atlas.

The anterior oval facet on the dens articulates with the facet on the posterior aspect of the anterior arch of the atlas.

Ligaments- 1) Fibrous capsule- It is loose and weak.

2) Transverse ligament of atlas- It is a strong band of collagen fibres extending across the ring of atlas behind the dens. It is attached laterally to a small tubercle on the medial side of each lateral mass. It is broad medially. Here it is covered anteriorly by a thin layer of articular cartilage. From the upper margin of ligament, a strong median longitudinal band extends and inserts into the basilar part of the occipital bone. From the inferior surface of the ligament a longitudinal band passes to the posterior surface of the axis. These transverse and longitudinal bands together form the cruciform ligament.

Synovial membrane- It lines the fibrous capsule.

Movements- rotation of axis.

Table no. 9 Muscles producing movements at the atlanto-axial joints.

Movements	**Muscles**
Rotation	Obliquus capitis inferior, rectus capitis posterior major, splenius capitis and sternocleidomastoid.

Intervertebral joints

There are three intervertebral joints between each adjoining vertebrae from the axis to the sacrum – one between the vertebral bodies and a pair between the articular processes of adjoining vertebral arches. The joint between the vertebral bodies is a symphysis and those between the articular processes are plane synovial joints.

Joints of the vertebral bodies [15]

The vertebral bodies are connected by following ligaments-

1) **Anterior longitudinal ligament**- It extends along the anterior surfaces of the vertebral bodies and intervertebral discs. It is attached superiorly to the basilar occipital bone and inferiorly to the anterior surface of the upper sacrum. Its longitudinal fibres are strongly attached to the intervertebral discs, hyaline cartilage laminae and margins of adjacent vertebral bodies. The fibres of ligament blends with the subjacent periosteum, perichondrium and periphery of the annulus fibrosus.

2) **Posterior longitudinal ligament**- It extends along the posterior surfaces of the vertebral bodies and intervertebral discs. It lies in the vertebral canal. It is attached superiorly to the body of axis vertebra and inferiorly to the sacrum. Superiorly it is continuous with the membrana tectoria. Its fibres are attached to intervertebral discs, hyaline cartilage laminae and margins of adjacent vertebral bodies.

Clinical Significance of the ligaments of the spine [16]

The ligaments of the spine allow for adequate motion while providing for fixed postural attitudes between vertebrae. The ligaments protect the spinal cord by restricting motion during daily activities and in addition, protect against the fast application of high loads. Ligaments resists only tensile forces and buckle when subject to compression and since ligaments transfer their tensile loads to the bone, a traumatic load may result in injury to either the bone or the ligament. In general, when an excess load is applied slowly it is the bone that fails, when it is applied rapidly it is the ligament that fails.

3) **Intervertebral discs**- Between vertebral bodies from axis vertebra to the sacrum are the intervertebral discs. Each disc absorbs the stress and shock; the body suffers during movement and prevents the vertebrae from grinding against one another. The superior and inferior surfaces of the body are covered by hyaline cartilages. The disc and the hyaline cartilages form an intervertebral symphysis. In cervical and lumbar regions, they are thicker anteriorly and form anterior convexity. In the thoracic region they are almost uniform; where the anterior concavity is mostly due to the vertebral bodies. Only the periphery of disc is supplied from adjacent blood vessels. Rest of its part is avascular and depends on the diffusion through the trabecular bone of adjacent vertebrae.

When the cervical spine is subjected to bending forces, one side of the disc is compressed and the other side is subjected to tension. During torsional movements as in flexion rotation or extension rotation there are shear stresses in the horizontal as well as axial planes of the annulus. The disc is subjected to various patterns of loading in different circumstances. The forces created are- 1) generation of tensile strength in the annulus 2) friction between various lamellae of the annulus 3) increased pressure within the nucleus.

Load has to be absorbed and energy has to be dissipated. This is done by tension and friction in the annulus and free water shift in the nucleus. There is constant gradient descending down along the spine between the centre of each vertebra for both speed and acceleration[17]. Each disc is made up of three parts- the annulus fibrosus, the nucleus pulposus and vertebral end plate.

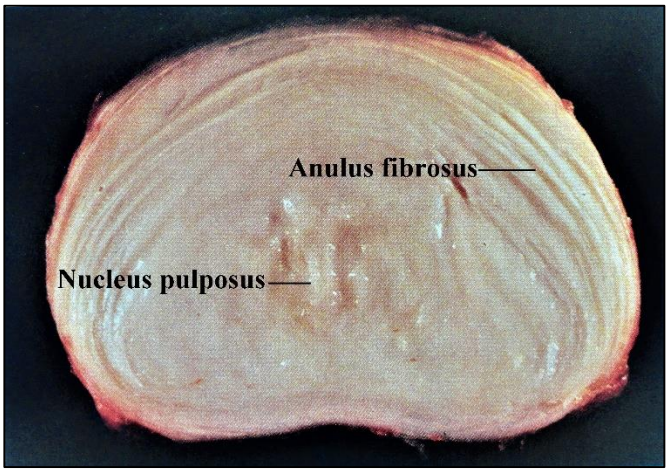


Fig. 17 Intervertebral disc seen from above [18]

1) **Anulus fibrosus**- It is the strong circular exterior of the intervertebral disc that surrounds the soft inner core, the nucleus pulposus. It connects the spinal vertebrae above and below the disc. This outer portion is composed of several layers of laminae.

This has an outer narrow collagenous zone and an inner wider fibrocartilaginous zone. Its laminae are convex peripherally and are incomplete collars connected by fibrous bands overlapping one another.

2) **Nucleus pulposus**- It is the inner core of the vertebral disc. The core is composed of a jelly-like mucoid substance that consists of water and a loose network of collagen fibres. The elastic inner structure allows the vertebral disc to withstand forces of compression and torsion. It is better developed in cervical and lumbar regions. It is present near the posterior surface of the disc. At birth it is large, soft and jelly-like with few notochordal cells. The notochordal cells disappear at the age of 10 years. Progressively mucoid substance is replaced by fibrocartilage (derived from the annulus fibrosus and the hyaline cartilaginous plates of vertebral body). Now the nucleus pulposus becomes less differentiated from the annulus fibrosus.

Fig. 18 TS of lumbar disc of 7 years old child: Bulging gelatinous nucleus that is well demarcated from surrounding anulus [19].

Fig. 19 TS of lumbar disc of 30 years male: Nucleus is less demarcated and does not protrude as much from surrounding anulus [20].

3) **Vertebral end plate**- These are the superior and inferior cartilaginous (hyaline+ fibrocartilage) plates of the intervertebral discs at the peripheral rim. They help to prevent pressure atrophy of the vertebral bodies. It contributes to the resilience of the motion segment. It participates in the hydrostatic distribution of the pressure absorbed by intervertebral disc during loading.

They have an important role in the nutrition of the intervertebral disc. Nutrients diffuse from the blood vessels within the vertebral bodies which contact the periphery of each end plate, through the cartilage matrix to reach the cells deep within the cartilaginous end plate. These are attached both to the disc and to the adjacent vertebral body. The end plate is also considered as the part of vertebral body. These are peripherally 1 mm thick and centrally 3mm thick. Vertebral end plates are very porous. They allow fluid to enter and leave the anulus fibrosus and nucleus pulposus through osmosis. The end plates begin to calcify and thin out to become brittle in old age.

Imbibition- It is the process in which a disc absorbs fluid from the vertebral bodies above and below. The nucleus pulposus absorbs the major part of the fluid received by the disc. The disc loses water when a load is applied. However, sodium and potassium are retained. This increased electrolyte concentration results into osmatic gradient which leads in quick rehydration when the discs are unloaded.

The discs need both, activities during the day and rest at the night. It is observed that the disc is thicker after rest than a day which includes physical activities. Although too much rest may result into decrease in the amount of fluid of the disc.

Biomechanical observations [21]

The intervertebral disc has a viscoelastic response when subjected to loads and deformation. It shows creep phenomenon under a constant applied load and exhibits stress relaxation under a constant applied deformation. The viscoelastic properties of cartilage depend on its two different physical mechanisms- 1) The intrinsic viscoelastic property of the macromolecules mainly consisting of collagens and proteoglycans that forms the cartilage 2) The fractional drag arising from the flow of tissue fluid through the porous permeable matrix.

The difference in the proportions of collagens and proteoglycans and their architectural organization in a given tissue influence the physical and mechanical properties of all musculoskeletal tissue. About 70% of the water within the cartilaginous tissue may be moved out during loading. The movement of water is important in controlling tissue deformation and mechanical behavior. The intervertebral disc exhibits viscoelastic properties like cartilage to mechanical loading. But the structure of intervertebral disc is different from cartilage. The fibrous framework and the annulus are built from types I and II collagen fibers. The nucleus contains selectively only type II collagen. The concentrated proteoglycan solution in the nucleus is protected by strong network of collagen fibers in the annulus.

When load is applied high tensile stress is generated in the annulus due to hydrostatic pressure within the nucleus. Differences in tissue structure, biochemical composition and material properties generate the magnitude of tensile stress and strain generated in the annulus fibrosus from the inner to outer regions.

Compressive forces are transmitted through the end plate interposed between the nucleus and bone, whereas tensional forces generated in the anulus are transmitted to the bone through *Sharpey's* fibers attached around the periphery [22].

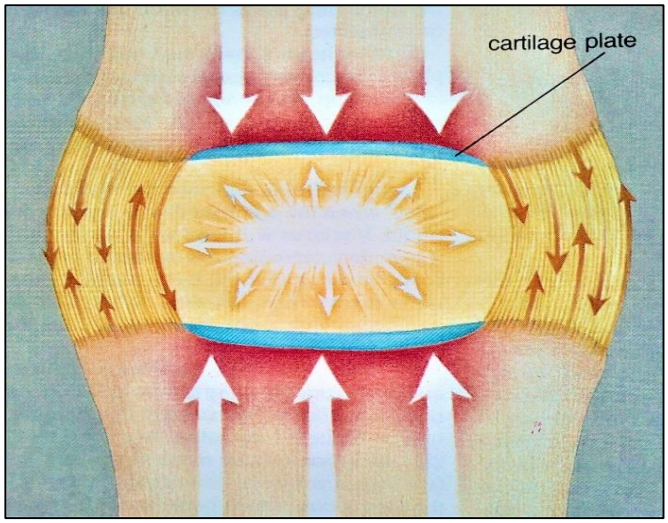


Fig. 20 Schematic drawing of the forces acting through the area of vertebral body and intervertebral disc [23].

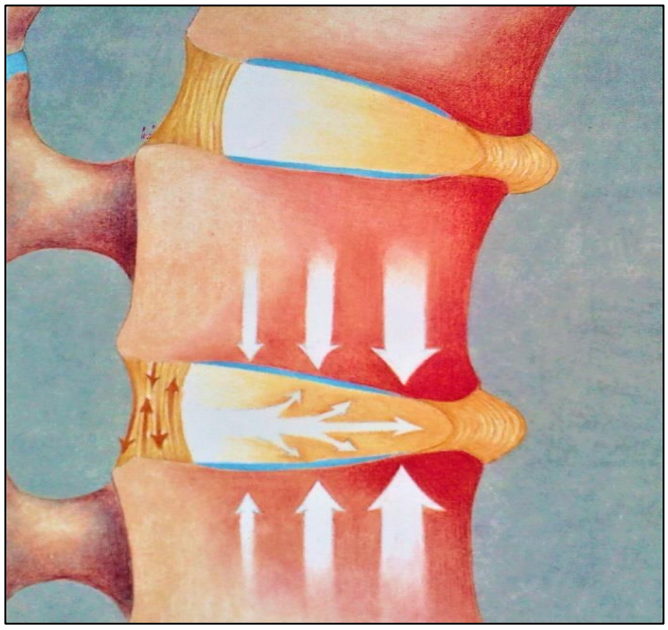


Fig. 21 Schematic drawing to show how flexion causes intervertebral disc to bulge in the direction of bend [24].

Composition of intervertebral disc

The disc is composed of water, primary chondrocyte like cells, fibroblasts, proteoglycan aggregates and collagen fibres.

Blood supply of the intervertebral disc

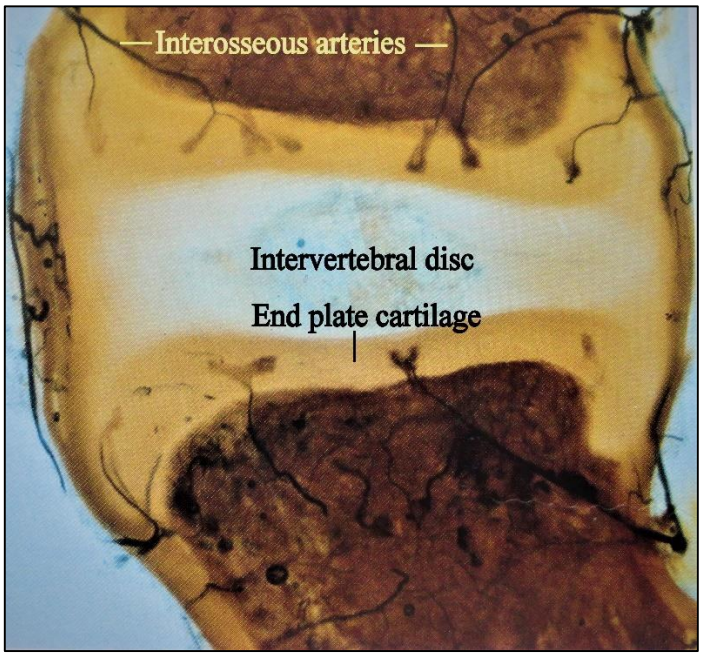


Fig. 22 Medial sagittal section at L5-S1 in a newborn: Pattern of distribution of interosseous arteries and some vascularization of the periphery of the anulus [25].

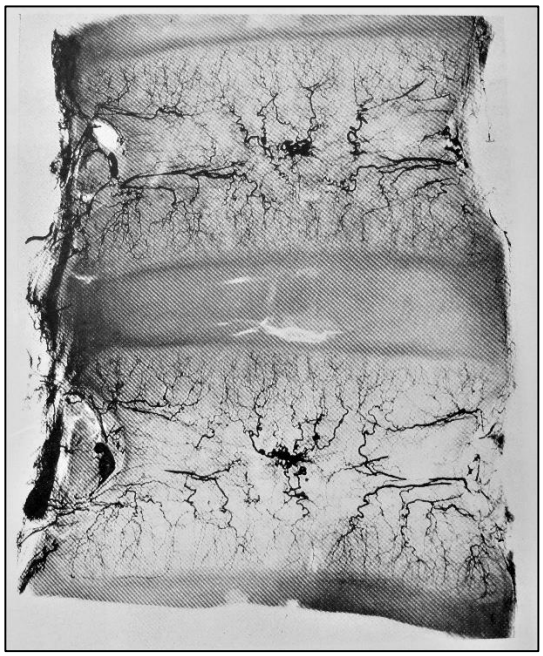


Fig. 23 Coronal section through lumbar vertebrae of 65 years male: Intraosseous distribution of arteries and absence of vessels in the intervertebral disc [26].

There is a reach blood supply to the intervertebral disc during the fetal life and in new born babies. But the blood vessels become narrow and get diminished in number until the age of twenty. And the intervertebral disc becomes almost completely avascular except for the most peripheral region of the annulus fibrosus.

Nerve supply of the intervertebral disc

The one third of the anulus fibrosus of the disc has both sensory and vasomotor nerve supply. The sensory nerves are both nociceptive (for sensation of pain) and proprioceptive (sense of self-movement and body position). The posterior aspect of the disc receives nerves from the recurrent meningeal nerve. The posterolateral aspect of the anulus receives both direct branches from the anterior primary division and branches from the gray rami communicants of sympathetic chain. The lateral and anterior aspects of the disc receive the nerves from gray rami communicants and from the sympathetic chain.

Clinical anatomy

1) The intervertebral disc is a very important structure. The diseases of it causes back pain. It can compress the exiting dorsal roots and spinal nerves, resulting in radicular symptoms. Regarding the cervical spine, herniation of intervertebral disc is predominant in the lower five cervical vertebrae [27].

2) In young adult intervertebral discs are very strong. Hence it is hard to damage. After 20 years of age; degenerative changes in disc may result in necrosis, replacement of the nucleus pulposus, softening and weakening of the annulus fibrosus. The strains may cause either internal derangement with eccentric displacement of the nucleus pulposus or external derangement, the nucleus pulposus then bulges or bursts through the annulus fibrosus, usually postero-laterally. Unequal tension in the joint causes muscle spasm and sudden severe pain. In the advanced stage a herniated nucleus pulposus may press on adjacent nerve roots with resultant referred pain. Such changes are usually at C5-C7. It may cause loss of power and reflexes. [28]

3) Remnants of notochordal cells in the cartilage end plate can develop weakness in it. This may result in herniation of the nucleus pulposus into the cartilage end plate and vertebral body. This condition is called Schmorl's node. This can result in rapid degeneration of the intervertebral disc. These nodes cause the vertebrae surrounding the lesion to move closer together. This movement may increase force on the posterior and anterior joints between the vertebrae. It increases the degeneration of the anterior interbody joint. It also causes more force on the facet joints to develop their degeneration.

4) The anterior aspect of the disc is stronger than the rest. The posterolateral aspect of each disc is the weakest region. Hence this region is most prone to protrusion and herniation.

5) The lamellae of the annulus fibrosus may tear. There are two direction of tear, circumferential and radial. In the circumferential tear, a separation of adjacent lamellae of the annulus takes place. The separation may cause the lamellae to tear away from their vertebral attachments. The radial tears run from the deep lamellae of the annulus to the superficial layers. This results in the bulging or extruding of nucleus pulposus into the vertebral canal. This is called **intervertebral disc herniation**. But Lipson (1988) has showed that the material seen in intervertebral disc herniation did not consists of nucleus pulposus. He concluded that the material herniated in disc prolapse was essentially metaplastic (transformation of one tissue into another) fibrocartilage from the annulus fibrosus.

6) The permeability of the end plate declines with age. If this permeability decreases to the point that the path for nutrients to the intervertebral disc and waste products from the intervertebral disc is blocked, metabolic waste products increase within the intervertebral disc. this may initiate the process of internal disc disruption and disc degeneration

7) Formation of bone inside the cartilaginous end plate initiates a reduction of the nutritional route to the intervertebral disc. Bone formation may first cause the destruction of its surface towards the disc which promotes the degeneration of the nucleus pulposus.

8) In the age group 20 to 30 years the cartilaginous end plate begins to calcify and the calcified areas gets invaded by blood vessels from the adjacent vertebral bodies. Calcification of the end plate has been related to the degenerative changes within the intervertebral disc as a whole [29]

9) Osteophytes without disc prolapse are known to produce pure motor weakness with atrophy without pain and without sensory disturbance [30]

10) A spine which is continuously subjected to motion with increased range, speed and acceleration for a period of more than 20 years results in reduction of mechanical strength in the intervertebral disc. The sequelae of such abnormal persistent load on the spine causes structural degradation starting in the annulus fibrosus just as it occurs in disc degeneration at a later age [31].

11) Irrespective of the age, disc degeneration may be advanced with increasing load on the disc. At least experimentally, overuse appeared to produce fatigue failure in the structures of the intervertebral disc [32].

12) Unlike in the lumbar vertebra; the intervertebral discs in the cervical spine are placed horizontally which helps to produce relatively less stress on the facet joints. [33]

13) Settled disc space- following degeneration in the intervertebral disc the intervertebral disc tissue becomes smaller in volume and the vertebral bodies start coming together causing settled disc space and ensuing pain in the neck. The settlement of disc space causes all longitudinal ligaments to be slack, increased loadbearing by vertebral body margins, increased loadbearing by facet joints, narrowing of the intervertebral foramina and retrolisthesis along with altered curvature of the cervical spine. [34]

Joints of the vertebral arches

These are- 1) zygapophyses 2) joints of the laminae, spines and transverse processes are syndesmoses.

Zygapophyseal joint (facet joint) [35]

It is the joint between the articular processes of vertebrae. Their size, shape and topology vary with spinal level. Though these joints allow movement, they more determine the direction and limitations of movements of vertebrae. The loss of movement or aberrant motion of these joints cause pain.

Classification- In cervical and thoracic- simple synovial

In lumbar- complex synovial

The articular surfaces of the processes are covered by hyaline cartilage.

Articular capsules- These are thin, loose and attached to the margins of the articular facets of adjacent zygapophyses. These are longer and looser in the cervical region. The capsule consists of an outer layer of dense fibroelastic connective tissue, a vascular central layer made up of areolar tissue and loose connective tissue and an inner layer consisting of a synovial membrane. The anterior and medial parts of the joints are covered by the ligamentum flavum. Superior and inferior external protrusions of the joint capsules are called recesses, that bulge out from the joint and are filled with adipose tissue.

Nerve supply of zygapophyseal joint [36]- The joint capsule is supplied by rich sensory innervation which is derived from the medial branch of the posterior primary division (dorsal ramus) at the level of the joint and a branch from the medial branch of the posterior primary division of the level above and the level below. This multilevel nerve

supply is one of the reasons why the pain from the zygapophyseal joint has broad referral pain.

Synovial folds (meniscus) of zygapophyseal joint

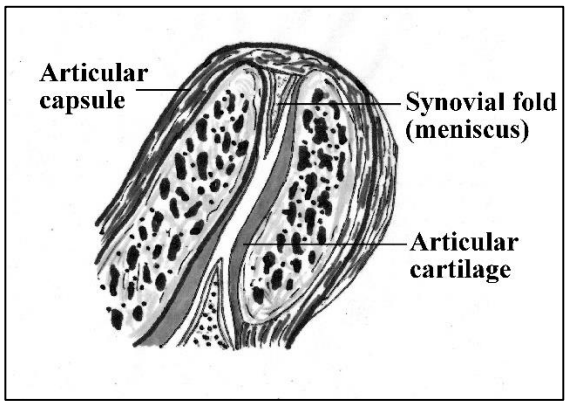


Fig. 24 Section passing through zygapophyseal joint

These are the synovium lined extensions of the joint capsule that protrude into the joint space to cover the part of the hyaline cartilage. The synovial folds vary in size and shape in the different regions of the spine. The synovial fold is attached to the capsule by loose connective tissue. Distal to the attachment is the synovial tissue and blood vessels and dense connective tissue. Free nerve endings are found within the folds. Hence the synovial folds are pain sensitive. If the synovial folds are compressed or trapped between the articular facets of zygapophyseal joint pain can be produced.

Clinical anatomy

1) The cervical zygapophyseal joint changes occur significantly with age. Before age 20 the articular cartilage is thick and smooth. The subarticular bone is regular in thickness. The articular cartilage becomes thin with irregularly thickened subarticular bone with age. These changes usually may not be detected by CT or MRI scan. [37]

2) Osteophytes (bony spurs) projecting from the articular processes and sclerosis (thickening) of the bone within the articular processes occur usually in adult cervical zygapophyseal joints.

3) The referred pain from the zygapophyseal joint can spread to- a) neck and head arising from C2 to C3 zygapophyseal joints b) neck and shoulder arising from C5 to C6 zygapophyseal joints [38]

Intervertebral joints between the laminae, spines and transverse processes (syndesmoses) [39]

The laminae, spines and transverse processes are connected through syndesmoses by the following ligaments connecting adjacent vertebrae-

1) **Ligamenta flava**- These are inside the vertebral canal and connect laminae of adjacent vertebrae. Their attachments extend from zygapophyseal capsules to the junction of two laminae forming the spine. Here their posterior margins partially fuse. The ligament is formed of yellow elastic tissue. It is thin broad and long in the cervical region. They limit separation of the laminae in spinal flexion and helps to restore an erect posture after flexion and protect disc from injury.

2) **Interspinous ligaments**- These connect adjacent spines. These are thin and membranous. Their attachments extend from the root to the apex of each spine. They meet the ligamenta flava in front of the supraspinous ligament behind. These are not well developed in the neck.

3) **Supraspinous ligaments**- These connect the tips of the spines of vertebrae from the seventh cervical to the sacrum.

4) **Ligamentum nuchae**- It continues with the supraspinous and interspinous ligaments. It forms a double layered fibroelastic septum that separates the dorsal muscles of the neck. It extends from the external occipital protuberance on the skull and median nuchal line, to the spinous process of C7. The deep fibers of the ligament attach to the external occipital crest, the posterior tubercle of the atlas and to the medial surface of the bifid processes of the other cervical vertebrae.

5) **Intertransverse ligaments**- These connect the adjacent transverse processes. In the cervical region these are almost replaced by intertransverse muscles.

Nerves- intervertebral joints are supplied by adjoining spinal and sympathetic nerves.

Biomechanical properties of the ligaments [40]

Resistance- ligaments offer resistance to stretch (tension)

Relaxation- on continued stretch there is gradual relaxation in tension in the ligaments.

Creep- gradual lengthening in the ligament during stretch exercises

Elastic deformation- the creep of gradual lengthening can be reversed totally on elimination of stretch suggesting that there has been no structural damage sustained to the ligament during stretching. The spine as a whole is an excellent example of viscoelastic properties of ligaments and demonstrates creep or lengthening with continued stress. The spine is elastic but there is a difference between a metallic spring and the spine. Unlike metallic spring which exhibits linear deformation, the spine exhibits nonlinear deformation.

Plastic deformation- the ligaments does not return to normal on elimination of stretch. This property is clinically used to stretch stiff ligaments and muscles during postoperative period

Break point- if the stretch is continued after plastic deformation the ligament breaks as the stress becomes more than the inherent capacity of the viscoelastic property of the ligament.

Table no. 10 The muscles acting on the cervical spine for various movements of the cervical spine [41]

Action	Muscles producing the action
Extension	Levator scapulae, splenius capitis, splenius cervicis, longissimus capitis, longissimus cervicis, iliocostalis cervicis, semispinalis capitis, semispinalis cervicis, multifidus and interspinales.
Flexion	Sternocleidomastoid, longus capitis, longus colli, scalenus anterior.
Lateral flexion	Sternocleidomastoid, scalenus anterior, scalenus medius, scalenus posterior, splenius capitis, splenius cervicis, levator scapulae, longissimus capitis, longissimus cervicis, iliocostalis cervicis, semispinalis cervicis, trapezius and intertransversarii.
Rotation	Splenius capitis and splenius cervicis of same side, longissimus cervicis and iliocostalis cervicis of same side, Sternocleidomastoid, semispinalis cervicis, multifidus, rotatores, scalenus anterior and trapezius of opposite side.

The cervical spine is the most mobile segment of the of the whole spine. Maximum range of motion is possible in this portion of the spine. Therefore, it is also subject to significant injury being extremely mobile. The spine as a whole and particularly the cervical spine is made of several segments. Thus, there are eight motion segments related to the cervical spine. Any motion simply cannot occur in one given motion segment. when a movement has to occur all motion, segments cooperate to produce a smooth gliding coordinated motion.

The motion segment [42]

The segment holding two vertebrae together and exhibiting motion is called motion segment. It constitutes the intervertebral disc, intervertebral foramen and facets, interlaminar space, ligamentum flavum, supraspinous ligaments and interspinous ligaments. A malfunction in one element produces stress on the whole segment.

Hysteresis [43] - It is the ability of the spinal segments to absorb axial impact. It is moderate in the cervical spine and maximum in lumbar spine. Hysteresis is reduced by age and repetitive loading as in dock workers, joggers, jockeys etc.

Movements of the spine

The movement between two adjacent vertebrae is slight but the combined movement of many vertebrae is great. The movements of spine are flexion, extension, lateral flexion, rotation, circumduction. Thicker intervertebral discs of the cervical and lumbar regions result in greater movements in these regions. The shape and the orientation of the articular facets regulate the movement between two adjacent segments.

Movements of the cervical spine [44]

Flexion- extension- These movements occur mainly at the occipito- atlantoide joint but to some extent throughout the cervical spine. Lateral flexion takes place throughout the cervical spine. Rotation occurs mainly at the atlantoaxial joint, with a small range of movement at the other joints.

Rotation of spine with lateral flexion

Lateral flexion of the cervical and lumbar regions goes together with axial rotation. This is due to the facing of the superior and inferior articular facets. Lateral flexion of the cervical spine is associated with the rotation of the vertebral bodies into the concavity of the arch formed by the lateral flexion.

In range of motion two parameters are involved and hence range of motion is different from motion in one movement. All motions have multiplanar coupling e.g. ratio of rotation in lateral bending varies at different levels depending on orientation of facets. Inclination of facet joints at 45^0 to 80^0 with respect to the horizontal plane of intervertebral disc causes simultaneous sliding and rotation. The orientation of facet

joints is partly responsible for this multiplanar coupling. it has been shown that at the level of C3 and C4 the superior articular facets are displayed postero-medially. At C7-T1 level the superior facet is displayed postero-laterally and it correlate well with the pattern of cervical movements.

Flexion and extension

Total extension is relatively less than total flexion. Total flexion possible is 53^0 and total extension is 38^0 with range of motion in flexion/ extension in normal adult is 130^0

Lateral bending

There is very little lateral bending in the upper cervical spine. All the lateral bending is done in the lower cervical spine. The range of motion is 88^0.

Range of movement at the atlanto occipital joints [45]

Movement	Amount of movement
Combined flexion and extension	25^0
Unilateral lateral flexion	5^0
Unilateral axial rotation	5^0

Range of movement at the atlanto axial joint [46]

Movement	Amount of movement
Combined flexion and extension	20^0
Unilateral lateral flexion	5^0
Unilateral axial rotation	40^0

Total range of movement of cervical vertebrae(C2-T1) [47]

Movement	Amount of movement
Flexion and extension	91^0
Lateral flexion	51^0 (Unilateral)
Axial rotation	33^0 (Unilateral)

Table no. 11 Anatomical structures limiting the spinal movements [48]

Motion	Anatomical structures limiting the motion
Flexion	Posterior longitudinal ligament, ligamenta flava, interspinous ligament, supraspinous ligament, posterior fibres of the intervertebral disc, articular capsules, tension of back extensor muscles, anterior surface of inferior articular facet against posterior surface of superior articular facet.
Extension	Anterior longitudinal ligament, anterior part of intervertebral disc, approximation of spinous processes, articular processes and laminae
Latera flexion	Contralateral side of intervertebral disc and intertransverse ligament, approximation of articular processes, approximation of uncinate processes (in cervical region), approximation of costovertebral joints (thoracic region) and antagonist muscles.
Rotation	Tightening of lamellar fibers of anulus fibrosus, orientation and architecture of articular processes.

Vertebral column [49]

The vertebral column is situated posteriorly in the mid line. Its average length in the male is about 71 cm and in female is about 61 cm. The vertebral column is made up of 33 vertebrae- 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal. The cervical, thoracic and lumbar vertebrae are movable or true vertebrae. The vertebrae of the sacrum and coccyx are fixed or false vertebrae. The vertebral bodies increase in size from cervical to the lumbar. They are separated from each other by the intervertebral discs. The transverse processes project laterally and differ significantly in form, size and direction. Posteriorly the tips of spinous process are palpable from sixth cervical (seventh is most prominent) down to the sacrum and coccyx.

When the individual vertebrae are united the articular processes of each side of the cervical spine form an articular pillar that bulges laterally at the pediculolaminar junction. Both the cervical articular pillars help to support the weight of the head and neck. Hence weight bearing in the cervical region is carried out by three longitudinal columns- anterior column formed by vertebral bodies and two posterior columns, which run through the right and left articular pillars.

Curvatures of the vertebral column

In sagittal plane [50]

Primary curves- These are present at birth and are due to the shape of the vertebral bodies. The primary curves are thoracic and sacral. Both of which are concave forwards. The thoracic and sacral curves are referred to as structural and are due to the slightly diminished vertical height of the anterior thoracic and sacral vertebral bodies in contrast to their posterior bony height. The compensatory anterior curves of the sacral and lumbar regions are due largely to wedge-shaped intervertebral discs.

Secondary curves- These are postural and are mainly due to the **shape of the intervertebral discs.** The secondary or compensatory curves are cervical and lumbar, both of which are convex forwards. The cervical curve appears during 4 to 9 months after birth when the infant starts supporting its head. It extends as far as the second thoracic vertebra. The lumbar curve convex forward; appears during end of 12 months when the child adopts the sitting posture and then an upright walking posture. It extends from the twelfth thoracic vertebra to the sacral promontory.

The kyphosis and lordosis of the spine, along with the intervertebral discs, help to absorb the loads applied to the spine. These loads include- 1) weight of the trunk 2) loads applied through the lower limbs during walking, running and jumping 3) loads applied by carrying objects with the upper extremities, pull of spinal muscles and various movements of the spine.

In coronal plane (lateral curve)

There is a slight lateral curve in the thoracic region with its concavity towards the left.

Abnormalities of the vertebral column [51]

Scoliosis is a term applied to abnormal lateral curvature of the spine, frequently accompanied by severe rotation of the vertebral bodies and torsions within the laminae and pedicles. Such abnormal curvatures may be of two types- 1) postural- it may result from the lower limbs being unequal in lengths. 2) structural- it is due to congenital abnormalities of the vertebrae (e.g. hemivertebrae) or it may be secondary to disease such as poliomyelitis or muscular dystrophies or they may be idiopathic.

Clinical significance

1) The straightening of cervical lordosis or an angulation in the reverse direction (kyphosis), is sometimes significant and may suggest an underlying abnormality. Any lateral or rotational deformity (torticollis) must also be noted. [52]

2) **Scoliosis**- It is a sideways curvature of the spine. The curve is usually 'S'- or 'C' shaped. The degree of curve may be stable; it may increase over time. Mild scoliosis does not cause complications, while severe cases can interfere with breathing.

3) **Kyphosis** (a hump)- It is an abnormally excessive convex outward curvature of the spine.

4) **Lordosis**- It is an abnormal inward concave curving of the cervical and lumbar regions of the spine.

Stability and instability of the spine [53]

Stability of the spine is the ability of individual vertebral segments to maintain normal relationship between vertebrae under normal physiological loads. The intervertebral discs contribute to 45% stability in the spine as a whole with facet joints contributing 45% and the remaining 10% of stability is contributed by ligaments. Articular buttresses and ligamentous brakes maintain smooth mobility and stability in the spine. All bony and ligamentous components of the cervical spine help to maintain stability.

The inbuilt mechanism to prevent excessive flexion is provided by posterior part of annulus, posterior longitudinal ligament, articular facets, ligamentum flavum and interspinous and supraspinous ligaments. Thus, ligaments play an important part in stability of spine.

On the other hand, instability is the inability of the vertebrae to maintain normal relationship. Instability is of two types- 1) Fixed instability- it is not reducible 2) Dynamic instability- which can be reduced. Clinically the instability has to be suspected when there is chronic pain, neurological deficit or deformity.

Vertebral canal [54]

The group of all vertebral foramina forms the vertebral canal. The intervertebral discs, ligamenta flava contribute to form the canal. The vertebral canal is large in the superior cervical region (because there is greater movement) and narrow from C3 to C6. The upper cervical canal is infundibular in shape i.e. wider superiorly than inferiorly. Less than 50% of the vertebral canal at the level of C1 is occupied by the spinal cord whereas spinal cord occupies 75% of the vertebral canal at the level of C6. Hence the lower cervical cord is predominantly susceptible to pathological affection. These are-

1) Intervertebral disc protrusion
2) Hypertrophy of the ligamentum flavum

3) Ossification of the posterior longitudinal ligament.

4) Zygapophyseal joint hypertrophy

5) Space occupying lesions

6) Arteriovenous malformations

7) Posterior spondylosis of the vertebral body

8) Spinal cord tumor

Clinical anatomy of vertebral canal

1) Vertebral canal stenosis- this abnormality develops due to the narrowing of the anteroposterior or the transverse diameter of the vertebral canal. This may be due to prenatal and perinatal growth disturbance.

2) The vertebral dimensions and canal size change with progressive aging.

Arterial supply of the spine [55] - The external part of the vertebral column gets its arterial supply from branches of deep neighboring arteries. The cervical part is supplied by the left and right deep cervical arteries and the right and left ascending cervical arteries. The thoracic region of the spine is supplied by intercostal arteries. And the lumbar region is supplied by lumbar segmental arteries.

The internal aspect of the vertebral canal is supplied by segmental arteries that send spinal branches into the intervertebral foramina. These segmental arteries are branches of the vertebral artery in the cervical region, the intercostal arteries in the thoracic region and the lumbar arteries in the lumbar region.

Spinal cord [56]

The spinal cord is an organ from the central nervous system (CNS). It is closely related with the vertebral column hence its anatomy is very important with respect to the disorders of spine. It is a long, thin and cylindrical bundle of nervous tissue and support cells. The sensory input travels along the white matter tracts present in the spinal cord towards the brain and motor output travels from the brain along the tracts toward the skeletal muscles and other tissues. The grey matter in the spinal cord is useful for the receiving and integration of sensory and motor information. It extends from the medulla oblongata to the lumbar region of the vertebral column.

Location- It lies in the upper two third part of vertebral canal. It starts at the upper border of atlas and ends at the junction between first and second lumbar vertebrae. As the spinal cord does not extend inferior to second lumbar vertebra, a lesion such as a herniated disc or trauma occurring below the second lumbar vertebra does not directly

affect the spinal cord. The cord is protected by the vertebrae and their ligaments. The cerebrospinal fluid and meninges also provide protection to it. The spinal cord is separated from the vertebral canal and the ligaments from the meninges, cerebrospinal fluid adipose tissue and a venous plexus.

Length- In male- 45 cm and in female- 43cm.

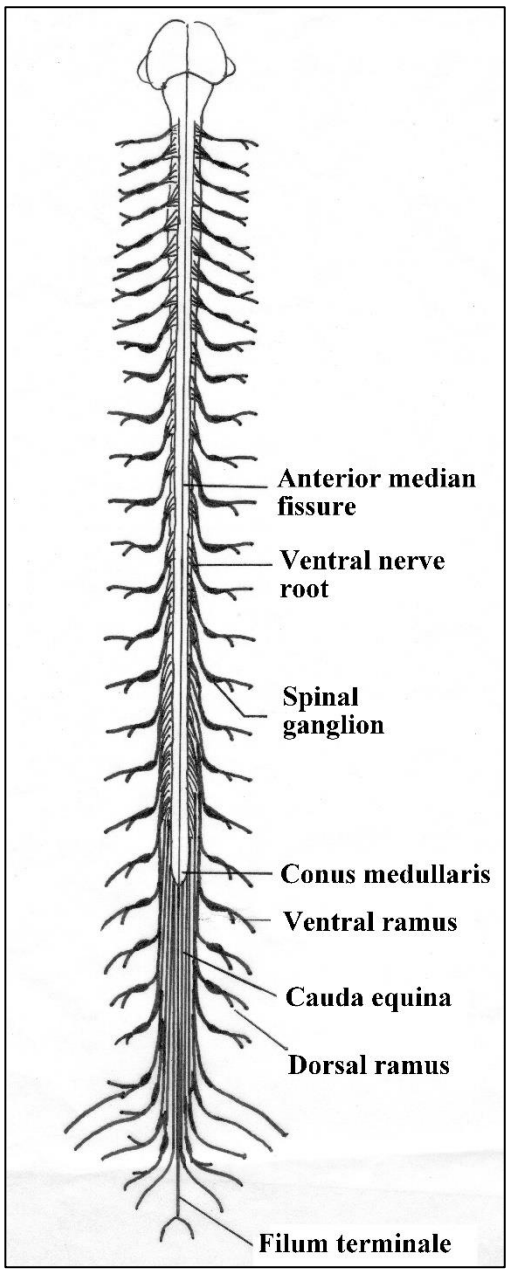


Fig. 25 Spinal cord and spinal nerve roots: anterior aspect.

The distal part of spinal cord is conical called *conus medullaris*. From the apex of conus medullaris, a filament extends up to the first coccygeal vertebral segment called the *filum terminale***.**

The width of spinal cord shows enlargements at two places these are-

Cervical enlargement- It extends from the third cervical to the second thoracic segments. This region of spinal cord provides nerves to the upper limbs.

Lumbar enlargement- It extends from first lumbar to the third sacral segment. This region provides nerves to the lower limbs. The *anterior median fissure, posterior median sulcus* and septum divide the cord into right and left halves. To each side of posterior median sulcus there is *posterolateral sulcus*. The dorsal roots of spinal nerves enter the cord along this sulcus. The white matter between the posterior median and posterolateral sulcus is called *posterior funiculus*.

In the cervical and upper thoracic segments one additional *postero-intermediate sulcus* with septum is present. It divides each posterior funiculus into two regions- medially the *fasciculus gracilis* and laterally *fasciculus cuneatus*. Between the posterolateral sulcus and ventral spinal root, the white matter is called *lateral fasciculus* and that between ventral spinal root and anterior median fissure is called *anterior fasciculus*.

Dorsal and ventral nerve roots

The pairs of dorsal and ventral roots of spinal nerves are continuous with the spinal cord. The length of the spinal cord is shorter than the vertebral canal hence the distal nerve roots have origin at higher level and they emerge from vertebral canal from their corresponding inter vertebral foramen at lower level. They form collection of nerve roots called *cauda equina*.

Spinal segments- The part of spinal cord associated with the emergence of a pair of nerves is a spinal segment.

The spinal cord gives rise to 31 pairs of spinal nerves attached to the cord by dorsal and ventral rootlets. Dorsal rootlets contain *afferent nerve fibers* and ventral rootlets contain *efferent nerve fibers*. The dorsal roots have *dorsal root ganglia* containing the cell bodies of primary afferent neurons.

Spinal meninges

These cover the spinal cord.

Dura mater - The cranial dura mater enters into the vertebral column through the foramen magnum to which it is attached and where the outer endosteal layer becomes the periosteum of the vertebral canal. It is separated from the spinal dura mater by the epidural space. The spinal dura mater sends tubular prolongations over the spinal nerve

roots for some distance. Inferiorly the spinal dura mater is fused with the periosteum of the coccyx.

Epidural space- It is the space between the spinal dura mater and the periosteum of the vertebral canal. It contains loose connective tissue, fat and venous plexus.

Subdural space- It is the space between the spinal dura mater and arachnoid mater. As these membranes are in close contact with each other, this space is called as potential space.

Arachnoid mater of spinal cord- The arachnoid mater of brain continues below with that of spinal cord. It surrounds the spinal cord. It also extends over the spinal vessels and nerves at the site of their entry or exit.

Subarachnoid space- It is wide. The trabeculae are few and delicate. It is filled with CSF.

Pia mater- It covers the surface of the spinal cord. It passes into the anterior median fissure. Thin ridges of pia mater on each side of the spinal cord are attached to the dura mater through the arachnoid mater called *ligamentum denticulatum*. There are about 21 processes on each side. This ligament suspends the spinal cord.

The spinal cord ends below the first lumbar vertebra. But the dura and arachnoid mater extend inferiorly enclosing the cauda equina. Thus, the subarachnoid space is extended to the second sacral vertebra. Here they close on the filum terminale which is covered by pia mater.

Nerves of cranial dura mater - 1) three divisions of trigeminal nerve 2) first three cervical spinal nerve 3) cervical sympathetic trunk.

T.S. of spinal cord

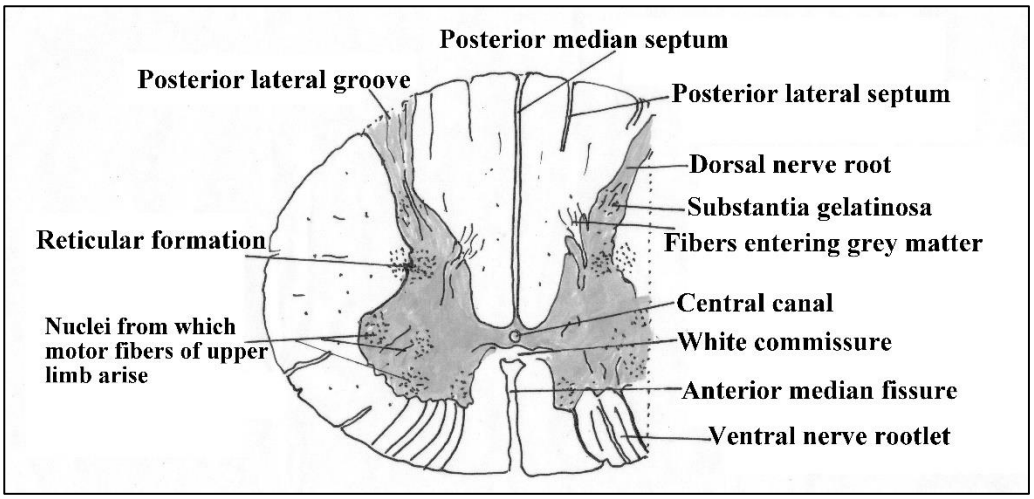


Fig. 26 T.S. of spinal cord: at the level of fifth cervical nerve.

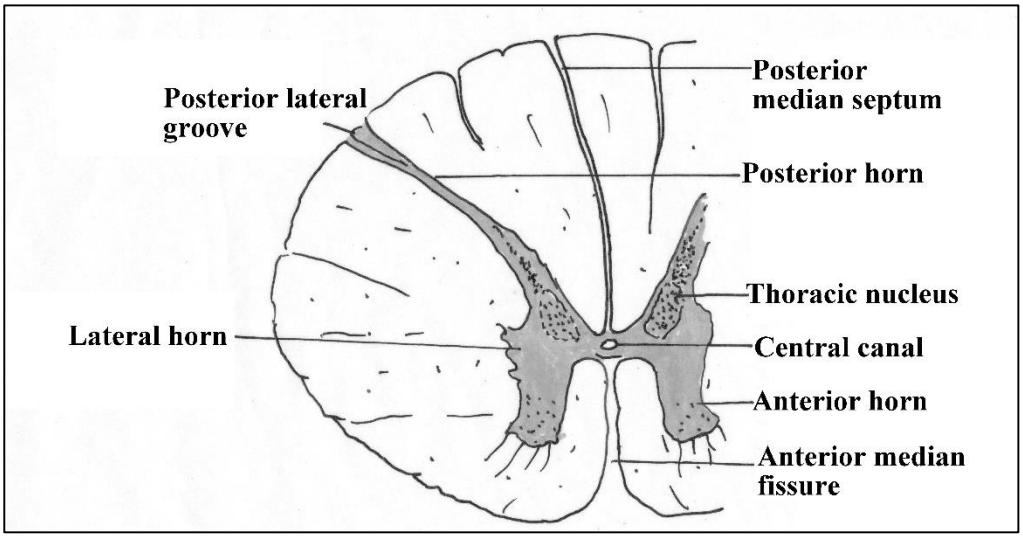


Fig.27 T.S. of spinal cord: through the midthoracic region.

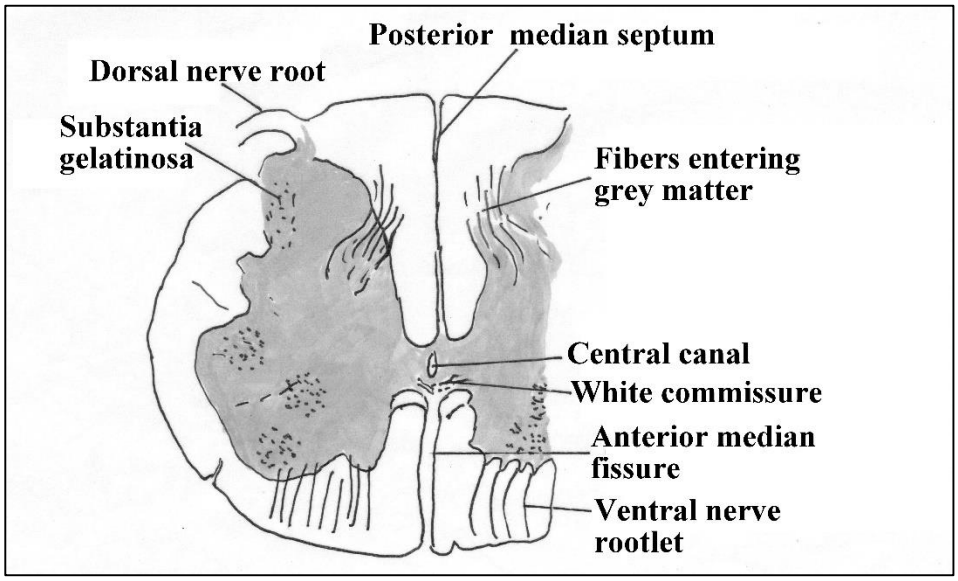


Fig.28 T.S. of spinal cord: at the level of fourth lumbar nerve.

The posterior median septum and anterior median sulcus divides the spinal cord into two lateral halves. The inner grey matter is surrounded by outer white matter. The grey matter is formed by collection of neuron cell bodies. White matter is formed of ascending and descending *tracts*. The *central canal* is present in the center of grey matter. It is continuous with the central canal of medulla oblongata. It is lined with ependyma and contains CSF.

Grey matter- It is H shaped. It has two *dorsal* and two *ventral horns* (columns). A small *intermediate lateral horn* (column) is present at thoracic and upper lumbar

portion of spinal cord. They extend towards the surface. The grey matter; anterior and posterior to the central canal unite the two halves are called ventral and dorsal *grey commissure*. The grey matter is formed by cell bodies, their processes, connective tissue and blood vessels.

Nuclei of grey matter are described in the three horns-

Nuclei of ventral horn- The neurons in this horn form many columns. The cells in the anterior horn are arranged in three groups.

1) Medial group- It is present in the entire length of spinal cord.

2) Lateral group- It is present in the cervical and lumbar enlargements.

3) Central group- It is present in upper cervical segments.

Nuclei of lateral horn- These are in two groups.

1) Intermedio-lateral nucleus- This is seen at two segments of spinal cord, from T1 to L2 and from S2 to S4

2) Intermedio-medial nucleus- It is formed of internuncial (neuron connecting two other neurons) neuronal column.

Nuclei of dorsal horn- Primary afferent fibers enter the spinal cord through the dorsal roots of spinal nerves. Some fibers enter the grey matter and others ascend and descend in the spinal cord. The four nuclei are-

1) Posterior marginal nucleus 2) substantia gelatinosa 3) nucleus proprius 4) nucleus dorsalis (thoracic nucleus)

White matter

It is formed of nerve fibers, connective tissue, blood vessels. The two lateral halves of white matter are connected by *dorsal* and *ventral white commissure*.

Collection of nerve fibers (tracts) run longitudinally in the spinal cord arranged in three masses- 1) dorsal 2) lateral 3) ventral funiculi.

Descending tracts (motor tracts)

1) Pyramidal (cortico-spinal)- a) anterior b) posterior.

2) Extrapyramidal- a) rubrospinal b) tectospinal c) vestibulospinal d) olivospinal e) reticulospinal- i) medial ii) lateral.

Ascending tracts (sensory tracts)

1) lateral spinothalamic 2) anterior spinothalamic 3) fasciculus gracilis 4) fasciculus cuneatus 5) dorsal spinocerebellar 6) ventral spinocerebellar.

Arteries- Branches of vertebral, intercostal, lumbar and lateral sacral arteries.

Veins- Median, anterolateral and posterolateral longitudinal veins.

Clinical significance

Acute poliomyelitis- It is an infectious disease of the anterior horn motor neurons of the spinal cord caused by poliovirus. Flaccid asymmetric paralysis and muscle atrophy are its clinical appearances, due to the loss of motor neurons and denervation of their related skeletal muscles.

Nerves present in the cervical region [57]

The dorsal and ventral rootlets of the cervical region originate from the spinal cord and unite to form dorsal and ventral roots. The dorsal and ventral roots fuse together within the intervertebral foramen to form the mixed spinal nerve. It is short and immediately divides into a dorsal ramus (posterior primary division) and ventral ramus (anterior primary division).

The cell bodies of all afferent nerve fibres are located in the dorsal root ganglia. These ganglia, with the exception of those of the C1 and C2 spinal cord segments, are located within the intervertebral foramens. The C1 dorsal root ganglion is found lying on the posterior arch of the atlas. The C2 dorsal root ganglion (only ganglion located outside the dura) is located between the posterior arch of the atlas and the lamina of C2. It contains the cell bodies of sensory fibres innervating the medial atlanto- axial joint, the lateral atlanto-axial joint, a large part of the neck and scalp (extending from the posterior occipital region to the vertex)

Clinical anatomy of spinal cord

1) Irritation to C1 rootlets are found to cause orbital pain (superior rootlets of C1), frontal pain (middle rootlets) and vertex pain (lower rootlets).

2) Anastomoses more frequently exist between rootlets of adjacent spinal cord segments in the cervical spinal cord. Sensory impulses conducting pain sensation through the dorsal root ganglion at one vertebral level may enter the spinal cord at the next spinal cord segment above or below. The pain sensation in such cases may be perceived one segment off, adding to the body's already difficult task of pain localization. These anastomoses may also complicate the presentation of radicular pain by disrupting the normal dermatomal pattern of innervation by dorsal roots and dorsal root ganglia.

Anterior primary division (ventral rami)

The ventral rami of spinal nerves supply the limbs and the anterolateral aspects of the trunk. The thoracic ventral rami are independent and have segmental distribution.

The cervical, lumbar and sacral ventral rami connect near their origins to form plexuses. Dorsal rami do not join these plexuses.

The cervical ventral rami except the first, appear between the anterior and posterior intertransverse muscles. The upper four form the cervical plexus. The lower four with first thoracic ventral ramus form a brachial plexus. Each receive at least one grey ramus communicans, the upper four from the superior cervical sympathetic ganglion, the fifth and sixth from the middle ganglion and the seventh and eighth from the cervico-thoracic ganglion.

Each ventral ramus of the cervical region leaves its mixed spinal nerve of origin and exits the spine by passing posterior to the vertebral artery and then between the anterior and posterior intertransversarii muscles. They supply to longus capitis, longus colli, rectus capitis anterior and lateralis muscles. The atlanto-occipital joints and the median and lateral atlanto-axial joints are innervated by the C1 and C2 ventral rami respectively.

The cervical ventral rami also supply to the vertebral bodies, anterior longitudinal ligament and anterior aspect of the intervertebral discs with sensory innervation. The anterior structures of the spine also get sensory nerve supply from the sympathetic chain and from the autonomic nerves accompanying the vertebral artery.

Dorsal rami (posterior primary divisions)

These are smaller than the ventral rami. After exiting the intervertebral foramen, the dorsal ramus curves posteriorly, close to the anterolateral aspect of the articular pillar. After reaching the posterior and lateral aspect of the superior articular process, each dorsal ramus divides into a medial and a lateral branch. The lateral branch of the dorsal rami of the upper cervical nerves (except C1) extend posteriorly after innervating the erector spinae, splenius capitis and cervicis muscles, to supply sensory innervation to the skin of the neck. The dorsal rami of C6, C7 and C8 usually do not have cutaneous branches.

Structures supplied by dorsal rami

Medial branch

1) deep back muscles and transversospinalis muscles 2) zygapophyseal joints 3) periosteum of posterior vertebral arch 4) interspinous, supraspinous and intertransverse ligaments, ligamentum flavum 5) skin

Lateral branch

1) erector spinae muscles 2) splenius capitis and splenius cervicis muscles.

Distribution of C1-C3 dorsal rami

The dorsal ramus of the C1 spinal nerve exits the vertebral canal by passing above the posterior arch of the atlas. It divides into a ventral and dorsal ramus. The dorsal ramus (suboccipital nerve) runs between the posterior arch of the atlas and the vertebral artery. Without dividing, it curves superiorly for a short distance and provides motor nerve supply to the suboccipital muscle. It sends a communicating branch to the dorsal ramus of C2.

The C2 spinal nerve branches into a dorsal and ventral ramus posterior to the lateral atlantoaxial joint. The dorsal ramus loops superiorly around the inferior border of the obliquus capitis inferior muscle and then divides into medial, lateral, superior communicating, inferior communicating and a branch to the obliquus capitis inferior.

The lateral branch of the dorsal ramus of C2 helps to supply motor innervation to the longissimus capitis, splenius capitis and semispinalis capitis muscles. The medial branch of the dorsal ramus of C2 is called the greater occipital nerve. It provides sensory nerve supply extending from the occipital region medially to the region superior to the mastoid process and posterior to the ear laterally. Superiorly they supply sensory innervation to the scalp from the posterior occiput to the coronal suture of the skull.

The C3 nerve divides into a dorsal and ventral ramus within the lateral part of the intervertebral foramen. The dorsal ramus extends posteriorly between the transverse processes of C2 and C3 and divides into deep and superficial medial branches, a lateral branch and a communicating branch with the C2 dorsal ramus. The superficial medial branch is called the third occipital nerve. This nerve provides articular branches to the C2-C3 zygapophyseal joint. It also assists the greater occipital nerve (C2) in its sensory innervation of the suboccipital region.

Table no. 12 Other supply of C3 ramus

Nerve	Structures getting supply
Deep medial branch of C3 dorsal ramus	Uppermost multifidus muscles
lateral branch of the C3 dorsal ramus	Longissimus capitis, splenius capitis, semispinalis capitis
C3 dorsal ramus	C2-C3 via dorsal ramus, to the third occipital nerve or a communicating branch and C3-C4 via the deep medial branch to zygapophyseal joints.

The atlanto-occipital joints and the median and lateral atlanto-axial joints are supplied by the C1 and C2 ventral rami respectively.

Clinical significance

1) Disorders of the upper cervical spine and irritation of the greater occipital nerve or the C2 ganglion may cause headache.

2) As the third occipital nerve has close relationships with the bony parts of C2-C3 intervertebral foramen, the osteoarthritis of the cervical spine may cause irritation to this nerve producing headache.

3) Irritation to the dorsal rami of the upper three cervical nerves may result in pain referral to the occipital regions and also to regions of the head innervated by the trigeminal nerve.

4) Many structures of the cervical region that can produce pain get the sensory supply from dorsal rami.

Distribution of C4-C8 dorsal rami

The spinal nerves of C4 through C8 exit through their respective intervertebral foramens. The dorsal rami extend posteriorly and supply to the posterior intertransversarii muscles. Then they divide into medial and lateral branches. The medial branches of C4 and C5 divide into a superficial and deep branch. The superficial branches supply to the semispinalis cervicis and capitis and send sensory cutaneous nerves to the skin of the posterior neck.

The deep medial branches of the dorsal rami supply to the multifidus muscles. Each nerve supplies those muscle fibres that attach to the spinous process of a segmental level numbered one less than the nerve. The deep medial branches of C4 to C8 also supply the zygapophyseal joints. Each deep medial branch sends a rostral branch to the zygapophyseal joint above and a caudal branch to the zygapophyseal joint below. The lateral branches of the C4 to C8 dorsal rami supply to the semispinalis capitis, longissimus cervicis, splenius cervicis and iliocostalis cervicis muscles.

Recurrent meningeal nerve

Each nerve originates from the ventral ramus and then receives a contribution from the gray communicating ramus and other sympathetic nerves that run with the vertebral artery. The recurrent meningeal nerve passes medially through the medial aspect of the intervertebral foramen and anterior to the spinal dura. It innervates (at the level where it enters the vertebral canal)- 1) posterior aspect of the intervertebral disc

and periosteum 2) posterior longitudinal ligament 3) anterior part of the spinal dura mater 4) posterior aspect of vertebral bodies 5) epidural adipose tissue.

The recurrent meningeal nerves of C1to C3 ascend to the posterior cranial fossa and innervate 1) atlanto-axial joint complex 2) tectorial membrane 3) components of the cruciate ligament 4) alar ligament 5) C3 recurrent meningeal nerve also supply the adjacent cranial dura mater.

Clinical anatomy

Disorders of the upper cervical spine affecting meningeal branches may produce occipital headache.

Cervical sympathetic

The cervical sympathetic chain lies anterior to the longus capitis muscle. It is composed of three ganglia- superior, middle and inferior.

Structures innervated by nerves associated with the sympathetic trunk and the gray rami communicants

1) Periosteum of the anterior and lateral aspects of the vertebral bodies.

2) Lateral aspect of the intervertebral disc.

3) Anterior aspect of the intervertebral disc.

4) Anterior longitudinal ligament.

Sympathetic plexus surrounding the vertebral artery

The plexus surrounding the vertebral artery (vertebral plexus of nerves) is formed mainly by the vertebral nerve. The vertebral nerve is the largest of the many branches arising from the cervicothoracic (stellate) ganglion to follow the vertebral artery through the foramen of the transverse process of C6. The other nerves of the plexus are arising from the middle cervical ganglion, intermediate ganglia, ventral rami of C1 to C3. The vertebral artery is also accompanied by the gray rami communicants.

The branches from this plexus supply sensory innervation to the lateral aspects of the cervical intervertebral disc

Clinical significance

The vertebral artery is capable to produce pain. The afferents for its nociceptive sensation run with the autonomic fibres. Therefore, irritation of these fibres by degenerative spur formation of the upper cervical uncovertebral or zygapophyseal joints may be cause of headache.

Nerves on the anterior aspect of the neck

These are-

1) Ventral rami of the cervical nerves forming the cervical and brachial plexuses 2) glossopharyngeal nerve 3) vagus nerve 4) accessory nerve 5) hypoglossal nerve

Ventral ramus of C1

It receives some fibres from the ventral ramus of C2 and they join the hypoglossal nerve. Some fibres follow the hypoglossal nerve and provide sensory innervation to the dura mater of the cranial fossa. Many fibres of ventral ramus of C1 continue along with hypoglossal nerve and gives many branches that leaves hypoglossal nerve.

Cervical plexus [58]

It is formed by the upper four cervical ventral rami.

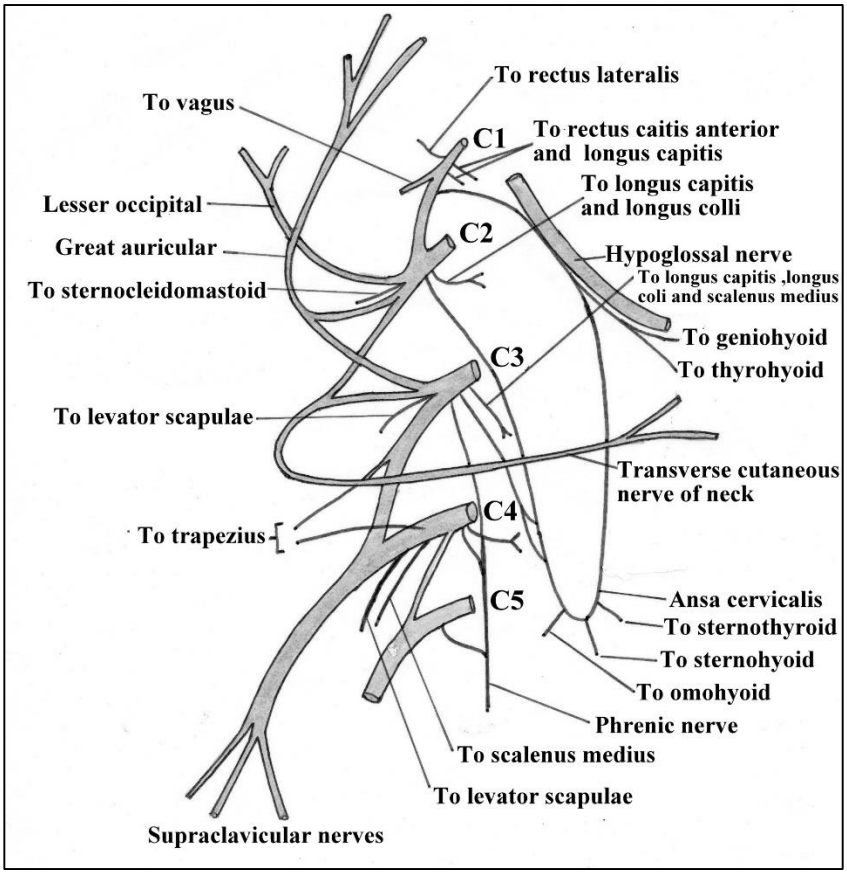


Fig. 29 Cervical plexus.

Table no. 13 Cervical plexus.

sr. no.	Name of nerve	Roots of the nerve	Structures supplied by nerve
Ascending superficial branches			
1	Lesser occipital n.	C2	Skin of scalp behind and superior to the ear.
2	Greater auricular n.	C2, C3	Skin anterior, inferior and over the ear. Skin over the parotid gland, mastoid process and extending behind.
3	Transverse cutaneous nerve of neck	C2, C3	Antero-lateral skin of neck.
Descending superficial branches			
1	Supraclavicular n.	C3, C4	Skin over superior part of chest and shoulder
Descending branches- medial series			
1	Ansa cervicalis- Inferior root	C2-C3	Sternohyoid, sternothyroid and omohyoid muscles.
2	Phrenic n.	C3-C5	Diaphragm
Descending branches- lateral series			
1	Muscular branches	C1-C4	Trapezius, sternocleidomastoid, levator scapulae and scalenus medius muscles.

Brachial plexus [59]

It is formed by C5-C8 ventral rami and T1 ventral ramus. It has roots, trunks, divisions, cords and branches.

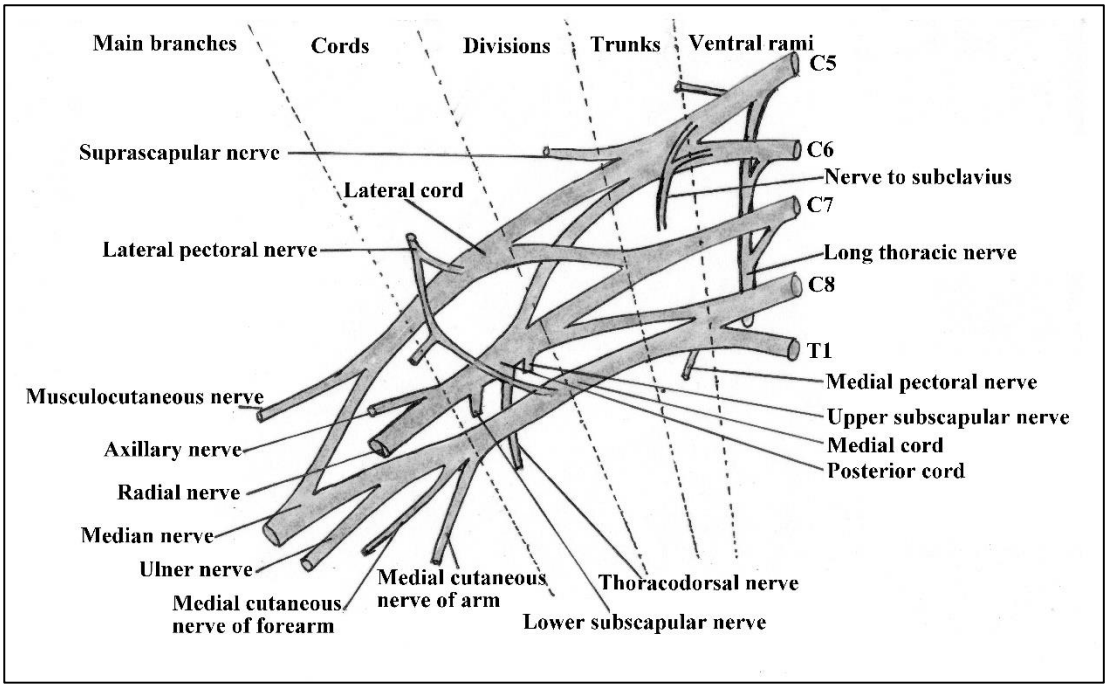


Fig. 30 Brachial plexus.

Roots- are formed by the ventral rami of C5,6,7,8 and T1

Trunks- 1) upper trunk- formed by roots of C5 and C6

2) Middle trunk- formed by root of C7

3) Lower trunk- formed by roots of C8 and T1

Divisions- each trunk divides into ventral and dorsal divisions which supply the anterior and posterior aspects of the limbs respectively.

Cords- 1) Lateral cord- It is formed by union of ventral divisions of upper and middle trunks.

2) Medial cord- It is formed by ventral division of lower trunk.

3) Posterior cord- It is formed by union of dorsal divisions of all three trunks.

Table no. 14 Brachial plexus

sr. no.	Name of nerve	Roots of the nerve	Arising from	Structures supplied by nerve
Supraclavicular branches				
1	Dorsal scapular n.	C5	Roots	Rhomboid major, rhomboid minor and levator scapulae muscles

2	Long thoracic n.	C5,6(7)	Roots	Serratus anterior muscle
3	Nerve to the subclavius	C5,6	Trunks	Subclavius muscle
4	Suprascapular n.	C5,6	Trunks	Supraspinatus and infraspinatus muscles, shoulder and acromioclavicular joint.
Infraclavicular branches				
1	Lateral pectoral n.	C5,6,7	Lateral cord	Pectoralis major and pectoralis minor.
2	Musculocutaneous n.	C5,6,7	Lateral cord	Coracobrachialis, brachialis and bi ceps brachii muscles
3	Superior subscapular n.	C5,6	Posterior cord	Subscapularis (upper part)
4	Thoracodorsal n.	C6,7,8	Posterior cord	Latissimus dorsi muscle
5	Inferior subscapular n.	C5,6	Posterior cord	Subscapularis (lower part) and teres major
6	Axillary n.	C5,6	posterior cord	Anterior branch- deltoid and a small area of overlying skin. posterior branch- teres minor, deltoid muscles and shoulder joint.
7	Median n.	C5,6,7 C8, T1	Lateral and medial cord	All of flexors in forearm (except flexor carpi ulnaris), thenar and intrinsic hand muscles, skin of lateral two thirds of palm of hand and fingers.
8	Radial n.	C5,6,7,8 , T1	Posterior cord	Triceps brachii, and other extensor muscles of the arm and forearm, skin of posterior arm and forearm, lateral two thirds of dorsum of hand and fingers over proximal and middle phalanges.
9	Medial pectoral n.	C8, T1	Medial cord	Pectoralis major and pectoralis minor muscles.

10	Medial cutaneous nerve of the arm	C8, T1	Medial cord	Skin of medial and posterior part of distal third of arm
11	Medial cutaneous nerve of the forearm	C8, T1	Medial cord	Skin of medial and posterior parts of forearm
12	Ulnar n.	C7,8, T1	Medial cord	Flexor carpi ulnaris, flexor digitorum profundus and hypothenar muscles 3rd and 4th lumbricals, interossei muscles of the hand. Skin of medial side of hand, little finger and medial half of ring finger. Elbow joint.

The description of the cranial nerves present in neck is summarized in the following table [60]

Table no. 15 Cranial nerves present in neck

Name of Nerve	Type	Components	Attachment to brain	Exit Foramen	Distribution	Function
IX. Glossopharyngeal	Mixed	Efferent 1) Branchial	Lateral surface of upper medulla oblongata	Jugular foramen	Stylopharyngeus muscle, superior and middle constrictor.	Pharyngeal movements and elevation of larynx.
		2) Parasympathetic preganglionic			Otic ganglion, lingual ganglia.	Secretomotor to parotid gland and glands in posterior $^{1}/_{3}^{rd}$ of tongue.
		Afferent			Mucous membrane of pharynx and tongue (post. $^{1}/_{3}^{rd}$) including vallate papillae and tonsillar region.	General sensibility and taste.
					Mucous membrane of auditory tube, tympanic cavity and antrum and mastoid air cells.	General sensibility.
					Carotid body and carotid sinus.	Vasosensory (chemoreceptors and pressure receptors).
X. Vagus (and cranial	Mixed	Efferent 1) Branchial	Lateral surface of medulla oblongata	Jugular foramen	Levator veli palatine muscle.	Lifts soft palate.
					Palatoglossus muscle	Lowers soft palate.

root of accessory)					Pharyngeal muscles	Swallowing and other pharyngeal movements
					Laryngeal muscles	Control of larynx in respiration and phonation
		2) Parasympathetic preganglionic			Muscles of oesophagus, stomach, intestine (up to transverse colon) and gall bladder.	Movements of these viscera.
					Pancreas and gastric glands.	Secretomotor
					Heart (nodal tissue and cardiac muscles)	Cardiac depressor
					Lungs (plain muscles and glands of bronchi and bronchioles)	Bronchoconstriction
		Afferent			Mucous membrane of alimentary and respiratory passages from epiglottis to transverse colon	General and visceral sensibility and some taste.
					Part of auricle and external acoustic meatus	General sensibility
					Lungs	Respiratory reflexes
					Carotid body and sinus, glomus aorticum and walls of aorta and great veins.	Vasosensory
XI. Accessory (spinal root)	Mixed (mainly motor)	Efferent branchial	Cervical part of spinal cord laterally, from its beginning up to sixth segment.	Ascends through foramen magnum and exits through jugular foramen.	Trapezius and sternocleidomastoid muscles.	Movements of head and shoulder.
XII. Hypoglossal	Mixed (mainly motor)	Efferent somatic	Ventral part of medulla oblongata between pyramid and olive.	Hypoglossal canal	Extrinsic and intrinsic muscles of tongue, except palatoglossus	Movements of tongue

Muscles of neck

Table no.16 Superficial muscles of neck [61]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Platysma	Fascia covering the upper parts of pectoralis major and deltoid.	Postero-inferior to symphysis menti, lower border of mandibular body, skin and subcutaneous tissue of lower face.	Depresses mandible, draws lower lip down.	Cervical branch of facial nerve.

Anterior muscles of the neck

Table no.17 Muscles in the anterior triangle of the neck [62]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Stylohyoid	Posterior side of the styloid process	Body of hyoid bone, laterally.	Elevates and retracts the hyoid bone	Facial nerve
2	Digastric	**Anterior belly**- digastric fossa of mandible. **Posterior belly** mastoid notch of the temporal bone.	Body and greater cornu of hyoid bone.	Elevates the hyoid bone, depresses the mandible.	Anterior belly- inferior alveolar nerve. Posterior belly- facial nerve.
3	Mylohyoid	Mylohyoid line of mandible.	Median fibrous raphe and nearby part	Elevates floor of oral cavity.	Inferior alveolar branch of mandibular nerve

			of hyoid bone.		
4	Geniohyoid	Inferior mental spine of mandible.	Body of hyoid bone	Elevates hyoid bone, depresses mandible.	Ventral ramus of C1 through hypoglossal nerve.
5	Sternohyoid	Posterior surfaces of manubrium and sternal end of the clavicle posteriorly.	Body of hyoid bone inferiorly	Depresses the hyoid bone.	Ansa cervicalis
6	Omohyoid	**Inferior belly**- upper border of the scapula. **Superior belly (**it is present in the posterior triangle**)-** intermediate tendon.	**Inferior belly**- intermediate tendon **Superior belly**-lower border of the hyoid bone	Depresses and stabilizes the hyoid bone.	
7	Sternothyroid	Posterior surface of the manubrium.	Oblique line of the thyroid cartilage.	Draws larynx downwards	
8	Thyrohyoid	Oblique line of the thyroid cartilage.	Body and greater cornu of the hyoid bone.	Elevates the larynx, depresses the hyoid bone.	Ventral ramus of C1 through hypoglossal nerve

Table no.18 Muscles in the posterior triangle of the neck [63]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Sternoclei- domastoid	Sternal head-anterior surface of manubrium clavicular head-medial one third of the clavicle.	Mastoid process and lateral half of the superior nuchal line.	Acting together, flex the neck acting individually, tilts head to shoulder.	Spinal accessory nerve, ventral rami of C2 and C3.
2	Trapezius	Superior nuchal line, external occipital protuberance, ligamentum nuchae, spines of C7 to T12	Posterior border of lateral one third of clavicle, acromion, spine of scapula.	Bends head and neck backward. Elevation, retraction, depression, rotation and steadying of scapula.	Spinal accessory nerve, proprioception rami of C3 and C4.
3	Splenius capitis	Ligamentum nuchae, spines of C7 to T4	Mastoid process, skull below lateral part of superior nuchal line.	Together draw head posteriorly individually rotate head to one side.	Dorsal rami of middle cervical nerves.
4	Levator scapulae	Transverse process of C1 to C4 and the posterior tubercles of the transverse process of C3 and C4.	Medial border of scapula; superiorly.	Elevates scapula	C3, C4 and dorsal scapular nerve (C4,C5)
5	Scalenus anterior	Anterior tubercles of the transverse processes of vertebrae C3-C6.	Scalene tubercle of the first rib.	Elevates the first rib, bends cervical spine anteriorly	Ventral rami of C4 to C6

				and laterally.	
6	Scalenus medius	Transverse processes of vertebrae C2-C7.	Upper surface of the first rib behind subclavian groove.	Elevates the first rib, bends cervical spine to the same side.	Ventral rami of C3 to C8
7	Scalenus posterior	Posterior tubercles of the transverse processes of vertebrae C4-C6.	Lateral surface of the second rib.	Elevates the second rib, bends cervical spine to the same side.	Ventral rami of C5 to C7

Table no.19 Prevertebral and lateral muscles [64]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Rectus capitis anterior	Lateral mass of atlas	Basilar part of occipital bone	Flexes the head	Ventral rami of spinal nerve C1, C2
2	Rectus capitis lateralis	Transverse process of atlas.	Jugular process of occipital bone.	Lateral flexion of the head.	Ventral rami of spinal nerve C1, C2
3	Longus colli 1) superior oblique part	Anterior tubercles of transverse process of vertebrae C3- C5.	Tubercle on anterior arch of atlas.	Anterior and lateral	Ventral rami of
	2) Inferior oblique part	Anterior surface of vertebral	Anterior tubercles of transverse		

		bodies of T1 to T3.	process of vertebrae C5-6	flexion of neck with its lateral rotation.	spinal nerve C2 to C6
	3) Vertical part	Anterior surface of vertebral bodies of T1 to T3 and C5 to C7.	Anterior surface of vertebral bodies of C2 to C4.		
4	Longus capitis	Transverse process of vertebrae C3-6.	Basilar part of occipital bone.	Flexion of head	Ventral rami of spinal nerves C1-3

Table no.20 Constrictor muscles of the pharynx [65]

No.	Name of muscle	Anterior attachment	Posterior attachment	action	Nerve supply
1	Superior constrictor	Pterygoid hamulus, pterygomandibular raphe and adjacent part of mandible.	Pharyngeal tubercle on basilar part of occipital bone and median pharyngeal raphe.	Constricts the pharynx	Nerve from pharyngeal plexus formed mainly by vagus nerve
2	Middle constrictor	Lesser and greater cornu of the hyoid bone and stylohyoid ligament.	Midline pharyngeal raphe.	Produces sphincteric and peristaltic action in swallowing.	
3	Inferior constrictor	Oblique line of the thyroid cartilage, lateral surface of cricoid cartilage.	Midline pharyngeal raphe	Constricts the pharynx	

Table no.21 Longitudinal muscles of the pharynx [66]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Stylophar-yngeus	Medial side of the bae of styloid process.	Pharyngeal wall	Elevates pharynx for swallowing and speech.	Branch of Glossoph aryngeal nerve.
2	Salpingoph-aryngeus	Inferior part of pharyngeal end of pharyngotympanic tube cartilage.	Pharyngeal wall	Elevates the pharynx	Pharynge al plexus
3	Palatopha-ryngeus	Upper surface of palatine aponeurosis.	Pharyngeal wall	Elevates the pharynx	Pharynge al plexus

Posterior muscles of the neck

Table no.21 Superficial muscles of back [67]- (See trapezius and levator scapulae in Table no. 18 - Muscles in the posterior triangle of the neck)

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Latissimus dorsi	Spines of T6 to L5 vertebrae, posterior layer of thoracolumbar fascia which is attached to spines of lumbar and sacral spines,	Floor of the intertubercular sulcus of humerus.	Extends, adducts and medially rotates the arm.	Thoracodorsal nerve of brachial plexus.

		posterior third of iliac crest, lower 3 ribs.			
2	Rhomboideus major	Spines of T2-T5 vertebrae.	Medial border of the scapula below the spine.	Retract and elevate scapula together with levator scapulae.	Dorsal scapular nerve
3	Rhomboideus minor	Inferior end of the ligamentum nuchae, spines of C7 and T1 vertebrae.	Medial border of the scapula at the root of the spine of scapula.		

Table no.22 Deep Muscles of back [68]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Splenius capitis	See in Table no.18 Muscles in the posterior triangle of the neck.			
2	Splenius cervicis	Spines of T3-T6 vertebrae.	Transverse processes of C1-C3 vertebrae.	Extends neck and head, rotates head to the same side.	Dorsal rami of lower cervical nerves.

Erector spinae muscles [69]

Erector spinae- It arises by a broad and thick tendon attached to the median and lateral sacral crests, spines of T1 to L5, posterior third of iliac crest. After origin, the muscle divides into three columns-

Laterally- Iliocostocervicalis.

Intermediate- Longissimus.

Medial- Spinalis.

Each of these is further divided into three parts mentioned in the table below.

Table no.23 Erector spinae muscles

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Iliocostalis lumborum	Median and lateral sacral crests, spines of T1 to L5, posterior third of iliac crest.	Angles of the lower six or seven ribs inferiorly.	Extends and laterally bends the head neck and trunk.	Dorsal rami of lower cervical, thoracic and upper lumbar spinal nerves.
2	Iliocostalis thoracis	Angles of the lower six ribs superiorly.	Angles of the upper six ribs superiorly and the transverse process of C7 vertebra posteriorly.		
3	Iliocostalis cervicis	Angles of the 3rd to 6th ribs	Transverse process of C4 to C7		
4	Longissimus thoracis	Transverse process of lumber vertebrae.	Transverse process of all thoracic vertebrae and lateral to the tubercles of lower nine ribs.		Dorsal rami of lower cervical, thoracic and lumbar spinal nerves
5	Longissimus cervicis	Transverse processes of T1 to T5 vertebrae	Transverse process of C-2 to C-6 vertebrae		
6	Longissimus capitis	Transverse processes of T1 to T5 vertebrae and articular processes of	Posterior margin of mastoid process.		

		lower four cervical vertebrae.			
7	Spinalis thoracis	Spinous processes of T-10 to L-2	Spinous processes of T-1 to T-8		Dorsal rami of lower cervical and thoracic spinal nerves
8	Spinalis cervicis	Lower part of ligamentum nuchae and spinous processes of C7.	Spinous process of axis vertebra.		
9	Spinalis capitis	Combines with semispinalis capitis.	With semispinalis capitis		

Table no.24 Muscles of back, deep to the erector spinae [70]

Sr. No	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Semispinalis thoracis	Transverse processes of T6 toT10.	Spinous processes of C6 to T4.		Dorsal primary rami of spinal nerves C1-T12
2	Semispinalis cervicis	Transverse processes of T1 toT5.	Spinous processes of C2 to C5.		
3	Semispinalis capitis	Transverse processes of C7 toT6 and articular processes of C4 to C-6.	Medial region between the superior and inferior nuchal lines of occipital bone.		
4	Multifidus	Dorsal surface of sacrum, aponeurosis of Erector spinae, posterior superior	Base of spinous processes of		

		iliac spine and dorsal sacro-iliac ligaments, mamillary processes of lumbar vertebrae, transverse processes of thoracic vertebrae and articular processes of lower four cervical vertebrae.	L5 to C2 vertebrae.	Extend and laterally bend trunk and neck and rotate them to opposite side.	Dorsal primary rami of spinal nerves
5	Rotatores thoracis	Postero-superior part of transverse processes of one thoracic vertebra.	Lower border and lateral surface of lamina of vertebra immediately above.		
6	Rotatores cervicis	Attachments similar to rotatores thoracis.			
7	Rotatores lumborum				
8	Interspinales	Attached above and below to the apices of spines of adjoining vertebrae.		Extend trunk and neck.	Dorsal rami of spinal nerves
9	Intertransversarii	Attached between the transverse processes of adjoining vertebrae.		Laterally bend trunk and neck.	Dorsal primary rami of spinal nerves

Table no.25 Muscles of back- suboccipital group [71]

Sr. No.	Name of muscle	Origin	Insertion	Action	Nerve supply
1	Rectus capitis posterior major	Spinous process of axis	Below inferior nuchal line	Extends the head, rotate to same side	Dorsal ramus of C1
2	Rectus capitis posterior minor	Posterior tubercle of atlas.	Below inferior nuchal line medially.	Extends the head	
3	Obliquus capitis superior	Transverse process of atlas.	Occipital bone above inferior nuchal line.	Extends the head, bends the head to same side	
4	Obliquus capitis inferior	Spinous process of the axis.	Transverse process of atlas.	Rotates the head to the same side	

Anatomical significance of neck muscles [72]

1) The muscles of the neck are generally divided into three groups- a) muscles involved in the movements of head and neck b) muscles involved in the movement and suspension of arms and c) muscles involved in the movement and suspension of thoracic cage. When a load is applied to the arms say, while lifting a weight to be placed on the head the weight of the load is transferred to the cervical spine through the muscles of the arms. Raising something by the hands mean raising it by the cervical spine. This explains why cervical spine degenerates early in workers doing heavy manual work.

2) Straightening of cervical spine and loss of cervical lordosis may be due to paraspinal muscle spasm in the neck.

3) To hold the head in proper position it is essential to have a delicate balance of contraction and relaxation among neck muscles. The free nerve endings in the cervical spinal musculature are disproportionately large and their discharges control not only the head position but also control the posture of the whole body. The small suboccipital muscles play a vital role in this function and the concentration of spindle density in these muscles is much higher than the density in the lumbrical muscles of the hand.

Major arteries in the neck [73]

The major arteries of neck begin in its root. These are-

1) Right and left subclavian

2) Right and left common carotid

The right subclavian and right common carotid arteries are the branches of the brachiocephalic trunk. The left subclavian and left common carotid originate directly from the arch of aorta.

Subclavian arteries

Each subclavian artery is divided into-

1) First part- from its origin to the medial border of the scalenus anterior

2) Second part- behind scalenus anterior

3) Third part- from the muscle's lateral margin to the first rib's outer border. Here it continues as axillary artery.

Each subclavian artery arches over the cervical pleura and pulmonary apex

Branches of subclavian artery

Branches of first part-

1) **Vertebral artery**- It arises from the supero-posterior part of the subclavian, passes through the foramina of all cervical transverse processes except the seventh, turns medially behind the lateral mass of the atlas and then enters the cranium via the foramen magnum. Near the lower border of the pons it joins its fellow to form the basilar artery.

Clinical significance [74]

1) Presence of osteophytes on the joint of *Luschka* can reduce the vertebral canal width. Being in the foramen at this level the vessel cannot slide laterally resulting in stricture in the vessel.

2) In elderly with established spondylotic changes the cervical spine is shortened and the vertebral artery is forced to persue a tortuous course and it can then cave into the vertebral body and needs care during anterior cervical fusion surgery or corpectomy surgery.

3) Usually the artery runs on the ventral side of the nerve root and it can be compressed much earlier by the osteophyte than the nerve root.

2) **Internal thoracic (mammary) artery**- It arises inferiorly about 2 cm above the sternal end of the clavicle, opposite the root of the thyrocervical trunk and descends behind the first six costal cartilages.

3) **Thyrocervical trunk**- This is a short and broad artery. It has following branches-

a) **Inferior thyroid artery**- It has following branches-

Muscular branches- These supply the infrahyoid, longus colli, scalenus anterior and inferior pharyngeal constrictor muscles.

Ascending cervical artery- It supplies the adjacent muscles and has one or two spinal branches which entre the vertebral canal through the intervertebral foramina to supply the spinal cord and membranes and vertebral bodies similar to the spinal branches of the vertebral artery. The Ascending cervical artery anastomoses with the vertebral, ascending pharyngeal, occipital and deep cervical arises.

Inferior laryngeal artery- It supplies the laryngeal muscles and mucosa.

Pharyngeal branches- It supplies the lower pharynx, trachea, oesophagus, thyroid and para thyroid glands.

b) **Superficial cervical artery**- It supplies to the trapezius, adjoining muscles and cervical lymph nodes.

c) **Suprascapular artery-** It supplies to the supraspinatus, sternocleidomastoid, subclavius, infraspinatus, acromioclavicular and glenohumeral joints, clavicle and scapula.

Branches of second part

4) **Costocervical trunk-** It has following two branches-

a) **Superior intercostal artery** b) **Deep cervical artery**- it supplies to posterior neck muscles and the posterior arches of the cervical vertebrae.

Branches of third part

5) **Dorsal scapular artery**- It supplies the rhomboids, latissimus dorsi and trapezius.

Carotid arteries

Common carotid artery- It is a large artery in the neck. At the level of the upper border of thyroid cartilage. Here it divides into internal and external carotid arteries.

Internal carotid artery- from carotid bifurcation it ascends to the cranial base, enters the cranial cavity through the carotid canal and supplies most of the cerebral hemisphere, eye and accessory organs, forehead and nose.

External carotid artery- It has following branches

1) Superior thyroid- it supplies the adjacent muscles and the thyroid gland. Its further branches are- Infrahyoid artery, sternocleidomastoid artery, superior laryngeal artery and cricothyroid artery.

2) Ascending pharyngeal artery- Its branches are pharyngeal, inferior tympanic and meningeal. Its smaller branches supply to longus capiti and longus colli, the

sympathetic trunk, hypoglossal, glossopharyngeal and vagus nerves and cervical lymph nodes.

3) Lingual artery- It is the main artery to supply to the tongue and buccal floor of the mouth

4) Facial artery- It supplies the muscles and tissues of the face, submandibular gland, tonsil and soft palate.

5) Occipital artery- It has following branches-

a) sternocleidomastoid branches b) mastoid artery-supplies to the mastoid air cells and dura mater c) stylomastoid artery d) auricular branch e) muscular branches-these supply the digastric, stylohyoid, splenius, longissimus capitis etc. f) descending branch g) meningeal branches- these supply the dura mater and bone of the posterior cranial fossa and the caudal four cranial nerves h) occipital branches.

6) Posterior auricular artery- Its branches are- a) stylomastoid artery b) auricular branch c) occipital branch.

7) Superficial temporal artery- Its branches are- a) transverse facial artery- it supplies to parotid gland and duct, masseter and skin b) anterior auricular branches c) zygomatico- orbital artery d) middle temporal artery e) frontal branch f) parietal posterior branch

8) Maxillary artery- it supplies to mandible, maxilla, teeth, muscles of mastication, palate, nose and cranial dura mater

Major veins in the anterior part of the neck [75]

External jugular vein- This drains the scalp, face and deeper parts. It is formed by posterior division of the retromandibular and posterior auricular veins along with few tributaries- posterior external jugular, transverse cervical, suprascapular and anterior jugular veins.

Internal jugular vein- It is a large vein collecting the blood from skull, brain, superficial parts of face and much of the neck. Its tributaries are inferior petrosal sinus, facial, lingual, pharyngeal, superior and middle thyroid veins. It joins with subclavian vein to form brachiocephalic vein.

Brachiocephalic veins- these are two large veins at the junction of the neck and thorax formed by the junction of internal jugular and subclavian veins

Lymphatic drainage of head and neck

Lymph nodes in the head and neck include a terminal (collecting) group and intermediary, outlying groups. The terminal group is related to the carotid sheath and

is named deep cervical. All lymph vessels of the head and neck drain into this, directly from tissues or indirectly through nodes in outlying groups. Efferents of the deep cervical nodes form the jugular trunk, which on the right may end in the jugulosubclavian junction or right lymphatic duct, on the left it usually enters the thoracic duct but may join the internal jugular or subclavian vein. In lymphatic drainage the tissues of the head and neck, like other regions can conveniently be considered as superficial and deep.[76]

Viscera in the anterior part of the neck

The pharynx and the oesophagus are present anteriorly in the midline while the larynx and trachea lie anterior to the oesophagus. The thyroid gland lies in contact with the anterolateral aspect of the inferior larynx and the superior trachea. It has two lobes, right and left united in the midline by the isthmus. The small parathyroid glands, four in number two on each side are located on the posterior aspect of the thyroid gland.

Embryological development of the vertebral column and related structures

Formation of germ layers [77]

1) After fertilization of the ovum by a spermatozoon a multicellular blastocyst is formed. It develops a three-layered embryonic disc. These germ layers are- endoderm, ectoderm and mesoderm. All tissues of the body are developed from these layers. It develops along with the development of the fetal membranes- chorion and amnion.

2) At one end of the margin of the embryonic disc the cubical cells of the endoderm become columnar. This circular area is called *prochordal plate*. It determines the head end.

3) the ectodermal cells of the tail end of the disc form an elevated *primitive streak*.

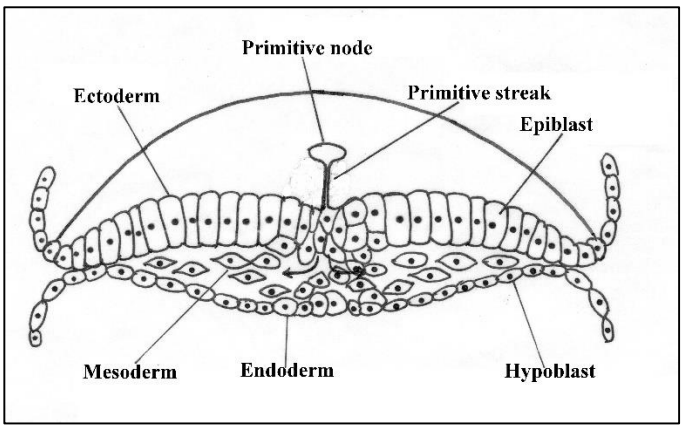


Fig. 31 TS through embryonic plate: movement of mesoblast in gastrulation.

4) The cells proliferating at primitive streak spread between ectoderm and endoderm forming *intra-embryonic mesoderm* (secondary mesoderm). This process is called gastrulation.

5) As the primitive streak and the disc elongate the connecting stalk remains small and attached to the tail end of the disc. Some intra-embryonic mesoderm behind the primitive streak passes into the connecting stalk, connecting endoderm to ectoderm. This part is called *cloacal membrane*.

Development of notochord [78]

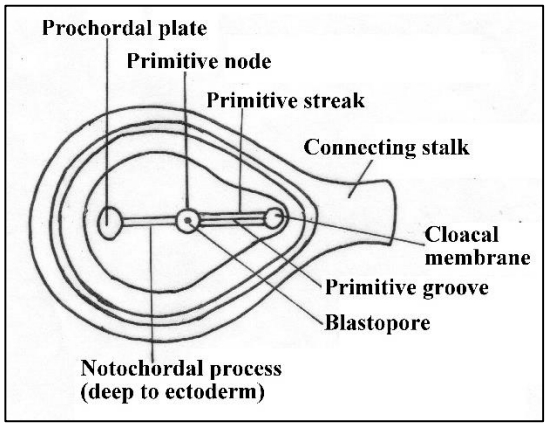


Fig. 32 Dorsal surface of embryonic area.

The notochord is developed between prochordal plate and primitive streak.

1) The *primitive node* with a pit called the *blastopore* is developed on primitive streak.

2) Cells from primitive node extend towards prochordal plate between the ectoderm and endoderm to form *notochordal process* which transform into *notochord*.

Development of neural tube [79]

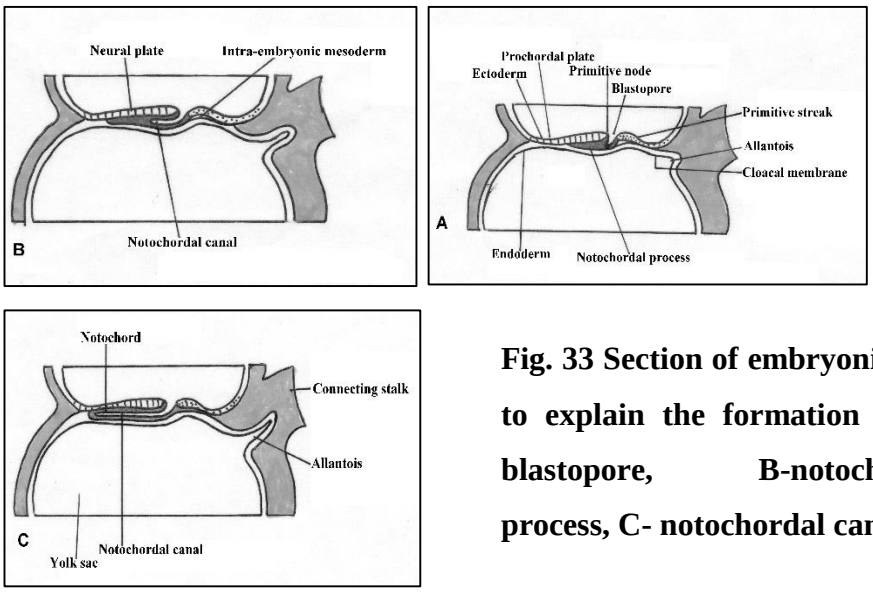


Fig. 33 Section of embryonic disc to explain the formation of A-blastopore, B-notochordal process, C- notochordal canal.

The neural tube develops into the brain and the spinal cord.

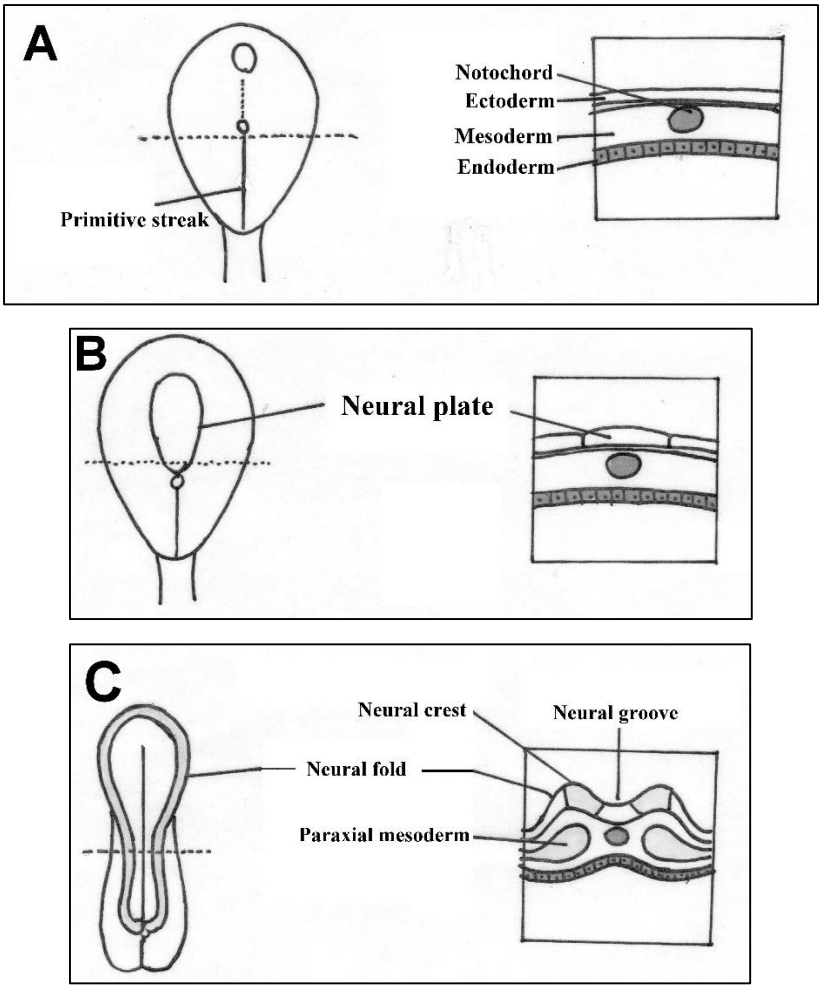
1) The neural tube is formed from the ectoderm over the notochordal process. (Fig.19.10) It extends from the prochordal plate to the primitive node. It becomes thick to form *neural plate*. The depression in its mid line is called neural groove. It becomes deeper and the two edges of the

neural plate approach each other and fuse, forming *neural tube*. It has enlarged cranial part and caudal tubular part. The cranial part forms the brain while caudal part forms the spinal cord.

2) The cavity of the developing brain develops three dilatations, cranio-caudally, these are *prosencephalon, mesencephalon* and *rhombencephalon*. The prosencephalon subdivides into *telencephalon* and *diencephalon*. The rhombencephalon also subdivides into a cranial part, *metencephalon* and a caudal part *myelencephalon*.

3) The spinal cord is developed from the caudal cylindrical part of the neural tube

Development of intra-embryonic mesoderm [80]



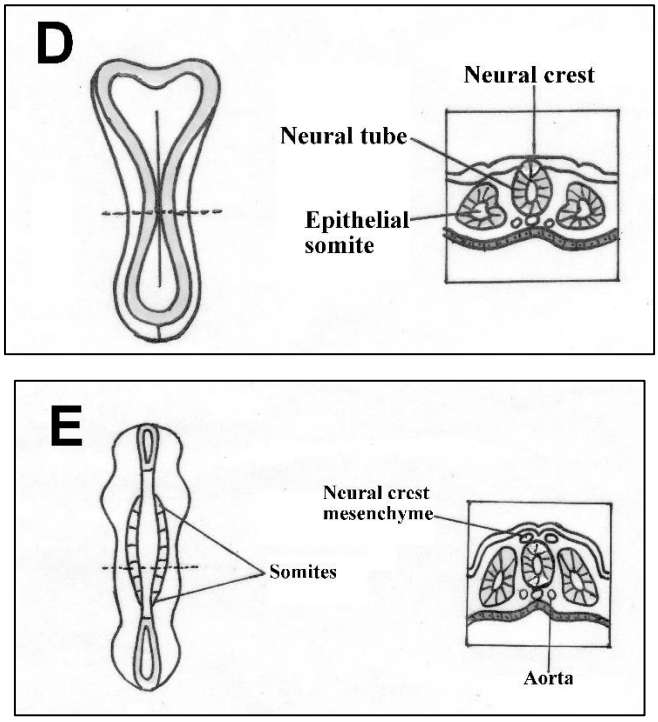


Fig. 34 Development of intra-embryonic mesoderm.

1) Cranial to the prochordal plate the mesoderm of the two sides meet in the midline. The intra-embryonic mesoderm is continuous with the extra-embryonic mesoderm at the edges of the embryonic disc.

2) Subdivisions of intra-embryonic mesoderm- i) paraxial mesoderm- it is on either sides of *notochord* ii) lateral plate mesoderm- it is more lateral iii) intermediate mesoderm- between these two.

3) Paraxial mesoderm- i) its cranial part is called somitomeres (7 in numbers) which develop bones and muscles of the head and jaw regions. ii) its caudal part is called somites (44 pairs) which develop muscles of the tongue, axial skeleton, skeletal muscles and skin.

Development of intra-embryonic coelom [81]

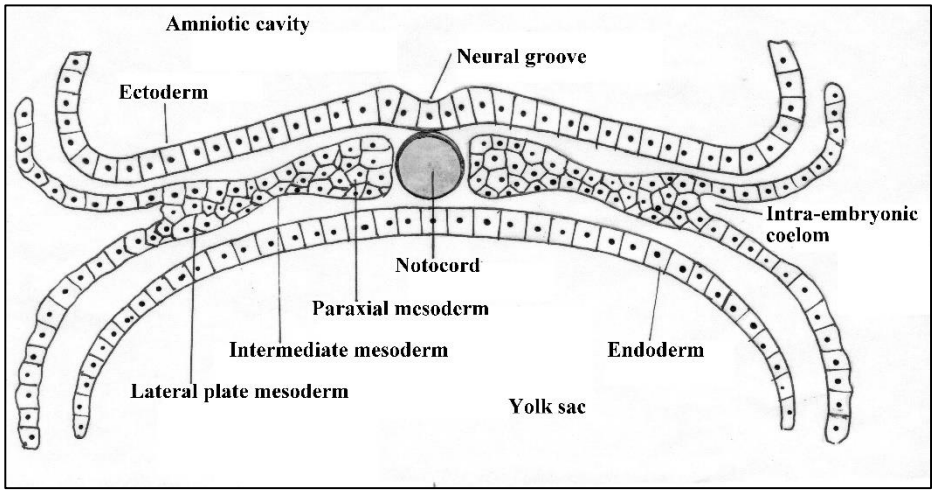


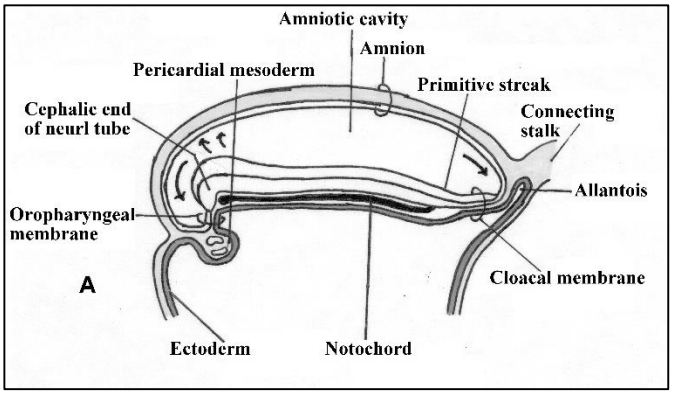
Fig. 35 Development of intra-embryonic coelom.

1) The large cavity formed in the lateral plate mesoderm is called the *intra-embryonic coelom* (it develops pericardial, pleural and peritoneal cavities). These bilateral cavities join together cranial to the prochordal plate.

2) The intra-embryonic coelom communicates with the extra-embryonic coelom.

3) Now the lateral plate mesoderm has two layers- i) somatopleuric or parietal intra-embryonic mesoderm, connected with ectoderm ii) splanchnopleuric or visceral intra-embryonic mesoderm, connected with endoderm

Development of embryonic disc and yolk sac [82]



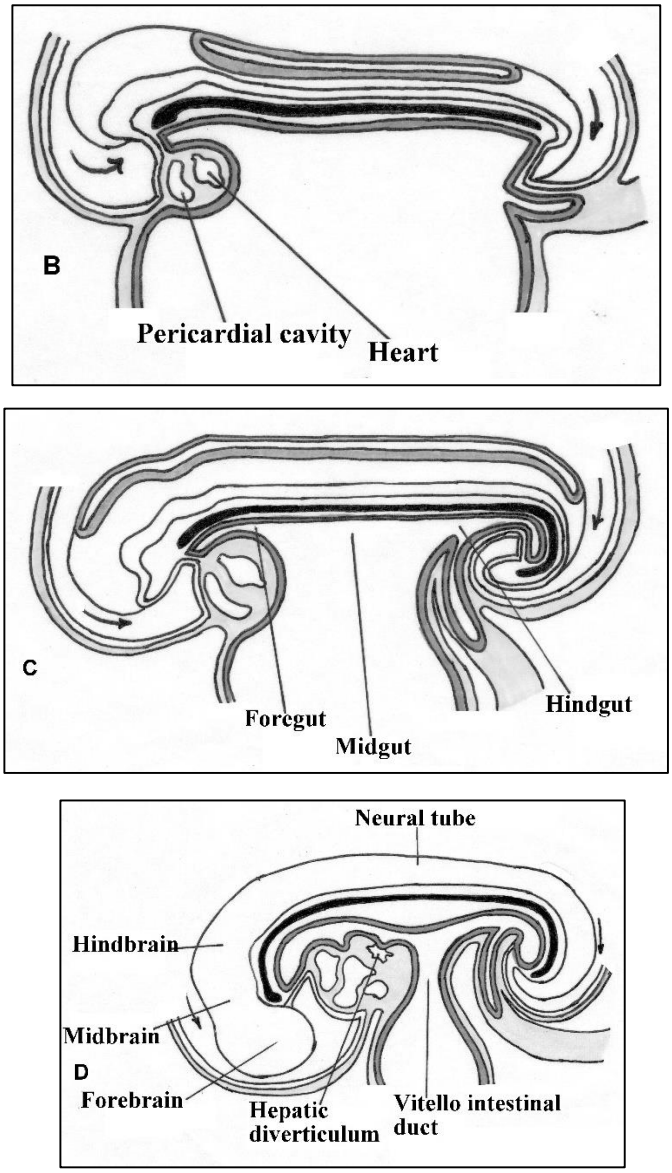


Fig.36 Stages of development of embryonic disc and yolk sac.

1) The embryonic disc increases. It bulges upwards in the amniotic cavity.

2) The head and tail ends of the disc get folded called the head and tail folds.

3) Parts of the yolk sac become enclosed within the embryo. Thus, a tube lined with endoderm is formed inside, called **primitive gut** (which develops into major part of GI tract)

4) From cranial to caudal ends, the parts of the primitive gut are divided into foregut, midgut and hindgut.

5) The yolk sac becomes narrow and called the definitive yolk sac. The narrow cavity connecting it to the gut is called the **vitello-intestinal duct**. The circular aperture around it is called umbilical opening.

6) The lateral folds are formed.

7) The amniotic cavity; containing fluid, expands and surround the embryo which floats in it.

Development of connecting stalk [83]

1) Gradually connecting stalk becomes smaller and its attachment near the caudal end of the embryonic disc; moves to the ventral aspect of the embryo in the region of the umbilical opening. The blood vessels pass through the connecting stalk.

2) The amnion surrounds the umbilical opening and a tube is formed with its contents called the *umbilical cord*.

Development of head and tail folds [84]

1) In the embryonic disc before folding, the structures from cranial to caudal ends are septum transversum, pericardial cavity and heart tube, prochordal plate, neural plate, primitive streak and cloacal membrane.

2) The head fold causes the pericardial cavity and heart tube to come ventral to the foregut.

3) The septum transversum comes behind the heart tube

4) The part of prochordal plate forms *oropharyngeal membrane*; closing the foregut.

5) Primitive streak disappears.

6) Distal end of the hindgut is closed by the cloacal membrane which comes ventrally. Thus, the fundamental growth of nervous system, cardiovascular system and the gut has been occurred. Further growth of the embryo develops various organs.

The vertebral column is developed from the sclerotomes of the somites. The cells of each sclerotome get converted into loose mesenchyme. This mesenchyme migrates medially and surrounds the notochord.

The mesenchyme then extends backward on either side of the neural tube and surrounds it.

Extensions of this mesenchyme also take place laterally in the position to be afterward occupied by the transverse processes, and ventrally in the body wall, in the position to be occupied by the ribs.

The mesenchyme derived from each somite can be seen as a distinct segment. The mesenchymal cells of each segment are at first uniformly distributed. But the cells soon become condensed in a region that runs transversely across the middle of the

segment. The condensed region is called the perichordal disc. Above and below it there are less condensed and more condensed parts.

The mesenchymal basis of the body (centrum) of each vertebra is formed by fusion of the more condensed part of one sclerotomic segment with the less condensed part of adjoining segment.

The perichordal disc becomes the intervertebral disc.

The neural arches and their processes are continuous with the less dense part of the sclerotomic segment. The neural arch, the transverse processes and the costal elements are formed similarly like the body.

The interspinous and intertransverse ligaments are formed similarly like the intervertebral disc.

The notochord disappears in the region of the vertebral bodies. In the region of the intervertebral disc the notochord expands to form nucleus pulposus.

1) The vertebra is an intersegmental structure made up from portions of two somites.
2) The intervertebral disc is formed at the centre of the somite.
3) The transverse processes and ribs are also intersegmental structures. They separate the muscles derived from two adjoining myotomes.
4) Spinal nerves are segmental structures; therefore, they emerge from between the two adjacent vertebrae and lie between two adjacent ribs.
5) The blood vessels supplying these structures derived from the myotome are Intersegmental like the vertebrae.

Development of spinal cord [85]

The spinal cord develops from caudal cylindrical part of the neural tube. When this part of the neural tube is formed its cavity is in the form of a dorsoventral cleft. The wall of the tube is subdivided into the ependymal or matrix cell layer, the mantle layer and the marginal layer. The mantle zone grows faster in the ventral part of the neural tube and becomes thicker than the dorsal part as a result the ventral part of the lumen of the neural tube becomes compressed. The line separating the compressed ventral part from the dorsal part is called the sulcus limitans. With its formation, the lateral wall of the developing spinal cord is divided into a dorsal or alar lamina and a ventral or basal lamina.

The cells of basal lamina are motor/ efferent in function and that of alar lamina are sensory/ afferent. With continued growth in thickness of the mantle layer, the spinal cord gradually acquires its definitive form. With growth of the alar lamina, the dorsal part of the cavity within the cord becomes obliterated and the posterior median septum is formed in this situation. The ventral part of the cavity remains as the central canal. Further enlargement of the basal lamina causes it to project forward on either side of the midline, leaving a furrow, the anterior median fissure, between the projecting basal laminae of the two sides.

Development of the spinal nerves [86]

The nerve cells that develop in the mantle zone of the basal lamina become the neurons of the anterior gray column. The axons of these cells grow out of the ventrolateral angle of the spinal cord to form the anterior/ ventral motor nerve roots of the spinal nerves. The nerve cells that develop in the mantle layer of the alar lamina form the neurons of the posterior gray column. These are secondary neurons of the second order. Their axons travel predominantly upwards I the marginal layer to form the ascending tracts of the spinal cord. Axons of cells developing in various parts of the brain grow downwards to enter the marginal layer of the spinal cord and form its descending tracts. These ascending and descending tracts form the white matter of the spinal cord. As the mantle layer takes on the shape of the anterior and posterior gray columns, the white matter becomes subdivided into anterior, lateral and posterior white columns.

The posterior/ dorsal/ sensory nerve roots are formed by the axons of cells that develop from the neural crest groups of these cells collect on the dorsolateral aspect of the developing spinal cord to form the dorsal nerve root ganglia. The axons of these cells divide into two processes. The central processes migrate towards the spinal cord and establish contact with the dorsolateral aspect of the latter and form the dorsal nerve roots. These axons synapse with neurons of the posterior gray column developing un the alar lamina. The peripheral processes of the cells of the dorsal nerve root ganglia grow outwards to form the sensory components of spinal nerves.

Development of muscles of spine and back [87]

Majority of skeletal muscles develop from somites (). Each myotome () establishes contact with one segmental nerve. Soon after the formation, each myotome, in the neck and trunk, separates into a small dorsal part (epimere) which gives rise to the muscles supplied by the dorsal primary ramus of the spinal nerve and a large ventral

part (hypomere), which gives origin to the muscles supplied by the ventral ramus of spinal nerve. The epimers give origin to the muscles of the back (extensors of the vertebral column). While the hypomeres give origin to the flexor muscles of the body wall and limbs

Development of joints [88]

The tissues of joints are derived from mesenchyme intervening between developing bone ends. This mesenchyme may differentiate into fibrous tissue, forming a fibrous joint (syndesmosis), into cartilage forming a cartilaginous joint. in the case of some cartilaginous joints; synchondrosis or primary cartilaginous joints, the cartilage connecting the bones is later ossified and the two bones become continuous. This is seen at the joints between the diaphysis and epiphyses of long bones.

For a synovial joint the mesenchyme is usually seen in three layers. The two outer layers are continuous with the perichondrium covering the cartilaginous ends of the articulating bones. The middle layer becomes loose and a cavity is formed in it. The cavity comes to be lined by a mesothelium that forms the synovial membrane. The capsule and other ligaments are derived from the surrounding mesenchyme.

Development of vertebral column [89]

The vertebral column is formed from the sclerotomes of the somites the of cells of each sclerotome get converted in to loose mesenchyme. This mesenchyme migrates medially and surrounds the notochord. the mesenchyme then extends backwards on either side of the neural tube and surrounds it. Extensions of this mesenchyme also take place laterally in the position to be subsequently occupied by the transverse processes, and ventrally in the body wall, in the position to be occupied by the ribs.

For some time, the mesenchyme derived from each somite can be seen as a distinct segment. The mesenchymal cells of each segment are at first uniformly distributed. However, the cells soon become condensed in a region that runs transversely across the middle of the segment. This condensed region is called the perichordal disc. Above and below it there are less condensed parts. the mesenchymal basis of the body or centrum of each vertebra is formed by fusion of the adjoining less condensed parts of the two segments. the perichordal disc becomes the intervertebral disc. The neural arch, the transverse processes and the costal elements are formed in the same way as the body. The interspinous and intertransverse ligaments are formed in the same manner as the intervertebral disc. The

notochord disappears in the region of the vertebral bodies. In the region of the intervertebral discs, the notochord becomes expanded and forms the nucleus pulposus.

From the above interpretation we may note that- 1) vertebra is an intersegmental structure made up from positions of two somites. The position of the centre of the somite is represented by the intervertebral disc. 2) the transverse processes and ribs are also intersegmental. they separate the muscles derived from two adjoining myotomes. 3) spinal nerves are segmental structures. They therefore, emerge from between two adjacent vertebrae and lie between two adjacent ribs. 4) the blood vessel supplying structures derived from the myotome e.g. Intersegmental like the vertebrae. Therefore, the intercostal and lumbar arteries lie opposite the vertebral bodies.

Microscopic anatomy [90]

The disorders of the spine are related with the zygapophyseal joints, intervertebral discs ligaments etc. Most tissues forming these joints is connective tissue. Pain arising from these structures is a significant cause of back pain. Therefore, the study of their microscopic anatomy is very much essential.

Zygapophyseal joint

This is a synovial type of joint between the articular processes of two adjacent vertebrae. The articular surfaces are covered with hyaline cartilage. The joint cavity is enveloped posteriorly by fibrous capsule of dense connective tissue. Anteriorly the ligamentum flavum takes the place of the capsule. The capsule is internally lined by the highly vascularized synovial membrane. Its cells secrete the synovial fluid.

Articular cartilage- 1) It protects the articular surfaces of the articular processes by acting as a shock absorber. 2) It allows the articular surfaces to move across one another with minimum friction.

It is bluish white and translucent. The thickness of the articular cartilage is 1 to 2 mm.

Composition

Water- 75%

Solids-25%

Cells- embedded in an abundant and firm matrix.

The cells that produce the cartilage matrix are chondroblasts and in mature cartilage they are known as chondrocytes. The matrix is made up of a complex network of collagen fibres surrounded by proteoglycans and glycoproteins. There are spaces distributed throughout the matrix called the lacunae, within which are the chondrocytes.

The articular cartilage has no nerve supply and no direct blood supply. The chondrocytes receive nutrients by diffusion across the cartilage matrix from these sources- 1) blood vessels within the synovial membrane 2) synovial fluid 3) blood vessels in the adjacent bone.

The chondrocytes are found either singly or in clusters f two or more called cell nests or isogenous cell groups. The cells of the articular surface appear flat and are closer together while the matrix is dense and fibrous.

The cartilage matrix- it surrounds the lacunae containing the chondrocytes. It consists of collagen (type II) fibres, elastic fibres and an amorphous ground substance which consists of proteoglycans and glycoproteins.

Clinical significance

1) The fluid moves out of articular cartilage when it is compressed and back in to the cartilage when the zygapophyseal joint is preoccupied. Such movement may help nutrients diffuse through the matrix to the chondrocytes.

2) If injured, articular cartilage heals slowly (1 mm defect heals in about 4 weeks).

3) Passive movement of the joint may stimulate cartilage regeneration, whereas immobility results in the development of adhesions. Intermittent light weight bearing activity does not stimulate cartilage regeneration however it stops the development of adhesions.

4) Articular cartilage becomes yellow, thinner and more brittle with age. Its surface becomes uneven. Fissures or cracks may be developed in it called fibrillation of articular cartilage. These fissures may be extended from the joint surface to the subchondral bone.

Articular capsule

It consists of an outer layer of dense fibroelastic connective tissue of collagen fibres, a vascular central layer made up of areolar tissue and loose connective tissue. It is lined by synovial membrane. The fibroblasts, fibrocytes and a small amount of ground substance are also found in the outer layer. The capsules have a rich sensory innervation. But it has a poor blood supply. Hence there is a slow healing when it is injured.

The articular capsules are thinner superiorly and inferiorly; where they form capsular recesses that cover fat-filled synovial pads. Defects exist within the superior and inferior aspects of the joint capsule and allow for the passage of small nerves and vessels.

Ligamentum flavum

This ligament passes from the anterior and inferior aspect of the lamina of the vertebra above to the posterior and superior aspect of the lamina of the vertebra below. The lateral fibres of this ligament extend anterior to the zygapophyseal joint, attach to its margins and form its anterior capsule.

The ligamentum flavum is 80% elastic fibres and 20% collagen fibres. The elastic fibres prevent its protrusion into the intervertebral foramen and vertebral canal.

Clinical anatomy of ligamentum flavum

Tearing and scarring of ligamentum flavum takes place due to excess of load applied suddenly. This may be an important source of pain in its region [91].

Synovial membrane

The innermost layer of the synovial membrane is composed of one to three layers of specialized cells called synoviocytes. Beneath this layer is a loose network of vascular areolar connective tissue containing rich blood supply called synovial subintimal layer. The synovial membrane is innervated by sensory nerve endings.

Synoviocytes- these are of two types – type A- these are numerous and are characterized by the presence of abundant cytoplasmic organelles such as endoplasmic reticulum. These are involved in secretion and are believed to synthesize hyaluronic acid and glycoproteins.

type B- these are similar to macrophages and are involved in phagocytosis. Both the synoviocytes are not connected by junctional complexes and do not rest on a basement membrane, hence they do not constitute an epithelial lining of the joint cavity. They form a smooth secreting surface for the synovial membrane. Small folds of synovial villi can be found along the surface.

Intervertebral disc

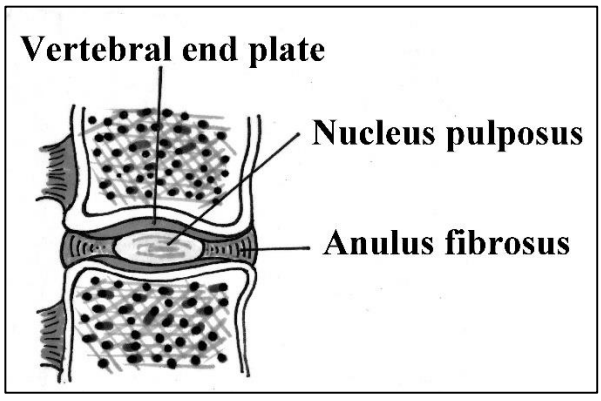


Fig. 37 Intervertebral disc

The intervertebral disc is a specialized connective tissue. It provides strength, mobility and resistance to strain. It consists of water, cells, proteoglycans and collagen.

Anulus fibrosus

It is the rigid, outer series of rings (lamellae). Its tightly packed collagen fibres do not allow the proteoglycans of the nucleus pulposus to pass between them. The adult anulus fibrosus is not distinctly separated from the nucleus pulposus and from the vertebral end plates. The outer ring of the anulus fibrosus consists of an external strong layer of dense collagenous connective tissue. The outermost fibres are the densest known as *Sharpey's* fibres, while the remainder of the anulus fibrosus is basically composed of overlapping concentric layers of fibrocartilage.

The anterior and lateral parts of the anulus fibrosus are composed of more than 20 moderately thick lamellae. The outer lamellae are loosely attached to the strong anterior longitudinal ligament. The posterior and posterolateral parts of the anulus fibrosus are much thinner lamellae. The outer collagen fibers of the anulus fibrosus are fused with the thin posterior longitudinal ligament and also attach to the posterior vertebral rims. The inner fibers of the anulus fibrosus are continuous with the cartilaginous end plates.

Nucleus pulposus

It is highly hydrated tissue at birth, with a water content of 88% . this falls to 69% at the age of 77 years. As the hydration declines with age, the tissues become firmer and loose their translucency and the boundaries between the nucleus pulposus and anulus fibrosus becomes less distinguishable. The nucleus pulposus has relatively few cells which are primarily notochordal cells, fibroblasts and chondrocytes

Cartilaginous end plate

It is a thin 3mm strip of hyaline cartilage containing many fine collagenous fibrils. The end plate separates the nucleus pulposus and medial aspect of the anulus fibrosus from the subchondral bone of the adjacent vertebral body. The collagen fibers of anulus fibrosus and nucleus pulposus enter the end plate and become enclosed in the end plate’s ground substance. The end plate is composed of parallel lamellae of chondrocyte cells and collagen fibers, arranged horizontally. The end plate’s ground substance consists of water within an amorphous matrix of proteoglycans.

Pain of the spinal origin [92]

Sympathetic pain- Diffuse burning pain, which may or may not radiate into the extremity is usually of sympathetic pain. These receptors may be stimulated by arachnoiditis to produce this type of pain

Somatic pain- The body structures are supplied by nociceptive (nerve endings sensitive to tissue damage) nerve endings. Aching is usually the result of muscle tightness or soreness and may be relieved by stretching and resting.

Neurogenic pain- Generalized extremity pain excluding aching pain is usually associated with a vascular or neurogenic disorder.

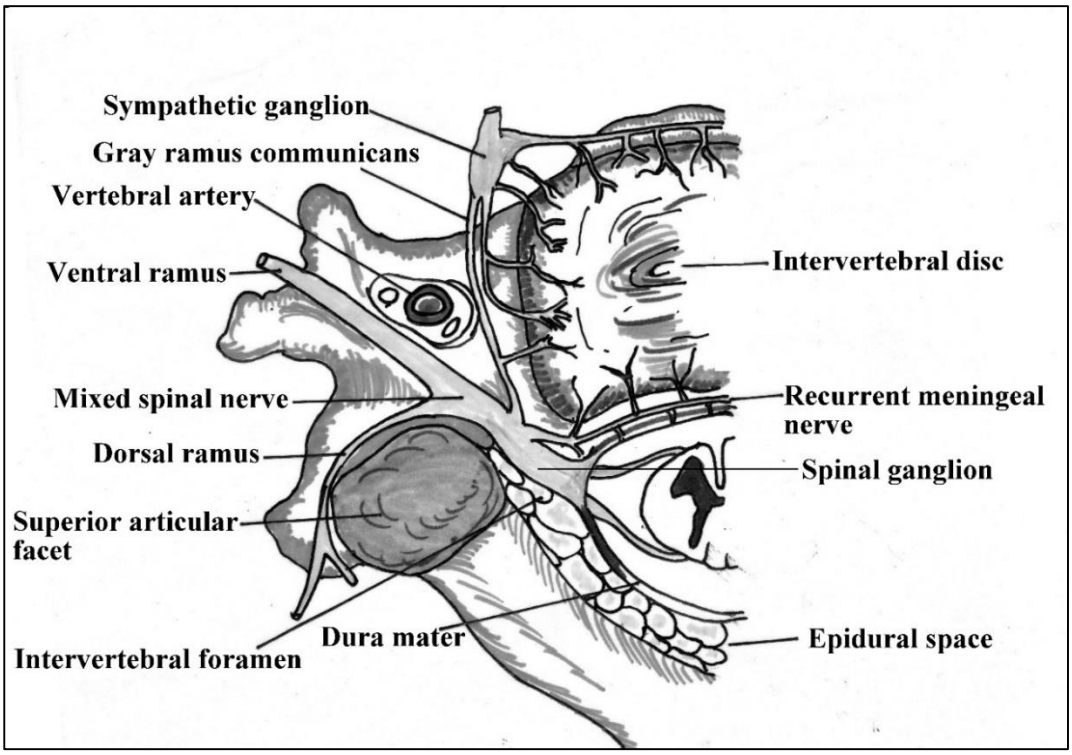


Fig. 38 Horizontal view of a cervical vertebra, the intervertebral foramina, the vertebral foramen and the nerves associated with this region.

The four main sources of neural innervation to spinal structures-

1) anterior primary division

2) posterior primary division

3) recurrent meningeal nerve

4) sensory fibers that course with the sympathetic nervous system.

All these nerves have their cell bodies in the dorsal root ganglia (spinal ganglion). These are located within the intervertebral foramina except C1 and C2. The

sensory fibres which are associated with the recurrent meningeal nerve and the sympathetic nervous system, provide a route for the transmission of nociception from somatic structures of the vertebral column's anterior aspect. Fibers arising from these sources pass through the anterior primary division for a short distance before reaching the mixed spinal nerve. They then enter the dorsal root.

Structures innervated by the anterior ramus which may produce pain

The anterior primary divisions of the cervical region innervate muscles of the neck and the upper limb.

Clinical significance

1) Strain or spasm of these neck muscles can be a source of neck pain and neck stiffness.

2) Transverse processes are also innervated by the anterior primary divisions and a bruise to its periosteum may result in pain.

Structures innervated by the dorsal ramus which may produce pain

1) The muscles may be strained or may be affected by areas of myofascial tenderness.

2) The ligaments may be sprained.

3) The zygapophyseal joint may be fractured or may be inflamed as a result of arthritic changes.

4) Discomfort can also arise from zygapophyseal joint articular capsule or synovial fold that has become entrapped within the joint or pinched between the articular surfaces. Degeneration of articular cartilage may produce inflammatory agents that may stimulate nociceptors of the articular capsule

5) Inactivity of spinal joints may cause pain.

6) The spinous processes may be fractured or repeatedly collide with one another.

Structures innervated by the recurrent meningeal nerve which may produce pain

Clinical significance [93]

1) The periosteum of a vertebral body may be affected by fracture or neoplasm within the vertebral body

2) The basivertebral veins may be affected by intraosseous hypertension, crush fractures or neoplasms of the vertebral body.

3) The epidural veins may be affected by venous engorgement.

4) The posterior aspect of the intervertebral disc can be affected by internal disc disruption, protrusion of the nucleus pulposus through the outer layers of the annulus fibrosus or tearing (sprain) of the outer layers of the anulus fibrosus.

5) The posterior longitudinal ligament can be torn (sprain) during severe hyper flexion injuries or may be pierced by an intervertebral disc protrusion.

6) The anterior aspect of the dura mater may be compressed by an intervertebral disc protrusion or may be irritated by the release of chemical mediators associated with internal disc disruption.

Nerves associated with the sympathetic nervous system

Clinical significance

1) Pathological conditions (fracture, neoplasm and osteomyelitis) of the periosteum of the anterior and lateral aspects of the vertebral body which are innervated by sensory fibres traveling with gray rami may result in pain.

2) Sprain of the anterior longitudinal ligament, the outer layers of the anterior or lateral part of the anulus fibrosis may result in pain conducted by fibers that course with the gray communicating rami.

Other structures producing pain in the cervical region

1) Irritation of the nerves surrounding the vertebral artery.

2) Nociception arising from uncovertebral joints

3) Nociception arising from almost any structure innervated by the upper four cervical nerves may refer to the head, causing headaches.

4) Pain originating from the region of the basi-occiput and occipital condyles frequently refers to the orbital and frontal regions

5) Autonomic symptoms such as sweating, pallor, nausea, alterations of pulse etc. have been found in association with disturbances of the suboccipital and upper cervical spine

Dorsal root ganglia

The dorsal root ganglia serve as modulators of spinal nociception. They contain many neuropeptides associated with the transmission of nociception (substance P, calcitonin, gene-related peptide, vasoactive intestinal peptide). These substances may be released from the peripheral terminals of sensory nerves that transmit nociception. The neuropeptides may reach these peripheral terminals (receptors) by axonal transport mechanisms.

Radicular pain [94]

It is caused by activation of sensory fibers at the level of the dorsal root ganglia. It is experienced as a thin band of sharp shooting pain along the distribution of the nerve or nerves supplied by the affected dorsal root. Pressure on the dorsal root ganglion

results in decreased blood flow to sensory nerve bodies which results in neural ischemia that is perceived as radicular pain.

Causes of radicular pain

1) Intervertebral disc protrusion
2) Disc lesion
3) Vertebral canal stenosis and other space occupying lesion e.g. tumor of the spinal canal.
4) Abscess (osteomyelitis and tuberculosis)
5) Spondylolisthesis
6) Malformation of the vertebral canal
7) Malformation of the spinal nerve root and its sheath
8) Miscellaneous diseases of bone
9) Histamine like chemicals released from degenerating intervertebral disc.

When a dorsal nerve root is affected, other sensory and motor modalities are also influenced. Hence radicular pain usually is accompanied by paresthesia (an abnormal sensation at the skin e.g., a tingling, pricking, chilling, burning, or numb sensation), hypesthesia (a diminished capacity for physical sensation) and decreased reflexes (as the sensory limb of the deep tendon reflex is affected). As the dorsal and ventral nerve root are adjacent to each other, compression of the dorsal root is usually accompanied by compression of the ventral nerve root as well. Compression of the ventral root results in motor weakness. Therefore, radicular pain may be accompanied by motor weakness.

Spinal imaging

Accurate diagnostic imaging of the spine is a crucial component in the valuation of a patient with spinal disorder. The most common imaging modalities used for the evaluation of spinal disorders include conventional radiographs, myelography, computed tomography (CT), Magnetic resonance imaging (MRI), scintigraphy and angiography.

Conventional radiographs

In many cases the initial imaging study obtained is the plane radiograph due to its universal availability, low cost and ability to provide a general overview image of the osseous spine.

In the cervical spine antero-posterior (AP) and lateral images are commonly obtained for sub axial disorders.

A *Swimmer's view* is used to include C7-T1 disc space which may be hidden due to overlying shoulders.

Limitations- 1) inability to visualize neurologic structures 2) high rate of false positive findings in asymptomatic patients [95].

Myelography [96]

It involves of the injection of water-soluble contrast agent into the thecal sac either through a lumber puncture or a C1-C2 puncture. This can allow for visualization of extradural composition of the numeral structures by a change in normal contour of the thecal sec or nerve root sleeves.

Computed tomography

The use of CT allows for axial imaging of the spine to provide an improved, direct visualization of impressive structures. CT has an ability to better differentiate the compression of neural structures by soft tissues versus compression by bone. It is useful in the patients those are contraindicated for MRI, pacemakers, stents, aneurysm clips and metallic dear debris in the eyes.

Disadvantage- exposure of the patient to ionizing radiation.

Magnetic resonance imaging (MRI)

It has become the imaging modality of choice for the evaluation of many spinal disorders. It provides high quality axial imaging of the spine with direct visualization of neural structures and other soft tissues including discs, ligaments, facet, capsules and muscles. MRI includes axial and sagittal T1 and T2 weighted images.

MRI has been found to be more sensitive than contrast- enhanced CT in demonstrating disc degeneration. MRI can also detect disruption of the posterior longitudinal ligament secondary to herniated nucleus pulposus. MRI allows for visualization of the discs, cerebrospinal fluid, spinal cord and the perimeter of the spinal canal in several planes without the use of intravenous contrast. Therefore, it is useful for detecting disorders of the spinal canal and spinal cord. Spinal cord tumors, syringomyelia, extramedullary tumors, metastatic disease to the vertebrae, spina bifida are very well evaluated by this method. It is useful for the pre-neurosurgical evolution of cervical radiculopathy (irritation, compression or injury to a nerve root that may cause pain, numbness, tingling sensation or weakness in the part of the body which is supplied with nerves from that root) and myelopathy (pathological change in the spinal cord)

Two of the primary properties of MRI images are related to the various responses of different tissues to the radio frequency applied during the MRI evaluation. These two characteristics are known as T1 and T2. Various MRI protocols can highlight either of these characteristics and thereby selectively enhance different tissues. T1 weighted images are particularly useful in the evolution of spinal cord and the bone marrow of the vertebrae.

The discs, osteophytes and ligaments are also well demonstrated on these images. T1 weighted images are more valuable than T2 weighted images in the evaluation of most spinal disorders.

T2 Weighted images are the most sensitive at showing decreased signal intensity resulting from desiccation of the disc. Because cerebrospinal fluid has a very high signal on T2 weighted images they also are valuable in evaluating the amount of narrowing of the subarachnoid space in case of the spinal stenosis. [97]

Advantages of MRI over CT

1) The superiority of MRI in the detection and staging of inflammatory and infective disorders of the spine is unquestionable.

2) The major advantages of MRI include multiplanar (consisting of or relating to several or many planes) capability, the direct demonstration of early bone marrow involvement or oedema and the unsurpassable assessment of spinal canal and neural involvement.

3) Skipped lesions are more easily and more often detected by MRI as compared to CT due to its capacity to screen the entire spine in a single examination.

4) MRI is also superior to CT for detection of epidural, meningeal and spinal cord contribution.

5) Planning of surgical treatment can be facilitated by MRI because of the clear display of the extent of the active infection and its complications including involvement of neural arch.

6) While tuberculosis can be surely diagnosed when the characteristics imaging features are present at times it may be difficult to distinguish this from other causes of bone marrow oedema in early stages and other conditions such as metastases and myeloma in atypical cases.

7) Soft tissue and intraosseous abscesses are also well demonstrated on MRI.

8) MRI has higher sensitivity for early infiltrative disease including endplate changes and marrow infiltration than bone scan and plain films.

Angiography

The spinal angiography can be useful for the evaluation of vascular malformations, vascular supply to a tumor or the spinal cord

Scintigraphy

Bone scintigraphy can be used for the identification of inflammatory changes in the spine. These studies use radionuclides to detect inflammatory changes in a patient with a known history of metastatic disease.

Disorders of cervical spine

The most common reason for generalized neck and back pain is a simple muscle strain. Usually there is no specific recollection of an injury. They get resolved without treatment. But there are certain diseases of spine which severely affect the spine and cause debility to the patient. The following disorders of the spine are included in the present study

1) **Degenerative disorders of spine**- The majority of spinal diseases are the degenerative disorders and include- degenerative disc, disc herniation, spinal stenosis etc.

2) **Inflammatory disorders of spine**- The other spinal disorders are **inflammatory spondyloarthropathies**, in which rheumatoid arthritis (excluded in present study) and sero-negative inflammatory spondylitis are considered.

3) **Metabolic disorders of spine**- These includes diseases resulting from disturbances in bone remodeling e.g. osteoporosis.

1) Degenerative disorders of spine

These are very common disorders becoming predominant with age. The development of degenerative spinal disorders is also more common in patients with a strong family history of spine problems due to a genetic predilection for these disorders. Also, the patients like laborers, athletes have a higher rate of degenerative spinal disorders. Once the degenerative cascade has begun, the disc is unable to repair itself due to the lack of blood supply [98].

Cervical spondylosis

This term refers to normal age-related degenerative changes that occur in the cervical spine. [99]

Beginning in the intervertebral discs, they affect the facet joints and produce pain and stiffness of the neck and frequently referred symptoms in the upper limb. [100]

Spondylosis occurs in all spinal segments, but is found most frequently in the more mobile segments of the spine (i.e. the cervical and lumbar segments). [101]

The cervical portion of the vertebral column possesses the greatest mobility and thus has the greatest susceptibility to functional stress and trauma. Therefore, clinical spondylosis of the cervical spine is very common and often is debilitating. [102]

Cause- the primary degenerative changes may be initiated by injury, but usually the condition is a manifestation of normal aging process.

Pathology of cervical spondylosis

Degeneration of intervertebral disc- The commonest orthopedic cause of neck disorder is degeneration of a cervical intervertebral disc. The process of degeneration in the disc begins after the age of thirty. Its consistency becomes less gelatinous. Its ability to absorb fluid decreases due to aggregating breakdown of the proteoglycan. This decreases its ability to withstand in the condition when loads are placed on it. This degeneration results in the narrowing of its superior to inferior dimensions. And the adjacent vertebral bodies become sclerotic. The discs also sink gradually into the adjacent vertebral bodies. [103]

Degeneration of disc results in reduction of disc space and peripheral osteophyte formation. The posterior intervertebral joint gets secondarily involved and generate pain in the neck. The osteophytes impinging on the nerve roots give rise to radicular pain in the upper limb. Exceptionally the osteophytes may press on the spinal cord giving rise to symptoms of cord compression. The cervical spondylosis occurs most commonly in the lowest three cervical intervertebral joints (the commonest is at C5-C6). [104]

As individuals age there is a characteristic degenerative cascade that develops in the intervertebral discs. Usually in the third decade there is a change in the proteoglycan content leading to reduced levels of chondroitin sulphate and increased levels of Keratin Sulphate. These changes diminish the disc ability to maintain its normal fluid concentration and leads to a decreased ability of the nucleus to resist normal compressive forces. These places additional stress on the outer annular fibres. The disc then loses a portion of its normal height.

This causes buckling of the ligamentum flavum, facet joint capsules, and annulus into the spinal canal and neuroforamen. This increases the resultant loading of the facet joints and leads to facet joint degeneration. Additional bone spurs can be formed and cause further narrowing of the spinal canal and foramen [105].

Repetitive loading produces a cumulative effect on the disc structure which degrades the architecture of the disc. During daily mechanical loading the annulus is subjected to repetitive tensile stresses. Microtrauma, delamination, loss of structural integrity and degeneration are the sequence of events in cervical spondylosis. The intervertebral disc has no capacity to undergo repair once it is damaged. The annulus

fibrosus provides no evidence of the capacity to repair the intrinsic structure of collagen and proteoglycan once it is destroyed. In response to trauma the cartilage tissue at molecular level is known to react to produce collagen and proteoglycan fibers in order to restore the cell matrix. But these fibers grow haphazardly without re-organization.

The intervertebral disc and chiefly the annulus fibrosus are not suited for compressive force or load. It can rupture during high magnitude short duration compressive load and can cause fatigue failure during low magnitude long duration load. The most common and somewhat risky stress to the cervical spine is flexion rotation which causes tension as well as torsion. The nucleus pulposus is responsible for producing turgor (the state of turgidity and resulting rigidity of cells or tissues, due to the absorption of fluid.). Degenerative changes slow water movement in the nucleus and reduces the turgor. When turgor becomes poor there is high risk of disc prolapse. With continued axial load the nucleus can prolapse centrally causing Schmorl's nodes.

The disc prolapse in the cervical spine is common during flexion rotation movement when the centre of rotation is located in the posterior one third of the disc making nucleus vulnerable to be prolapsed postero-laterally through weak portion of posterior longitudinal ligament. [106]

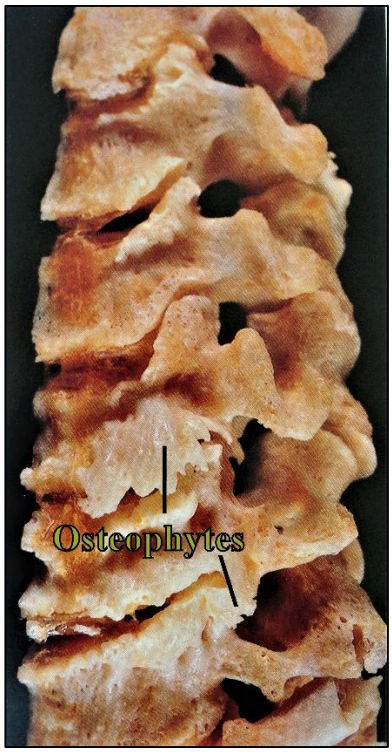


Fig.39 Cervical spine of 77 years old female osteophyte formation of uncovertebral joints. encroachment of the osteophytes on intervertebral foramina. [107]

Clinical features-

1) Pain and stiffness- this is the commonest presenting symptom, initially intermittent but later persistent in the neck or in the upper limb or both. Neck symptoms consists mainly of aching pain in the back of the neck or in the trapezius area, a filling of stiffness and grating on movement. Occipital headache may occur if the upper half of the cervical spine is affected.

2) Radiating pain- In the upper limb there may be a vague, ill-defined and ill-localized referred pain radiating to the shoulder or downwards on the outer aspect of the forearm and hand along the course of the affected nerve or nerves, often reaching the digits. There may be paraesthesiae in the hand, in the form of tingling or pins and needles. Muscle weakness is uncommon.

3) Giddiness- the patient may present with an episode of giddiness because of vertebro-basilar syndrome (a temporary set of symptoms due to decreased blood flow, ischemia).

4) On examination-

a) There is loss of normal cervical lordosis and a limitation in neck movements.

b) There may be tenderness over the lower cervical spine or in the muscles of the paravertebral region (myalgia).

c) Neck movements are not markedly diminished except during acute exacerbation or when the degenerative changes are very advanced.

d) Audible crepitations on movement is common.

e) The upper limb may have signs suggestive of nerve root compression. Motor weakness is uncommon.

Radiographic features

Fig. 40 Sagittal MRI of the cervical spine demonstrating multiple-level spondylosis

1) Narrowing of the intervertebral disc space.

2) Formation of osteophytes at the vertebral margin.

3) A single vertebral level may be affected.

4) Encroachment of osteophytes upon an intervertebral foramen.

5) Nerve root compression may be seen.

6) spinal cord compression may be seen.

Disc herniation (prolapsed disc)

The term prolapsed disc means the protrusion or extrusion of the nucleus pulposus through a rent in the annulus fibrosus. It is not a one-time phenomenon. It is a sequence of changes in the disc, which finally leads to prolapse. [108]

Disc herniation can be described according to the degree of disruption of the disc outside its normal boundaries. Disc herniation can occur independently or in combination with other degenerative changes.

Pathology of disc herniation [109]

Disc herniation is a sequence of changes in the disc as following-

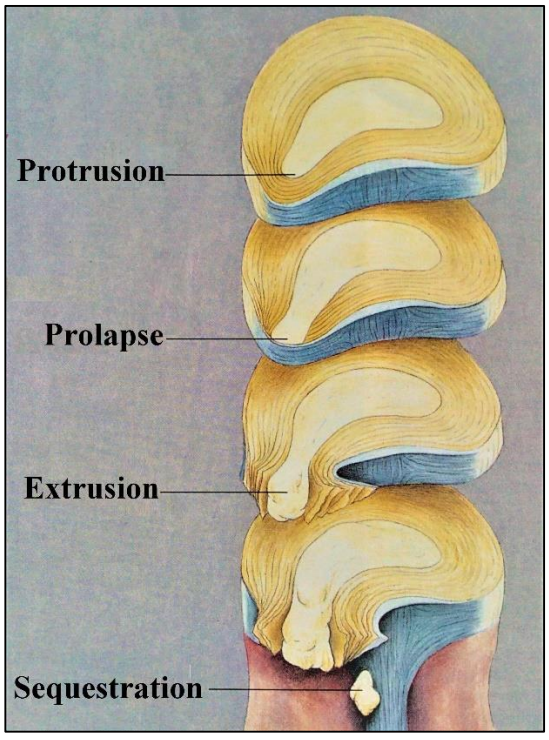


Fig. 41 Different types of disc tissue displacement [110]

1) **Nucleus degeneration**- Degenerative changes occur in the disc before displacement of the nuclear material. These changes are- a) softening of the nucleus and its fragmentation b) weakening and disintegration of the posterior part of the annulus.

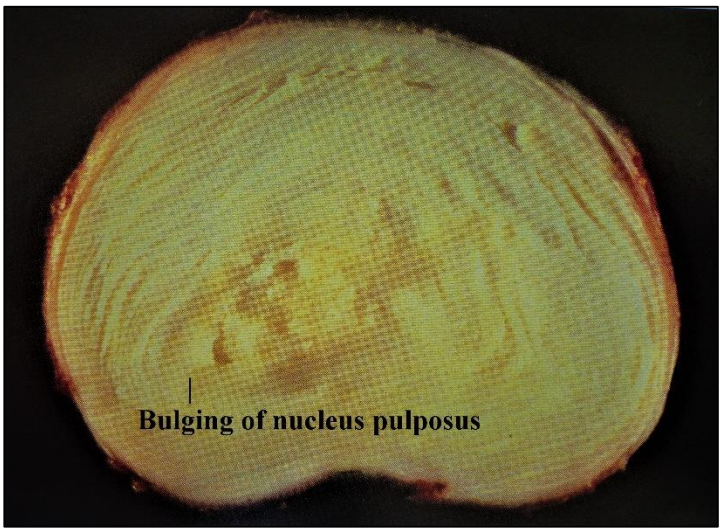


Fig. 42 Cross section through intervertebral disc showing protrusion of the nucleus pulposus into the anulus postero-laterally [111].

2) **Nucleus displacement**- This happens with the following steps-

a) The nucleus is under positive pressure at all times. When the annulus becomes weak, either because a small area of its entire thickness has disintegrated spontaneously or because of injury, the nucleus tends to bulge through the defect. This is called **disc protrusion**.

b) This tendency is greatly increased if the nucleus is degenerated and fragmented. Further the nucleus protrudes more and separates fibers of the anulus called **Disc prolapse**.

c) Finally, the nucleus comes out of the annulus and lies under the posterior longitudinal ligament, though it has not lost contact with the parent disk. This is called **disc Extrusion**. Once extruded this disk does not go back. The posterior longitudinal ligament is not strong enough to prevent the nucleus protruding further.

d) The extruded disc may lose its contact with the parent disk, when it is called **Sequestrated disc**. The sequestrated disc may come to lie behind the posterior longitudinal ligament or may become free fragment in the canal.

3) **Stage of fibrosis**- This is the stage of repair. This begins alongside of degeneration. Residual nucleus pulposus becomes fibrosed. The extruded nucleus pulposus becomes flattened, fibrosed and finally undergoes calcification. All

together new bone formation occurs at the points where the posterior longitudinal ligament has been stripped form the vertebral body and spur formation occurs.

Direction of disc displacement [112]

Displacement of disc tissue (generally the nucleus pulposus) from the intervertebral disc space may occur anteriorly, posteriorly, superiorly or inferiorly. The anterior disc displacement generally produces spondylosis deformans, while posterior displacement produces pressure on the nerve roots or encroachment on the contents of the spinal canal. The superior or inferior displacement into the adjacent vertebral bodies produces *Schmorl's* nodes.

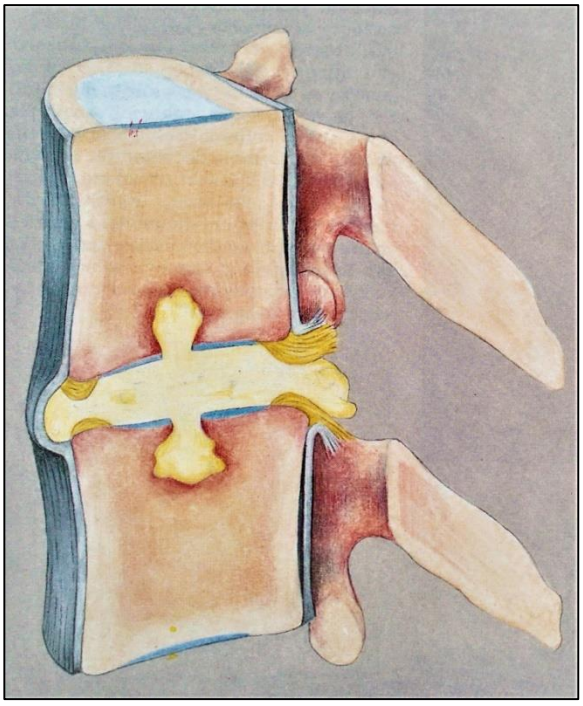


Fig. 43 Several directions in which disc tissue displacement may occur anteriorly, posteriorly, superiorly, inferiorly.

The site of exit of the nucleus is usually posterolateral on one or the other side. Occasionally it can be central (posterior- midline) disc prolapse. The commonest level of disc prolapse in the cervical spine is C5 -C6. [113]

Patient presentation

The nucleus pulposus may cause bulging of the outer annular fibres or may protrude (herniate) through the anulus. Bulging or herniation of the disc may be a primary source of pain or pain may result because of pressure on the exiting nerve roots within the medial aspect of the intervertebral foramen. It is also believed that proteoglycan leaking out of a tear in the anulus may also cause pain by creating a

chemical irritation of the exiting nerve roots. The pain resulting from pressure on a nerve root radiates in a dermatomal pattern. This pain is known as **radicular pain** as its origin is from the dorsal root or the dorsal root ganglion.

The intervertebral disc can produce pain due to its nociceptive innervation. Hence its diseases- internal disc disruption, tears of the outer third of the anulus fibrosus and severe degeneration of disc can produce pain in the spine. [114]

Stiff neck is a common feature in the early stages of relapsed prolapsed cervical disc. [115]

Patients with cervical disc disease frequently present with a chief complaint of posterior neck pain. The pain is often located in the cervical paraspinous muscle with extension into the posterior shoulder girdles and trapezius muscles. Extension of the pain up to the occiput can frequently results in headaches. Patients may have trigger points deep in the muscles that are tender to palpation. Pain that worsens with neck flexion suggests a myofascial etiology, while exacerbation in neck extension suggests a discogenic origin.

Patients with cervical disc herniation or foraminal stenosis present with upper extremity complaints of pain, paresthesia or weakness with or without associated neck pain. In most cases of herniated disc, the radiculopathy is unilateral, but in case of a central disc herniation or foraminal stenosis, the symptoms can occur bilaterally. Extension and lateral bending towards the affected arm increase the symptoms. [116]

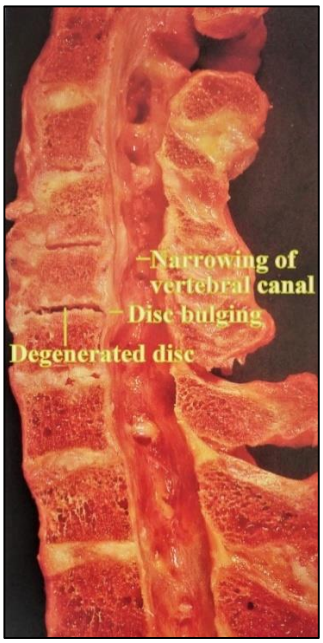


Fig. 44 Sagittal section of cervical spine 74 years old female: Cleft formations in intervertebral disc narrowing of spinal canal. [117]

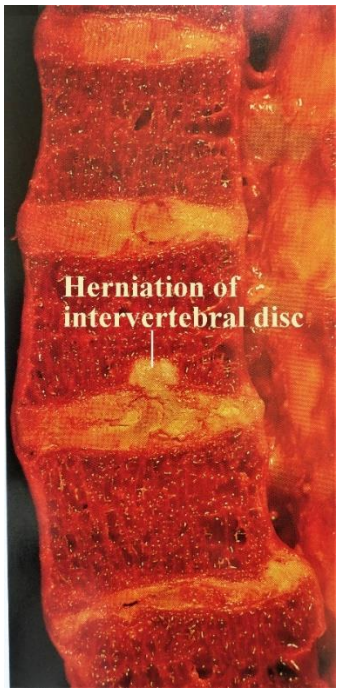


Fig. 45 sagittal section through the vertebra of 83 years old female herniation of intervertebral disc into the lower surface of L2. [118]

Spondylosis deformans [119]

It is originated by tears that occur anteriorly in the periphery of the annulus where the collagen bundles attach to the vertebral bodies by *Sharpey's* fibers. Tear in this area leads to both anterior and anterolateral herniation of nuclear disc tissue, a process that is accentuated when the nucleus pulposus is comparatively normal to begin with. The displacement is potentiated by weight bearing and by spinal motion, and it is for this reason that spondylosis deformans is found only rarely in inactive or immobilized individuals. Once displacement has occurred, dissection of the anterior longitudinal ligament from its bony attachment by the displaced disc tissue permits extension of tissue cephalad or caudad, between the anterior longitudinal ligament and the vertebral body wall.

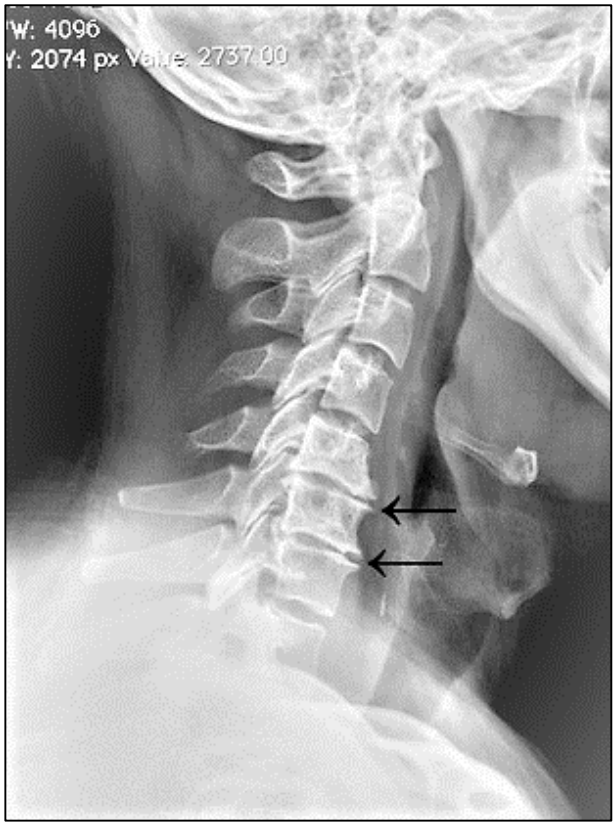


Fig. 46 Anterior and anterolateral herniation of nuclear disc tissue.

As the anterior longitudinal ligament has only weak attachments to the annulus, continuous tearing of this attachments by prolapsed disc material will stimulate the development of bony outgrowths called osteophytes, particularly along the anterior and lateral aspects of the vertebral column. These bony outgrowths extend first in a horizontal direction and then in a vertical direction following the attachments of the ligament. Beaklike spurs are formed which ultimately may grow to bridge the intervertebral disc space. The form and severity of the clinical manifestations related to vertebral osteophytes while difficult to assess will depend upon the size and location of the outgrowths and on their relationship to adjacent soft tissues and neurologic structures. Symptoms may include dysphagia, neck stiffness and pain.

Relationship between prolapsed disc and cervical spondylosis [120]

The clinical features of the two conditions are similar. Distinction is difficult if the radiographs shows arthritic changes, because the arthritis may be only incidental and itself symptomless. Nerve pressure is possibly greater in prolapsed disc than in osteoarthritis, consequently the symptoms tend to be more clearly defined and pain very severe and the objective signs are more marked.

Osteochondrosis [121]

Osteochondrosis describes the pathologic changes that occur in the intervertebral disc as a result of disruption in the region of the end plate. Indication of degeneration in the cartilaginous end plates is seen as microfractures in the bone cartilage interface, an advancing of calcification into the cartilage from the bony surface and an invasion of blood vessels from the subchondral bone into the cartilage with subsequent endochondral ossification. As a result of these changes mechanical failure at the end plate compromises the mechanical function of the disc as a whole and may produce herniation of disc material into the adjacent bone of the vertebral body.

With disruption of the cartilaginous end plate, the other disk components show a rapidly progressive degeneration, with focal necrosis fissuring, calcification, radial or circumferential tearing of the annulus fibrosus and replacement of normal disc issue by fibrous tissue. In the nucleus pulposus replacement by fibrous tissue and amorphous material takes place. Large horizontal clefts develop in the central part of the disc tissue.

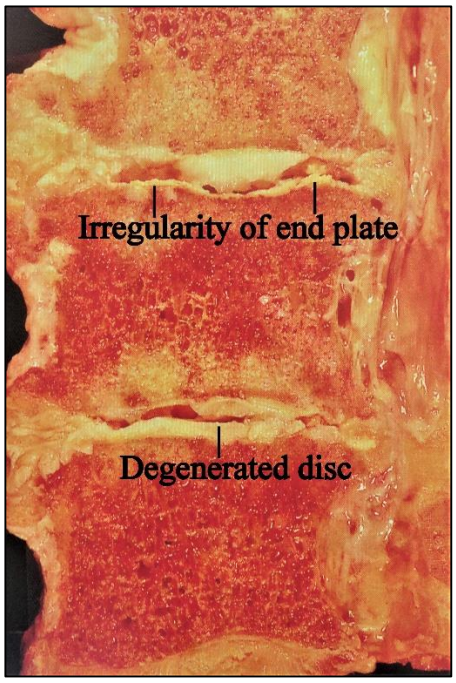


Fig. 47 Sagittal section of spine of 72 years old male: Severe disc degeneration, along with irregularity of the end plates and adjacent sclerosis of bone [122]

Extension of blood vessels through the subchondral bone and cartilaginous end plate also may occur. Injury to these vessels may result in haemorrhage into the intervertebral disc and in subsequent discoloration of disc material by blood pigments. As disc tissue degeneration with subsequent narrowing of the disc space

progresses, formation of new bone is seen around the periphery of the disc, at the junction of the annulus and the vertebral body. New bone formation also occurs as a result of endochondral ossification of the cartilaginous end plate, which contributes to the narrowing of the disc space. Here it should be noted that the bony out-growths (osteophytes) seen in association with degenerative disc disease are not nearly as prominent as those seen in association with anterior disc herniation called spondylosis deformans.

Following vascular invasion, progressive breakdown of the disc tissue contents will result in their resorption. At this stage the narrow space between the vertebral bodies will be occupied by a small amount of vascularized fibrous tissue, and the bone of the vertebral bodies on each side of the disc will become increasingly irregular and sclerotic. Frequently the final stage of the resorption process is the spontaneous fusion of the adjacent vertebral bodies.

Degenerative spondylolisthesis [123]

It is the displacement of a vertebral body on the one directly below it. In severe degenerative disc disease, the displacement of one vertebral body on another may occur in any direction i.e. Anterior displacement, posterior displacement and lateral displacement. The anterior displacement (spondylolisthesis) is most common. Degenerative spondylolisthesis results from degeneration of the facet joints which sequentially results from narrowing of the intervertebral disk space. Bony erosions of the articular surfaces of the facet joint result in a more horizontal disposition of the facets and in an increasing tendency toward forward slippage, potentiated by the narrowing of the disc space.

Forward slippage is stopped only when the inferior surface of the pars inter-articularis (isthmus) of the slipped vertebra abuts on the upper margin of the superior articular process of the vertebra below. Occasionally spontaneous fusion of the involved facet joints prevents further slippage. The outcome of degenerative spondylolisthesis is spinal stenosis.

Fig. 48 Degenerative Retrolisthesis of the cervical spine [124]

Degenerative retrolisthesis and lateral listhesis

Retrolisthesis is the posterior displacement of one vertebra on the subjacent one. Degenerative retrolisthesis, like spondylolisthesis affects the most mobile segments of the spine, i.e. the cervical and lumbar segments. With rotation or angular deformities, a lateral slippage associated with retrolisthesis is also observed.

Spinal stenosis [125]

It is the abnormal narrowing of the vertebral canal caused by encroachment of bone, disc etc. It may result from the developmental or acquired lesions or a combination of both, and it may affect all regions of the spine in adults and children. It may be symmetrical or asymmetrical and central or confined to the lateral recesses.

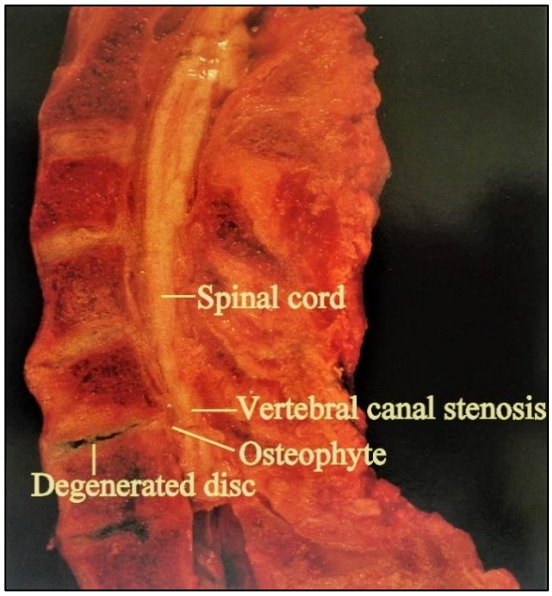


Fig. 49 Sagittal section of cervical spine of 67 year male showing central stenosis of cervical canal as a result of disc degeneration and posterior osteophyte formation. [126]

The narrowing seen in the spinal stenosis may be produced by soft-tissue changes such as disc herniation, fibrous scar or tumor or it may be the result of bony changes. The reduced volume and altered shape of the canal can lead to a spectrum of clinical syndromes arising from compression of neural elements within the spinal canal and intervertebral foramina. [127]

Vertebral canal stenosis can also occur due to 1) disc herniation 2) congenitally short pedicles 3) osteophyte formation 4) facet or ligamentous hypertrophy.

In the cervical and thoracic spine this can develop symptoms of *myelopathy*. In severe cases spinal cord compression can occur that can lead to *myelomalacia*. Lateral recess stenosis can cause radicular symptoms similar to those of disc herniation and results from a lateral disc herniation, facet hypertrophy, facet cysts or lateral osteophyte formation. [128]

Cervical spine stenosis

It is a condition in which a progressive narrowing of spinal canal leads to the compression of spinal cord. When it becomes symptomatic it causes cervical spondylotic myelopathy [129]. Patients with cervical spinal stenosis causing myelopathy generally experience gradual stepwise decline of neurologic function [130].

Fig. 50 MRI scans of a patient having cervical spondylosis with vertebral canal stenosis it shows spinal cord compression at two levels from disc and osteophyte. [131]

The spinal canal is limited anteriorly by the vertebral body, intervertebral disc and posterior longitudinal ligament, laterally by the neural foramen, pedicles and ligamentum flavum, posteriorly by the lamina, facet joints and ligamentum flavum. Changes in any of these structures can reduce the available space and cause spinal stenosis. [132]

Dimensions of spinal canal [133]

The normal anteroposterior diameter of the sub axial cervical spinal canal is 17-18 mm and the diameter of the spinal cord is approximately 10 mm. A spinal canal diameter of **13 mm or less** indicates stenosis. The antero-posterior and transverse diameters of the spinal cord have been reported to vary from 8.8 mm × 12.4mm at C2 to 8.7mm× 14 mm at C4 to 7.4 mm × 11.4mm at C7. The mean cross-sectional area of the spinal cord is 110mm^2 at C2, 121.9mm^2 at C4 and 84.6 mm^2 at C7.

With advancing degenerative changes of the cervical spinal canal, there is reduced space available for the spinal cord. The symptoms of cervical spondylotic myelopathy are thought to occur from a combination of the extrinsic compressive forces on the spinal cord as well as the alteration of the normal spinal cord blood supply. The cross-sectional area of the spinal cord at the most involved level has been found to be the most accurate predictor of neurologic recovery in patients with cervical spondylotic myelopathy.

There are normal changes in the canal dimensions during range of motion of the neck that can cause dynamic cord compression. The change in canal diameter is linearly related to the amount of flexion or extension motion in the neck. In addition to altering the canal diameter, flexion and extension of the neck lead to morphologic changes in the spinal cord. The spinal cord is stretched during neck flexion and shortens and thickens with neck extension. Thickening of the spinal cord can increase the risk of pressure from the in folded ligamentum flavum or lamina. During flexion there is increased risk of extrinsic pressure anteriorly on the spinal cord from bulging discs or osteophytes from the vertebral body.

Furthermore, instability of a motion segment adjacent to an area of stenosis can lead to further spinal cord compression. Segmental instability can also compromise the spinal cords intrinsic blood supply leading to further potential damage. There is a common pattern of lesion progression associated with progressive cervical myelopathy.

The initial findings include atrophy and neuronal loss in the anterior horn and intermediate zone. This is followed by degeneration of the lateral and posterior funiculi.

Symptoms of cervical spondylotic myelopathy-

1) clumsiness 2) altered gait 3) loss of fine motor skills in the hands 4) axial neck pain 5) upper extremity radiculopathy 6) in more severe cases motor weakness or muscle atrophy in the upper or lower extremities. 7) in more progressive cases loss or alteration of bowel and bladder function is also found.

MRI findings [134]

MRI scan can show the degree of spinal cord and nerve root compression from disc, osteophytes and ligamentous structures. It is generally supposed that increased signal intensity of T2-weighted MRI scans represent edema which may resolve and has less clinical significance. A combination of high signals on T2- weighted images and low signals on T1-weighted images may signify more severe lesions including necrosis, myelomalacia or spongiform changes

More review of cervical stenosis

Altogether, an antero-posterior diameter of the spinal canal less than 11mm, is suggestive of cervical stenosis. Degenerative cervical stenosis may develop from cervical disc degeneration, articular bony outgrowths of the facet joints, osteoarthritis of Luschka's joints, or osteophyte formation with encroachment on the spinal canal and neural foramina. Degenerative cervical stenosis is most common in the mobile mid and lower cervical regions. Cervical stenosis is accentuated by the presence of degenerative spondylolisthesis or retrolisthesis. [135]

Fig. 51 Stenosis of the spinal canal in a degenerative spondylolisthesis. The arrow points to the slip level and the cord compression. [136]

Neuropathic (charcot) spine [137]

Trauma to the articulations with their ultimate destruction, may occur due to impairment of pain or proprioceptive sensation and is generally called neuropathic arthropathy. Tabes dorsalis (neurosyphilis), diabetes, syringomyelia, paraplegia, peripheral neuropathy and congenital indifference to pain, and intra-articular steroid injections, are considered etiologic factors in the development of neuropathic arthropathy. When the cervical spine is involved syringomyelia is most often underlying disease. Pain is the usual appearance. From the radiograph the progression usually is one of disk space narrowing, sclerosis of the vertebral end plates and osteophytes.

General MRI findings of degenerative disorders of spine

Typical MRI findings consist of loss of disc space height, loss of fluid, osteophyte formation and endplate edema. The presence of a high intensity zone recommends a tear of outer layers of annulus fibrosus of the disc. [138]

Modic MRI vertebral endplate changes associated with age-related degeneration. [139]

Modic type	MRI findings
I	Decreased marrow signal on T1-weighted images Increased marrow signal on T2-weighted images
II	Increased marrow signal on T1-weighted images Isointense to slightly increased marrow signal on T2-weighted images
III	Decreased marrow signal on T1 and T2 weighted images

Inflammatory disorders of spine

Inflammatory spondyloarthropathies [140]

In the spine, there are more than 130 articulations, Including both amphiarthrosis as well as the synovial lined diarthrodial joints. Accordingly, many diseases affecting the spine will affect one or more of these joints resulting in symptoms of joint disfunction i.e. arthritis.

Sero-negative inflammatory spondylitis [141]

Inflammatory spondylitis is generally seen in patients who have a negative test for rheumatoid factor. Many of these patients are probable to be suffering from systemic disorders such as psoriasis or inflammatory bowel disease. Osteoporosis is not usually

seen and in marked contrast to rheumatoid disease, there is bony proliferation and intra-articular osseous fusion.

Psoriatic spondylitis [142]

Peripheral arthritis associated with psoriasis is well known. It is frequently affecting young men and women. In this disease there is a 90% prevalence of the HLA B27 antigen.

Ankylosing spondyloarthropathies

Ankylosing spondylitis [143]

It is a systemic ankylosing arthropathy. The spinal disease may develop in an ascending manner to involve the thoracic and cervical vertebrae, along with the axial articulations such as the pubic symphysis and ribs. HLA B27 antigen occurs in 90% to 95% of patients with ankylosing spondylitis.

Fig. 52 MRI of Ankylosing cervical spondylitis [144]

Radiographic findings

Early and distinguishing radiographic findings of ankylosing spondylitis is symmetrical sacroiliitis, apophyseal irregularities, osteopenia of the vertebrae and squaring of the vertebral bodies and marginal syndesmophytes (a bony growth originating inside a ligament). In the initial phase of the disease, the discs appear to be fairly well preserved but in the end stage they are clearly bridged centrally by bone

tissue. As the disease progresses, the apophyseal joints of the spine generally are completely ankylosed. The intervertebral foramina also show narrowing and the spine always shows an increase in the thoracic kyphosis, which frequently is markedly accentuated. As the spine becomes fused, so the cancellous bone becomes increasingly porotic and the cortices of the vertebrae become more prominent. This together with the ossification along the peripheral parts of the disc transforms the segmented column of the normal spine into a tube-like osseous rod mentioned as a *bamboo spine*.

Ankylosing hyperostosis of the spine [145]

It is an ankylosis of the vertebral column that occurs as a result of ligamentous ossification without significant disc disease. It is usually found in older men, with mild clinical symptoms. The diagnostic measures include the presence of focal spinal ankylosis, intact vertebral end plates, normal intervertebral disc height and flowing ossification of the anterior longitudinal ligament.

Although enclosing ankylosing hyperostosis occurs independently of disc disease, the disc spaces may be mildly narrowed. Disc calcification also may be present. Osteoporosis in general is not a common association. Patients with severe involvement of the cervical spine may develop dysphagia. Ossification of the posterior longitudinal ligament occurs sometime it leads to cord compression

Metabolic disorders of spine

Osteoporosis of the spine

A decrease in bone density to below normal limits is known as osteoporosis. It has a clinical significance as the spine is the weight bearing structure. Decreased bone density may cause vertebral fracture. [146]

Osteoporosis is also defined as normally calcified but quantitatively deficient bone which has resulted in clinical disability. It occurs following an imbalance in the rates of bone formation and resolution. Back pain associated with loss of height due to vertebral compression and increased thoracic kyphosis is a common appearance. Neurologic complications are uncommon in osteoporosis. [147]

Osteoporosis is the most common metabolic bone disorder affecting the spine. Its effects vary significantly depending on the severity of the disease but can include generalized or localized back pain, vertebral compression fractures, progressive kyphosis or scoliosis, pulmonary dysfunction and cardiac compromise. [148]

Pathophysiology of osteoporosis

The spine is often one of the first areas of the skeleton to be affected by osteoporosis. This is largely due to the relative composition of cortical and trabecular bone in the spine. Cortical bone is the strong, dense outer layer of bone, while trabecular bone is the less dense inner proportion of bone. Trabecular bone is metabolized at a rate eight time faster than cortical bone.

In the appendicular skeleton the ratio of cortical to trabecular bone is approximately 4:1, while in the spine the ratio is 1:2. As a result the loss of trabecular bone mass associated with osteoporosis has a larger effect on the vertebrae than the appendicular skeleton due to the greater percentage of trabecular bone. Osteoporosis can lead to a noticeable loss of trabecular bone mass and subsequent loss of strength in the vertebrae. It is found that there is a more loss of horizontal versus vertical trabecular bone inpatients with osteoporosis. [149]

Osteoporosis results from an imbalance in the standard mechanism of bone remodeling that leads to a decrease in bone strength and subsequent increased risk for fracture. An Individual typically achieves a peak level of bone mass between the age 18 and 25 years. There are numerous factors that affect the value of an individual's peak bone mass together with genetics, nutrition endocrine abnormalities, physical activity, smoking and generalized health. More than 20 specific genes have been recognized that play a role in the development of osteoporosis and have been shown to contribute to up to 80% of the variation in peak bone mass in the studies of twins.

Osteoporosis can happen either through an individual’s failure to achieve a normal peak bone mass or through excessive bone resorption. It is well known that postmenopausal women are at the utmost risk of developing osteoporosis due to estrogen deficiency. [150]

In osteoporosis of the spine, the intervertebral discs often become ballooned because of the collapse of the cancellous bone of the vertebral bodies. The changes are seen most commonly in the thoracic and upper lumbar spine. [151]

Patients presentation

In most cases of osteoporosis the patients are initially asymptomatic prior to diagnosis. The onset of pain associated with a fracture is frequently the first indication that a patient has osteoporosis.

Osteopenia (low bone density) is a precursor to osteoporosis. It is considered to be a risk factor for the development of osteoporosis. There are several biologic and

lifestyle factors that increase the risk for osteoporosis. Osteoporosis can be either primary or secondary. Primary osteoporosis does not have an identifiable cause, while secondary osteoporosis results from another concomitant disorder e.g. hypogonadal disorders hemophilia, sickle cell disease, gastrointestinal disorders etc. [152]

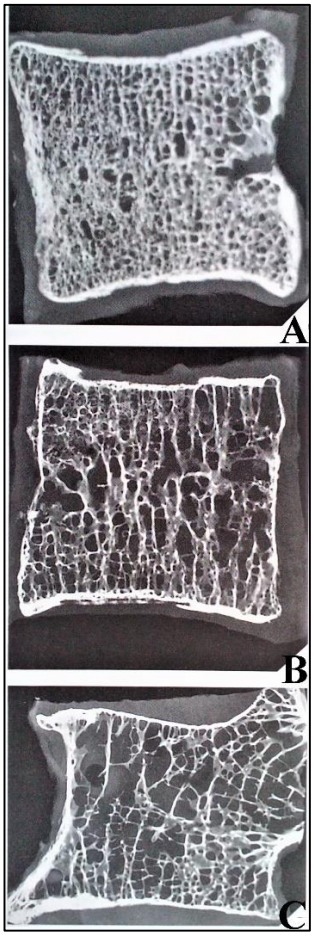


Fig. 53 Radiograph of vertebral body. A-Normal bone texture, density and pattern. B-Moderate degree of osteopenia with accentuation of the vertical trabeculae and a selective loss of the horizontal trabeculae. C-Severe osteoporosis with irregular pin trabeculae and partial central collapse of the superior end plate.

Radiographic findings

The radiographic diagnosis of osteoporosis in the spine is created on bone porosity, a change in trabecular pattern and a change in vertebral body shape. From 30% to 50% off the bone must be lost before a detectible abnormity can be seen on routine spinal radiographs. In the vertebral bodies it has been observed that there is a selective loss of horizontal trabeculae with a resultant accentuation of the vertical trabeculae. This leads to the presence of prominent vertical radio dense striations or bars.

Osteoporotic changes include flattening of the vertebral body, anterior wedging of the vertebra and a biconcavity of the vertebra that is sometimes mentioned as a fish mouth vertebra. All of these deformities are owing to compression fractures within the vertebral body, with the type of deformity seen depending on the local mechanical situation as determined mainly by location. [153]

Deposition diseases affecting the spine [154]

In children intervertebral disc calcification mostly involves cervical spine it is symptomatic in 80% of affected children with neck pain as the usual symptom. The nucleus pulposus is the usual site affected by this condition. In the adult the disc of the thoraco-lumbar spine are frequent sites of calcification while the lower lumbar and cervical regions of the spine are less commonly affected. Though generally asymptomatic calcification of the intervertebral disc seldom may lead to clinical symptoms with spinal cord or nerve root compression due to herniation of the calcified mass. Such deposits may also accelerate disc degeneration by interfering with disc nutrition and mechanical function. The calcium deposits may occur at single or multiple levels. The deposits of calcific material are also found in the paraspinal ligaments and in the facet joints.

Ochronosis [155]

The term ochronosis is used to describe an abnormal breakdown pigmentation of the cartilage and other connective tissues, which is the effect of the failure to metabolize homogentisic acid due to an inherited deficit of the enzyme homogentisic acid oxidase.

In general, the affected individual is asymptomatic until adult life; at which time ochronotic arthropathy may develop in the joints of the appendicular and axial skeleton.

When the spine is involved back pain and stiffness are the usual complaints and usually there is loss of the normal sagittal alignment accompanied by the restriction of movement. Postural deformity eventually may simulate that of ankylosing spondylitis. The earliest findings of ochronosis are seen in lumbar spine, as black brown pigmentation of the intervertebral discs, which is more pronounced in the cartilaginous plate and annulus fibrosus. Pigmentation also may be present in various vertebral ligaments.

In the spine natural history of the disease is one of a decrease in the disc space height with subchondral sclerosis, boney proliferation around vertebral bodies (in the form of osteophytes) and subsequent bridging of the bodies. An association between intervertebral disc calcification and ochronosis is well known.

Genetic factors in degenerative changes in the spine [156]

Genetic factors are supposed to be contributing to the onset of structural and degenerative changes in the spine. Spondylolisthesis, scoliosis, Schmorl's nodes etc. show familial clustering. X ray and MRI analysis of identical twins show matching degenerative changes suggestive of contribution of genetic factors. It is observed that juvenile prolapse of intervertebral disc show family aggregation and hereditary predisposition (or genetic susceptibility is an increased likelihood of developing a particular disease based on a person's genetic makeup).

Cervical radiculopathy [157]

A constriction of the venous blood flow from the nerve root can lead to edema and fibrosis of the nerve root. Various neurogenic and non-neurogenic chemical pain mediators have also been reported to be released from the degenerative disc that can result in radicular symptoms. These include substance P, somatostatin, vasoactive intestinal peptide, calcitonin gene-related peptide, angiotensin II, bradykinin, serotonin, histamine, acetylcholine and prostaglandin E1 and E2.

Table no. 26 Neurologic findings associated with cervical radiculopathy [158]

Nerve root	Motor function	Sensory location	Reflex
C5	Deltoid, biceps	lateral arm	biceps
C6	biceps wrist extensors	lateral forearm thumb and index finger	brachioradialis
C7	Triceps, wrist flexors, finger extensors	middle finger	triceps
C8	Finger flexors	medial forearm ring and small fingers	none
T1	Interossei muscles	medial arm	none

Differential diagnosis of cervical disc disease [159]

It includes cardio pulmonary disorders, angina, temporomandibular joint disease inflammatory arthritis, peripheral nerve entrapment, rotator cuff pathology, brachial plexitis, herpes zoster, thoracic outlet syndrome, cervical epidural abscess, cervical stenosis, cervical spine fracture, and cervical spine tumor.

History and physical examination of the spine [160]

There are certain clues that can be identified based on the patient's recent history, past medical history age and physical examination findings that can lead the clinician to a differential diagnosis. The most important initial goal line is to rule out the presence of any serious pathology that needs emergent treatment i.e. cancer, infection and fracture.

The most common complaint of patients with spinal disorders is pain. Character of the pain can be described as sharp, dull, burning, cramping etc. It can be isolated to the axial spine or radiate to the extremities.

Axial pain is more commonly associated with degenerative disc disease, facet joint degeneration and muscular and ligamentous structures. Radicular pain is more commonly caused by root compression from disc herniations or stenosis. The location of radicular pain often follows a specific nerve root distribution that can help in determining the location of the pathology.

Dissection of neck

Dissection of antero-lateral aspect of neck

Cut and reflect the antero-lateral skin of neck. In the reflection of the skin take care to work superficially to avoid damage to the supraclavicular and accessory nerves. Make an incision through the skin form the mastoid process to the sternal end of the clavicle along the middle of the sternocleidomastoid muscle. Extend the incision along the clavicle to its acromial and reflect the flap to the anterior border of trapezius. Divide the platysma along the line of the clavicle and turn it upwards and forwards. Find the external jugular vein trace it upwards till it is joined by the posterior auricular vein and downwards till it pierces the deep fascia. Identify the three supraclavicular nerves.

Fig.54 Neck surface before dissection.

Fig. 55 Anterior of neck after removal of skin.

Clean the contents of the posterior triangle. Cut through the attachment of sternocleidomastoid and reflect this part of the muscle forwards. Expose the scalenus anterior muscle. And observe sternohyoid, omohyoid transverse cervical artery anterior jugular vein subclavian vein and phrenic nerve.

Fig. 56 Superficial dissection of the neck.

Remove the superficial muscles observe the larynx, thyroid cartilage, thyroid gland, carotid sheath and its contents.

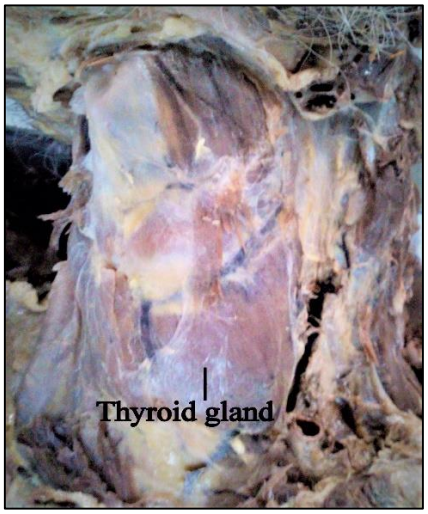


Fig. 57 The larynx, thyroid cartilage, thyroid gland, carotid sheath and its contents.

Remove the larynx and trachea to see the oesophagus lying posteriorly after the removal of oesophagus the anterior aspect of the cervical spine is seen the floor of mouth and remove the muscles tongue along with the mandible so as to expose complete anterior aspect of cervical spine muscles of the neck that is longus capitis, longus coli, scalenus anterior etc.

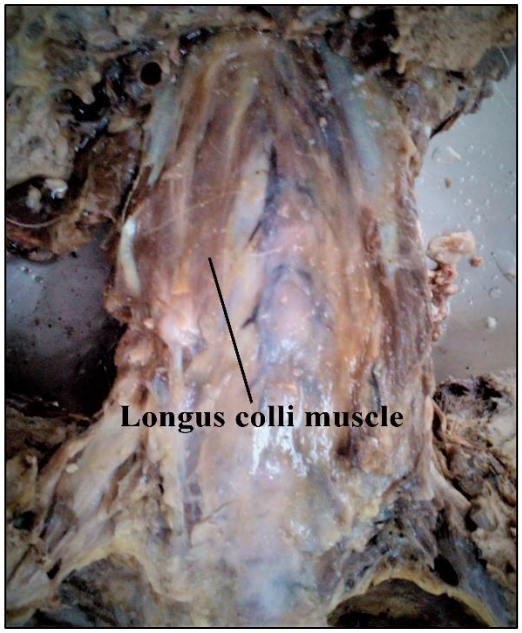


Fig. 58 Anterior aspect of cervical spine.

Remove the scalenus anterior and longus capitis from their origin and expose the small intertransverse muscles. They are separated by the ventral rami of the cervical nerves and the dorsal rami pass posteriorly medial to the posterior intertransverse

muscles. The vertebral artery may now be exposed in the intertransverse spaces by removal of the intertransverse muscles. After removal of vertebral muscles anterior longitudinal ligament is found attached to the vertebral bodies and the intervertebral discs.

Fig. 59 Vertebral bodies, intervertebral discs and anterior longitudinal ligament.

Dissection of the back of neck

Make a vertical median incision through the skin from the external occipital protuberance to the seventh cervical spine and a horizontal incision laterally from this to the acromion. Reflect the skin flap and examine the posterior triangle from the back.

Fig. 60 Neck surface before dissection

Fig.61 Trapezius seen after removal of skin and fasciae.

Clean the surface of trapezius separate the muscle from the occipital bone and divide it vertically from the vertebral spines. Reflect the muscle laterally and identify the accessory nerve the branches of the 3rd and 4th cervical nerves. Identify the attachments of the levator scapulae. Reflect the serratus posterior superior and find its nerve entering its deep surface. remove the thoracic part of thoracolumbar fascia and study splenius. Detach splenius from its origin and turn it towards its insertion.

Clean the semi-spinalis and longissimus capitalistic. Clean the artery deep to the mastoid process by reflecting longissimus. Clean the parts of the suboccipital muscles that are exposed. Detach the semi spinalis capitals from the occiput and turn it literally. Find the deep cervical artery in the dense fascia beneath it. A twig may be found entering it from the first cervical dorsal ramus and a larger branch from the greater occipital nerve. Clean the muscles which surround the sub occipital triangle.

Fig. 62 Paraspinal muscles seen after removal of trapezius.

Fig.63 Deeper dissection of neck.

Remove all the muscles of the back and clean the laminae and spines of the vertebrae.

Remove the posterior wall of the vertebral canal in one piece by sawing through the lateral parts of the laminae and dividing the ligamenta flava in a coronal plane. Take care not to cut completely through the laminae but complete the division by levering up the laminae and spines. The spinal cord and its covering lie deep to this and should not be injured. Clean the outer surface of the dura mater and the collateral prolongation which it sends as sheaths over the spinal nerves.

Fig. 64 Laminae and spines of vertebrae after removal of back

Fig. 65 Dural tube inside the vertebral canal.

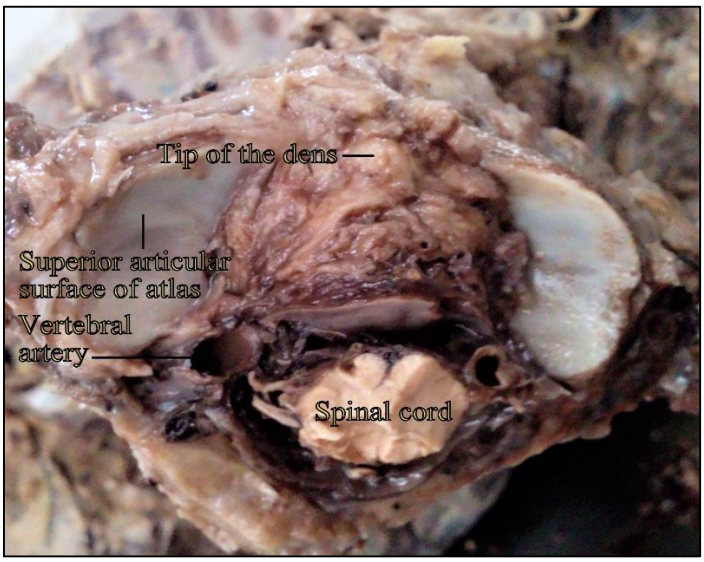


Fig. 66 Structures inside the atlas seen from above

Open the dura with the scissors take care not to injure the arachnoid mater, which is applied to its deep surface. Take an incision through arachnoid mater and explore the subarachnoid space.

Follow the nerve roots of one or two spinal nerves in each region into the corresponding intervertebral foramina by snipping away the articular processes with bone forceps. Note the position of the spinal ganglia and study the dural sheets of the roots. Note the union of the two roots, the spinal nerve and its two rami attempt to find the recurrent meningeal branch. display the pia mater with the ligamentum

denticulatum. Note the rootlets of the spinal part of the accessory nerve which ascends posterior to the ligamentum denticulatum in the upper cervical region.

Divide the spinal nerves in the intervertebral foramina leaving as long a piece of each nerve attached to the dura as possible. Examine the exit of the roots of spinal nerve through the dura from the inside. Note that the dorsal and ventral root each receive a separate dual sheath. examine these by passing a fine blunt probe into each foramen. It is usually possible to reach the distal part of the ganglion along the sheath of the dorsal root without piercing the dura.

Fig.67 Spinal cord with nerve roots and meninges.

Remove the muscles completely so as to examine the vertebral joints and their ligaments. Clean the column of laminae that was laid aside when the vertebral canal was opened and exposed the ligaments which connect its parts. Remove the remaining cervical laminae and spines below the axis by cutting through the laminae medial to the articular processes.

To expose the other ligaments, remove the laminae of the axis and the posterior arch of the atlas with bone forceps. Remove the tube of spinal dura matter and remains of the spinal cord and expose the membrana tectoria. Remove the membrana tectoria and expose and clean the cruciate and accessory atlantoaxial ligaments. Identify the divided right alar ligament and clean out the left alar ligament.

After the remove of neural tube with spinal cord, posterior aspect of vertebral bodies and intervertebral disc are exposed covered by posterior longitudinal ligament. Inspect for any intervertebral disc bulge. Cut the inferior articular process to see the intervertebral canal and foramen. The nerve roots are observed under the covering of dura mater. Transforaminal ligaments are observed attaching dural sheath to the intervertebral canal.

Fig.68 Articular surface of articular process and intervertebral canal.

Fig. 69 Nerve roots in the tube of dura mater and transforaminal ligaments.

Take mid sagittal section with bone cutting saw in the bodies of the upper part of the cervical spine. Observe the interior of the bodies and intervertebral disc in the section. Anterior bulging of any disc can be seen in the section prominently. Take transverse section passing through any intact intervertebral disc of cervical spine observe the section. identify the annular fibrosus and nucleus pulposus.

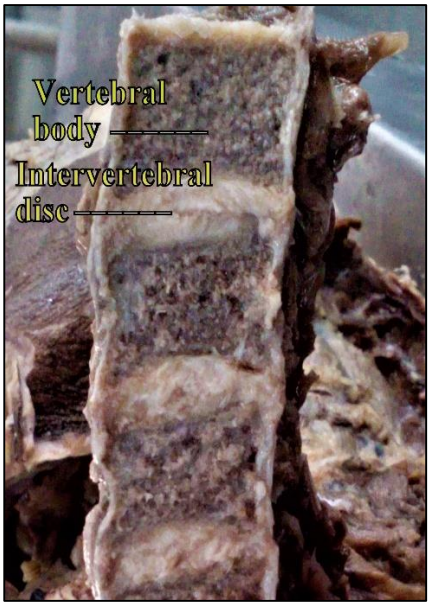


Fig.70 Mid sagittal section through bodies.

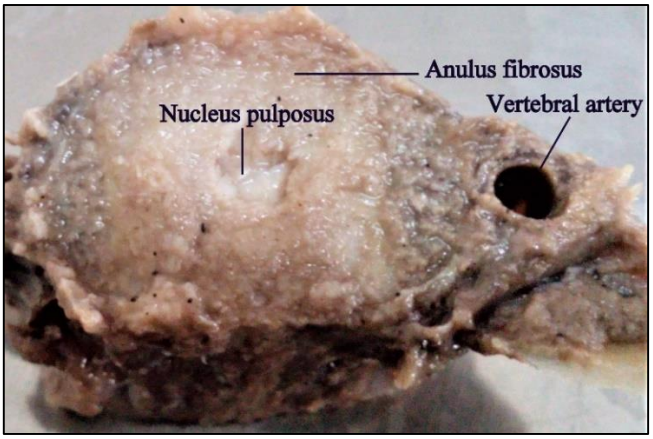


Fig.71 Transverse section passing through the intervertebral disc.

Goniometer measurement of neck movements

A combination of pain and stiffness, leading to loss of function, is a classic feature of joint disease. [161]

Range of movement [162]

When examining joints for range of movement it is usually sufficient to estimate the degree of limitation based on comparison with the normal side or on the examiner's previous experience. For accurate description the actual range of movement should be measured with a goniometer. Limitation of movement in a joint may be due to pain, muscle spasm, contracture, inflammation, increased thickness of the capsular or periarticular structures, effusion into the joint space, bony overgrowth, bony ankylosis, mechanical factors such as a torn meniscus or to painful conditions quite unconnected with the joint.

The following neck movements should be tested

Flexion

Extension

Lateral bending

Rotation

Goniometer

It is a device used to measure the angle of joint movement or range of joint motion in degrees.

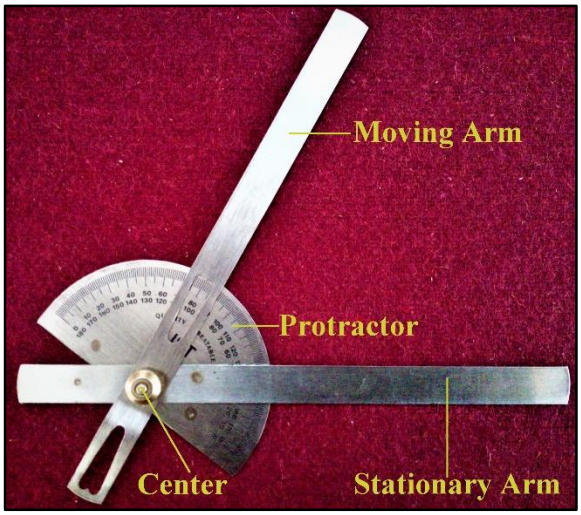


Fig. 72 Goniometer

It is provided with **stationary arm**, **moving arm** and **protractor** for the measurement of angle between the arms. All three parts are fixed at the center of the protractor by an adjustable screw.

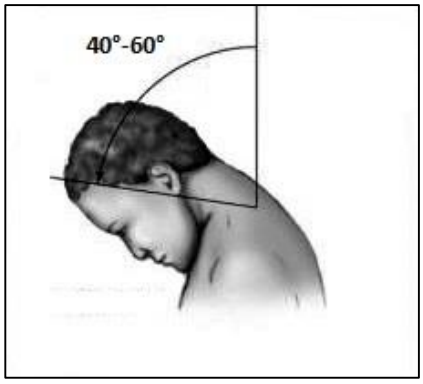
Measuring the angle of movement

Test position- 1) Give sitting position to the patient.

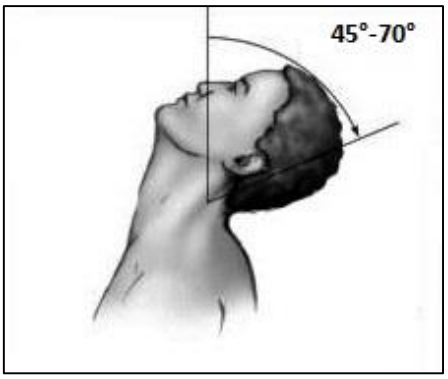
2) Stabilize lumbar and thoracic spine.

3) Ask the patient to move head and cervical spine to measure the angle of movement.

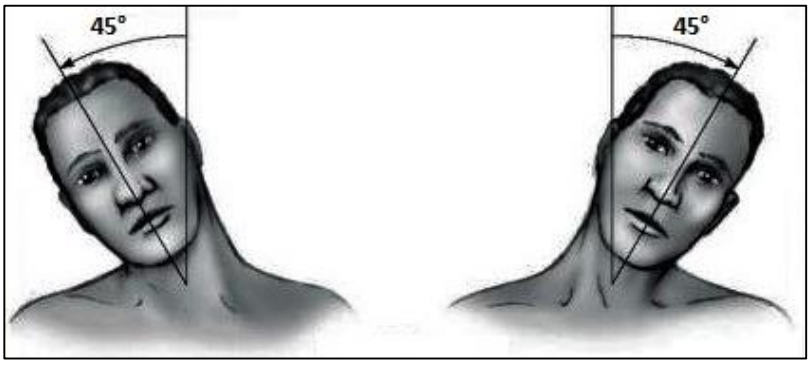
Goniometer alignment- Both the arms should be aligned suitably for measuring specific angle of movement.



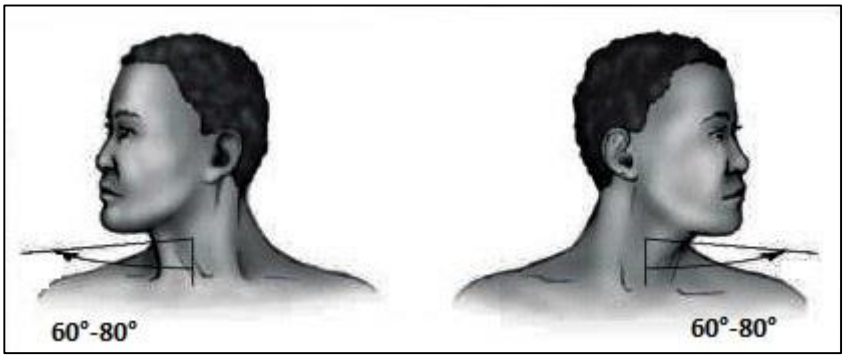
Forward flexion



Backward extension



Right and left lateral flexion



Right and left rotation

Fig.73 Angles of head and neck movement

Review of degenerative spinal diseases through the MRI study [163]

MRI as imaging modalities

Magnetic resonance imaging is often the modality of choice in evaluation of spine because of its superior soft tissue contrast. Dynamic plain films, weight bearing CT or MRI have been used for the study of spinal stenosis. Previously occult abnormalities including disc herniation, ligamentous infolding subluxation may all be demonstrated using kinematic MRI. Functional information concerning vertebral stability may also be provided on the dynamic examination

The distribution of axial load determines the common sites of spine degeneration. In the cervical spine it is C5- C6 and C6 - C7 levels as these are the sites of lordosis inversion.

Degenerative joint disease is a general term to describe degenerative alterations in any type of articulation, i.e. synovial, cartilaginous or fibrous. It is a disease of the entire joint in which all articular structures are affected. Osteoarthritis has a greater preference for involving certain joints in while sparing others. For example, it is highly prevalent in the spine and knees. Imaging evaluation of osteoarthritis has become mainly significant due to the occurrence of the condition, the increased life span of the population newer treatments that are being developed.

Degenerative disorders of the spine

Degenerative diseases of the spine are collection of conditions that represent some of the most common indications for advanced imaging studies. Degenerative changes may rise in the vertebrae, intervertebral discs, facet joints and ligaments. Degeneration at various sites is associated to each other since the main common pathogenetic factor is chronic overload. Since involvement of one site predisposes the other sites to degenerative changes owing to altered biomechanical forces, patients often present with degenerative changes in multiple sites.

Distinguishing age-related changes and degenerative changes of disc with MRI

The intervertebral disc undergoes marked changes with aging which must be distinguished from degenerative changes in the disc. Prevalence of degeneration increases with age, but most disc in normal aging individuals do not show changes in height and morphology that characterize degenerating discs. With aging, small concentric and transverse tears may develop in the annulus. The composition of the intervertebral disc may change with decrease in glycosamineoglycans and increase in collagen, and hence a decrease in affinity for water. Therefore, aging can decrease the

signal intensity of the disc by a few percent. However, loss of high signal intensity on T2WI or loss of disc height cannot be entirely attributed to ageing.

Degenerating disc may suffer dehydration, fissures, bulging and herniations. On MRI the earliest appearance of degeneration of the nucleus is desiccation, manifest as low signal intensity on T2 weighted images instead of high signal of normally hydrated discs. Although it is usually asymptomatic, it suggests disc overload and is a precursor to further degenerative abnormalities. There is a progressive loss of disc height. One morphological feature that characterizes disc degeneration is annular radial tears. Development of annular radial tears results in shrinkage of fibrocartilage in the nucleus pulposus and replacement by dense fibrous tissue and cystic spaces. The disc becomes more and more fibrous and organized with no clear distinction between nucleus and annulus. Negative pressure produced by abnormal spaces pulls in gas, predominantly nitrogen resulting in *vacuum disc phenomenon*.

The disk may show linear or patchy low signal intensity either due to gas or sometimes, calcification. When occasionally fluid may be pulled instead of Nitrogen, there may be inconsistent high signal appearance of the disc on T2WI instead of the low signal intensity of desiccated disc. Associated disc narrowing and endplate changes and osteophytes are pointers that this seemingly hydrated disc is a degenerated disc. With progress of degeneration, disc calcification may occur. This can appear as increased or decreased signal on T1WI. Paradoxical high signal onT1WI may be seen depending on the amount and state of calcium.

Annular Disruption is a serious factor in degeneration. Annular fibre degeneration may result in tears 1) type 1 -circumferential or concentric tears 2) type 2 radial tears 3) type 3- transverse tears. Concentric tears are tears that run longitudinally along the plane of collagen fibres and precede annular bulging. These are seen as focal hyperintense areas in the external aspect of annulus. Transverse tears are raptures of *Sharpey's* fibres adjacent to the ring apophysis and can be seen in normally hydrated disc. Radial tears are linear rupture of the annulus fibres extending from the nucleus pulposus traversing the entire inner to outer dimension of the annulus and correlate with shrinkage and disorganization of the nucleus. This can progress to more severe disruption and disc herniation. On MRI radial tears look as hyperintense transverse band into the annulus. These high intensity zones may increase suggesting growth of

granulation tissue. Presence of high intensity zones or even their enhancement is no more supposed to be correlated with the acuity of the tear.

Study of disc herniation with MRI

Disc herniation is restricted displacement of the disc material involving less than 50% of the circumference of the disc. In contrast, disc bulge by definition is not herniation and is the term used when there is a smooth circumferential extension of the disc margin beyond the boundary of the adjacent vertebral end plates in over and above 50% of the disc circumference. This is typically less than 3 mm beyond the edges of the vertebral body. The annulus fibrosus is grossly intact, although weakened due to tears in the oblique collagen bridges between the concentric annular fibres. The concentric fibres are intact.

On MRI there is uniform circumferential extension of the outer disc margin. There is usually loss of height of the involved disc space and desiccation of the nucleus pulposus. Apart from degeneration disc bulge has several etiologies, normal variation, ligamentous laxity, vertebral body remodeling because of osteoporosis or even partial volume averaging.

Disc herniation can be classified into disc protrusion and disc extrusion. When the greatest distance between the ages of the disc material beyond the disc space is less than the distance of the edges at the disc base in all planes, it is referred to as disc protrusion. The disc protrudes through a defect in the inner annulus but the outer annular fibres are intact. Protrusions may be classified as focal or broad based on their degree of disc involvement. It is termed a focal protrusion when it involves less than 25% of the disc circumference, whereas the term broad based protrusion is used when it involves between 25% and 50% of the disc circumference.

When the distance between the ages of the disc material beyond the disc space is greater than the distance between the ages of the base in at least one plane it is called disc extrusion. The extruded disc suggests complete rupture of the annulus fibrosus. Disc extrusions may be further classified into migrated or sequestrated discs. The disc that displaces away from the site of extrusion but still maintains continuity with the parent disk is known as the migrated disc. Sequestration are disc extrusion that get detached from the parent disk.

In the axial plane it is classified into various zones as central, subarticular (lateral recess), foraminal and extraforaminal (far lateral). The medial edge of the facet articulations and the borders of the pedicles or the neural foramina are used for

anatomic landmarks, although they may be difficult to interpret on axial images as they are curved structures.

The axial classification is useful as it describes the herniation relative to the various exiting and traversing nerves. In the cervical spine disc herniations tend to involve the nerve root at the same level. This Information is important to determine whether patient's symptoms are attributable to MRI imaging findings, for preoperative planning and to avoid surgery at the incorrect spinal level. MRI is the most frequently used technique for assessment of disc herniation.

CT is more sensitive than MRI for detecting the presence of transdiscal gas, predominantly nitrogen. This is known as the vacuum phenomenon and is very precise for disc degeneration and is only rarely encountered in infective discitis. CT is so more accurate in detection of the discal calcification and posterior osteophytes which may have therapeutic implications. On MRI, bright T1 signal may be found with mild to moderate intradiscal calcium deposition.

Imaging studies with 6 to 12 months follow-up have demonstrated that nearly 63% of disc herniations may show spontaneous reduction in size. This may be due to dehydration, fragmentation and phagocytosis of the disc material. This is greatest in extrusion and sequestrations.

Endplate changes

Modic Type 1 changes (vascular pattern) correspond to active inflammation, showing decrease signal on T1WI and high signal T2WI. Type 2 changes (fatty pattern) reflect fatty infiltration and show bright signal on both T1 and T2 weighted images. Type 3 changes (sclerotic pattern) are seen in advanced chronic stage, and correspond to bone sclerosis. This is seen as decrease signal on both T1 and T2 weighted images. These changes are also apparent on radiographs and CT. Sometimes more than one type of modic change can be seen at the same level.

On MRI we can see direct continuity of the disc material into the region of the end plate defect. In Acute /subacute cases there may be increased T2 signal, typically following the contour of the end plate which may also demonstrate enhancement.

Diseases of facets, uncovertebral joints and ligaments

Like father synovial joints these are predisposed to arthropathy with alterations of articular cartilage. Facet joint changes may be primary or secondary to disc degeneration. The letter is believed to be the main inciting factor for facet osteoarthritis.

Secondary to disc degeneration, increased loading on facets and increased mobility at a segment can contribute to facet arthropathy. Facet tropism (asymmetry) and more sagittal orientation of facets greater than 45 degrees are other hypothesized causes. It has been postulated that facet joint degeneration is more likely associated with patient symptoms as this is less frequently found in asymptomatic individuals compared to disc degeneration. Imaging findings include joint space narrowing, subchondral sclerosis and cyst formation, osteophyte formation, vacuum phenomenon and hypertrophy of the articular processes. In addition, edema in the adjacent posterior elements and soft tissues.

In the cervical spine additionally, vertebral joints can undergo degeneration. These develop between the uncinate processes of the lower vertebrae and the lateral margin of superior vertebrae and are found from C2-3 level to C6 -C7 level. These are variable joints, not present at all levels and not seen in the infants. These joints are lined with cartilage, which is presumably continuous with the adjacent cartilaginous endplate. These are clinically important as degeneration of these joints plays an important role in foraminal stenosis and nerve root compromise in the cervical spine.

Narrowing of the intervertebral disc may lead to abnormal contact between spinous processes, leading to degeneration of the spinous processes and interspinous ligaments. This may result in interspinous pseudoarthrosis and cyst formation and has been termed *Baastrup's phenomenon*. There is localized tenderness that is exacerbated with Extension and relieve with flexion. Redundant interspinous ligaments, interspinous Bursae or hypertrophic degeneration may extend anteriorly contributing to spinal canal stenosis.

Spondylosis deformans and intervertebral osteochondrosis

Spondylosis deformans essentially affects the annulus fibrosus and adjacent apophysis. The classic sign of Spondylosis deformans is osteophytosis. Osteophytes are bony spurs that originate on the antero-lateral aspect of the vertebral body a few millimetres form the margins of the disc space. Increased vertebral motility due to weakening and radial degeneration of annular fibres and resultant traction on Sharpey's fibres stimulates osteogenesis. Initially osteophytes have a triangular horizontal extension (in contrast to syndesmophytes in seronegative arthropathies which are vertically oriented).

In more advanced cases osteophytes become hooked and grow more vertically. These may fuse together on either side of the disc space to form bridging osteophytes.

The mucoid matrix of the disc becomes fibrous. However, disc height is normal or only slightly decreased and the disc margins are regular. Posterior osteophytes, although less common, are clinically more relevant because of possible compression of neural structures. They have a triangular shape with marginal location. Large posterior osteophytes may result in spinal stenosis with compressive myelopathy especially in the cervical region.

Computed tomography and MRI although can depict osteophytes are useful for other associated degenerative changes or to establish relationship between osteophytes and neural structures.

Vertebral osteochondrosis is a pathological process although not always symptomatic. It involves primarily the nucleus pulposus and vertebral endplates. There is accompanying fissuring of the annulus fibrosus. Early disc changes seen on sagittal FSE T2 WI include loss of normal T2 hypointensity within nucleus. Late changes include further decreasing signal within the nucleus pulposus, loss of distinction between nucleus pulposus and annulus fibrosus, disc space narrowing, disc bulging, vacuum phenomenon and endplate changes. posterior osteophyte formation may also occur at this stage.

Complications of degenerative spinal disease

Acquired stenosis is most commonly due to degenerative changes and usually involves the cervical and lumbar spine. The central canal may be narrowed anteriorly by degenerative disc, posterior bulging of posterior longitudinal ligament or posterior osteophytes and posteriorly by facet joints and ligamentum flavum. Other less common causes of acquired spinal canal stenosis include ossification of the PLL and/or LF and epidural lipomatosis.

Although absolute measurements may not be clinically relevant in all cases, the diagnosis of spinal canal stenosis should be considered if the anteroposterior diameter of the cervical and lumbar canal is less than 12 mm and in the thoracic region if it is less than 10 mm. Stenosis may also be considered is the ratio between canal sagittal diameter and vertebral body sagittal diameter is less than 0.8. more than objective canal measurements, it is the subjective evaluation of canal morphology and relationship between containing and contained structures that correlates better with patient's symptoms.

Epidural fat is reduced or disappears. multiple anterior and posterior notches can be observed on the dura sec, with disappearance of the subarachnoid space and

narrowing of the spinal cord. The stenosis is severe if CSF signal is completely affected on axialT2 W I or CT myelogram images. Myelopathy is the most serious complication of canal stenosis. It is thought that continuous pinching of the cord can result in chronic hypoperfusion and result in demyelination and neuronal death. Increased intramedullary signal on T2 W I is seen that indicates the presence of edema, chronic ischemia, myelomalacia or rarely syringomyelic cavitation. Enhancement on T1 W I may confirm the abnormity. Low signal on noncontract T1 WI suggest a poor prognosis. However, it must be remembered that absence of abnormal signal does not rule out myelopathy, as clinical and electrophysiological criteria may be more sensitive.

Facet hypertrophy, PLL thickening or disc herniation can lead to encroachment of lateral recesses. this is best evaluated on axial images and is found most commonly at L4-5 level. the normal sagittal diameter of the lateral recess is less than 5 mm, when this space is less than 4 mm, it is considered stenotic disc and facet degeneration can also project into the neural foramina, causing their narrowing. remodeling of the endplates secondary to disc degeneration results in wider and shorter vertebral body and this may also cause narrowing of the spinal canal, lateral recess and neural foramina.

Loss of disc height may result in anterosuperior slippage of the facet joint and narrow the craniocaudal diameter of the foramen and hence contributing to neural foraminal narrowing. In the cervical spine neural foraminal narrowing is most commonly caused by uncovertebral osteophytes.

Cervical neural foramina are best evaluated on axial MR images. On sagittal MRI foramen is seen as an ovoid structure, filled with cerebrospinal fluid and fat. Mild narrowing is seen as a keyhole appearance. Moderate narrowing effaces the inferior portion of the foramen at the level of the disc. Severe narrowing results in effacement of the fat in the foramen. There may be loss of fat around the exiting nerves and thecal sac. Inflammatory changes around the entrapped nerve may enhance on gadolinium administration. It must be remembered that correlation with symptoms of radiculopathy is essential to diagnose nerve root impingement.

Segmental instability

Disc degeneration can lead to narrow disc space and buckling of ligamentum flavum which can further result in an unstable vertebral segment. Resultant malalignment may result in antero-listhesis, postero-listhesis, roto-listhesis (rotational spondylolisthesis) or lateral spondylolisthesis. Degenerative roto-listhesis occurs

classically secondary to disc degeneration and results in canal and foraminal stenosis. It may also occur secondary to asymmetric facet degeneration. In patients with degenerative scoliosis, lateral and roto-listhesis is often encountered. Postero-listhesis which is associated with facet and disc degeneration is frequent at more mobile spine segments such as the cervical and lumbar spine.

Secondary to segmental instability, hypertrophy of the ligaments, facet osteoarthritis, and osteophyte formation may develop which have an additive effect on narrowing of the spinal canal and foramina. These osteophytes may aid in stabilizing the spinal segment which may be shown on kinematic MRI imaging. Vertebral body moment may be seen on flexion, Extension and lateral bending radiographs where instability may be diagnosed as loss of alignment of one or more vertebral lines. Other radiographic signs are vertebral slippage, variations in pedicle length, narrowing of neural foramina, and loss of disc height. Conventional MRI has a limited role. It may show displacement and pseudo bulging of disc at the involved level. Axial loaded MRI or upright MRI can provide functional information regarding vertebral stability.

Materials

1) A case record form containing-

a) Ayurvedic method of examination of patient for *manyāstambha*

b) Documentation of findings from MRI of cervical spine.

2) Randomly selected 150; screened patients of *manyāstambha.*

3) Reports of their MRI of cervical spine.

Inclusion criteria-

1) Patients suffering from chronic (at least from last 1 years) *manyāstambha.*

In *manyāstambha*; the stiffness or rigidity of the neck may be associated with pain and both may be due to the structural involvement and changes in the cervical spine.

2) Patient selection was irrespective of gender, religion, education, occupation and economical status.

3) Patient age criteria was from 30-70 yrs.

Exclusion criteria –

Patients of *manyāstambha* having following conditions are excluded from the study.

1) Patients having traumatic injuries of spine.

2) Patients suffering from any infections of spine

3) Patient diagnosed as Potts spine (tuberculosis of spine).

4) Patients suffering from rheumatoid arthritis.

5) Patients suffering from malignancy of spine or any other organ.

6) Spinal cord and spinal nerves disorders e.g. injuries, infections, a blocked blood supply, and compression by a fractured bone or a tumor.

7) Neurologic disease (e.g., multiple sclerosis, Parkinson's disease)

8) Pregnant women.

9) Patient having Congenital Structural Deformities of spine.

10) Patients who have previously undergone spinal surgery.

11) Patients contraindicated for radiological investigation.

12) Patient age below 30 and above 70 yrs.

Methodology

150 patients of *manyāstambha* were selected from the hospitals and OPDs, considering the inclusion and exclusion criteria. Detail description of *manyāstambha* is not found in ancient texts. The symptom found in this disease is chronic neck stiffness. This was considered for the diagnosis of this disorder. There is restriction in the movement of the neck due to advancement of the disease and pain.

The patients were enrolled for the study by the following steps.

1) The purpose of this project was explained to participating patient.

2) All the aspects of physical examination were explained to participating patient.

3) The patients were enrolled after explaining the method of clinical examination and study

of radiological investigation (MRI of cervical spine) findings.

4) After the enrollment, the patients were examined according to the steps mentioned in the case record form and findings from their MRI of cervical spine were marked.

Ayurvedic parameters for assessment of *manyāstambha*

Trividha parikṣan method described in *Āyurved* i.e. *darṣan*, *sparṣan* and *praṣna* were applied for the assessment of *manyāstambha*. The movements of cervical spine are- 1) forward flexion, 2) backward extension, 3) right lateral flexion, 4) left lateral flexion 5) right rotation, 6) left rotation. These movements are restricted in *manyāstambha.*

Method of examination	Examination
Darṣan	Observation of range of movements of neck i.e. 1) forward flexion, 2) backward extension, 3) right and 4) left lateral flexion and 5) rotation with goniometer.
Sparṣan	Observation of neck rigidity.
Praṣna	Patient was asked questions for determining the extent of various neck movements and pain.

By means of the goniometer we get goniometric measurements of combined movements of head and cervical spine. This can specify restriction of neck movement. The following table summarizes the method to obtain goniometric measurements of these movements-

Table no. 27 Goniometry of the cervical spine and head

Movement	Testing Position	Stabilization	Center	Stationary Arm	Moving Arm
Flexion	Sitting straight, the patient is asked to touch chin to chest.	Shoulder girdle is stabilized to prevent flexion of thoracic and lumbar spine	Over the external acoustic meatus	Perpendicular to ground	Towards the center of cranial aspect of head
Extension	Sitting straight, the patient is asked to look up to the ceiling.	Shoulder girdle is stabilized to prevent extension of thoracic and lumbar spine	Over the external auditory meatus	Perpendicular to ground	Towards the center of cranial aspect of head
Lateral flexion	Sitting straight, the patient is asked to bend the neck sideways and try to touch the shoulder with the ear without raising the shoulder at both sides.	Shoulder girdle is stabilized to prevent lateral flexion of thoracic & lumbar spine	Over spinous process of C7	Spinous processes of thoracic vertebrae so that arm is perpendicular to ground	Dorsal midline of head. Reference occipital protuberance.
Rotation	Sitting straight, the patient is asked to look over one, then the other shoulder	Shoulder girdle is stabilized to prevent rotation of thoracic and lumbar spine.	Over center of cranial aspect of head	Parallel to imaginary line between the two acromial processes	With the tip of the nose.

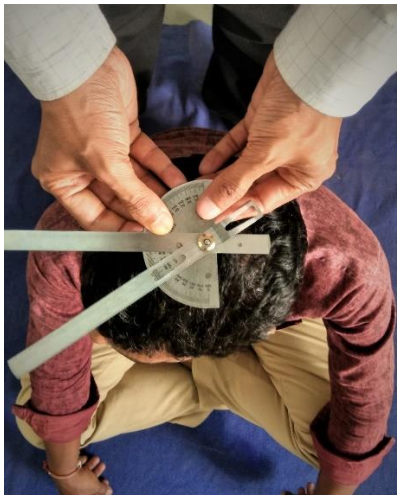
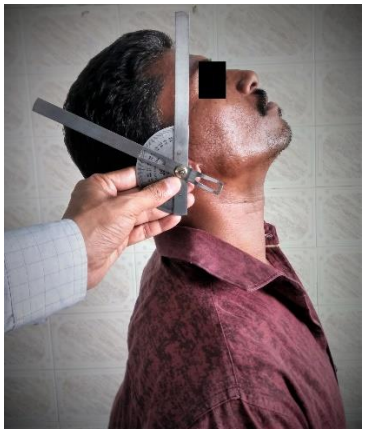
Flexion and Extension	Lateral flexion	Rotation
		
Straight sitting position	Straight sitting position	Straight sitting position
		
Flexion	Right lateral flexion	Right lateral rotation
		
Extension	Left lateral flexion	Left lateral rotation

Fig. No. 73 Method of Goniometry of the cervical spine and head

Table no.28 The range of restriction of neck movement

Gradation	Range of restriction of neck movement
grade 1	1 % to 25%
grade 2	26 % to 50%
grade 3	51 % to 75%
grade 4	76 % to 100%

Table no.29 Summery of the goniometry examination

Sr. No.	Neck movement	Standard range of neck movement	Goniometric measurements	Restriction of neck movement	Gradation
1	Forward flexion	40˚ to 60˚			
2	Backward extension	45˚ to 70˚			
3	Right lateral flexion	45˚			
4	Left lateral flexion	45˚			
5	Right rotation	60˚ to 80˚			
6	Left rotation	60˚ to 80˚			

Modern Parameters for Assessment of *manyāstambha* –

To find the structural involvement and changes in the cervical spine; investigation findings from MRI of cervical spine of the patients were recorded in the Case Record Form.

Table no.30 Findings from MRI of cervical spine

No.	**Structure**	**Probable findings**
1	Cervical muscles	Muscle spasm
2	Vertebral alignment	Change in the vertebral alignment due to displacement of vertebrae in the form of listhesis.
3	Curvature of cervical spine	Straightening of cervical spine in the form of loss of lordosis, development of kyphosis and scoliosis.
4	Ligaments	Thickening and ossifications.
5	Atlanto-occipital joint	Various arthritic changes

6	Vertebral body	Compression, fractures
7	Osteophytes	Osteophytes formation at various parts of the vertebrae
8	Facet joints	Various arthritic changes
9	Spinal canal	Narrowing, stenosis
10	Thecal sac	Indentation of thecal sac due to disc protrusion and osteophytes
11	Spinal cord	Compression, ischemia
12	Intervertebral foramen	Narrowing due to disc protrusion and osteophytes
13	Nerve root compression	Due to disc protrusion, osteophytes, enlarged blood vessels and soft tissue swelling
14	Intervertebral disc	Various degenerative changes, structural changes, various stages of disc herniation, sites of disc herniation i.e. central, lateral, superior, inferior etc.
15	Inter vertebral spaces	Reduction in the space
16	Other findings	Any other unusual finding not listed above.

Observations and Results

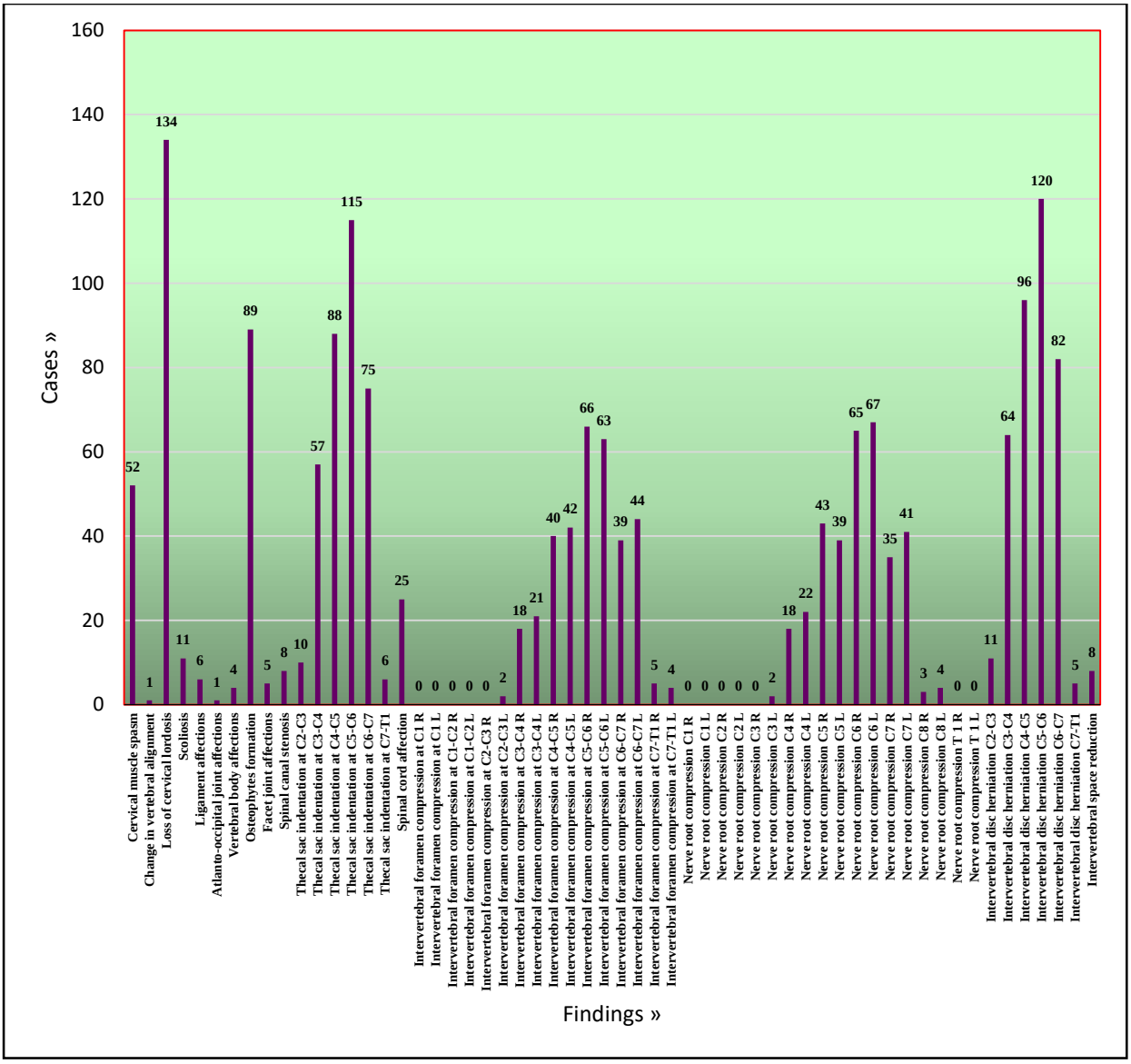
In the presents study, the objective was to find involved/ affected structure and changes in the parts of the cervical spine. Specially designed Case Record Form was used to record investigation findings of 150 patients suffering from *manyāstambha.* Criteria of investigation was MRI of cervical spine.

In this section these findings are listed and represented in tables and graphs. The data has been analysed statistically and results are discussed below.

Table no. 31 Structural affections in all accessed structures

Sr.no.	Findings	Cases
1	Cervical muscle spasm	52
2	Change in vertebral alignment	1
3	Loss of cervical lordosis	134
4	Scoliosis	11
5	Ligament affections	6
6	Atlanto-occipital joint affections	1
7	Vertebral body affections	4
8	Osteophytes formation	89
9	Facet joint affections	5
10	Spinal canal stenosis	8
11	Thecal sac indentation at C2-C3	10
12	Thecal sac indentation at C3-C4	57
13	Thecal sac indentation at C4-C5	88
14	Thecal sac indentation at C5-C6	115
15	Thecal sac indentation at C6-C7	75
16	Thecal sac indentation at C7-T1	6
17	Spinal cord affection	25
18	Intervertebral foramen compression at C1 R	0
19	Intervertebral foramen compression at C1 L	0
20	Intervertebral foramen compression at C1-C2 R	0
21	Intervertebral foramen compression at C1-C2 L	0
22	Intervertebral foramen compression at C2-C3 R	0
23	Intervertebral foramen compression at C2-C3 L	2
24	Intervertebral foramen compression at C3-C4 R	18
25	Intervertebral foramen compression at C3-C4 L	21
26	Intervertebral foramen compression at C4-C5 R	40
27	Intervertebral foramen compression at C4-C5 L	42
28	Intervertebral foramen compression at C5-C6 R	66
29	Intervertebral foramen compression at C5-C6 L	63
30	Intervertebral foramen compression at C6-C7 R	39
31	Intervertebral foramen compression at C6-C7 L	44

32	**Intervertebral foramen compression at C7-T1 R**	**5**
33	**Intervertebral foramen compression at C7-T1 L**	**4**
34	**Nerve root compression C1 R**	**0**
35	**Nerve root compression C1 L**	**0**
36	**Nerve root compression C2 R**	**0**
37	**Nerve root compression C2 L**	**0**
38	**Nerve root compression C3 R**	**0**
39	**Nerve root compression C3 L**	**2**
40	**Nerve root compression C4 R**	**18**
41	**Nerve root compression C4 L**	**22**
42	**Nerve root compression C5 R**	**43**
43	**Nerve root compression C5 L**	**39**
44	**Nerve root compression C6 R**	**65**
45	**Nerve root compression C6 L**	**67**
46	**Nerve root compression C7 R**	**35**
47	**Nerve root compression C7 L**	**41**
48	**Nerve root compression C8 R**	**3**
49	**Nerve root compression C8 L**	**4**
50	**Nerve root compression T 1 R**	**0**
51	**Nerve root compression T 1 L**	**0**
52	**Intervertebral disc herniation C2-C3**	**11**
53	**Intervertebral disc herniation C3-C4**	**64**
54	**Intervertebral disc herniation C4-C5**	**96**
55	**Intervertebral disc herniation C5-C6**	**120**
56	**Intervertebral disc herniation C6-C7**	**82**
57	**Intervertebral disc herniation C7-T1**	**5**
58	**Intervertebral space reduction**	**8**



Graph no.1 Structural affections in all accessed structures

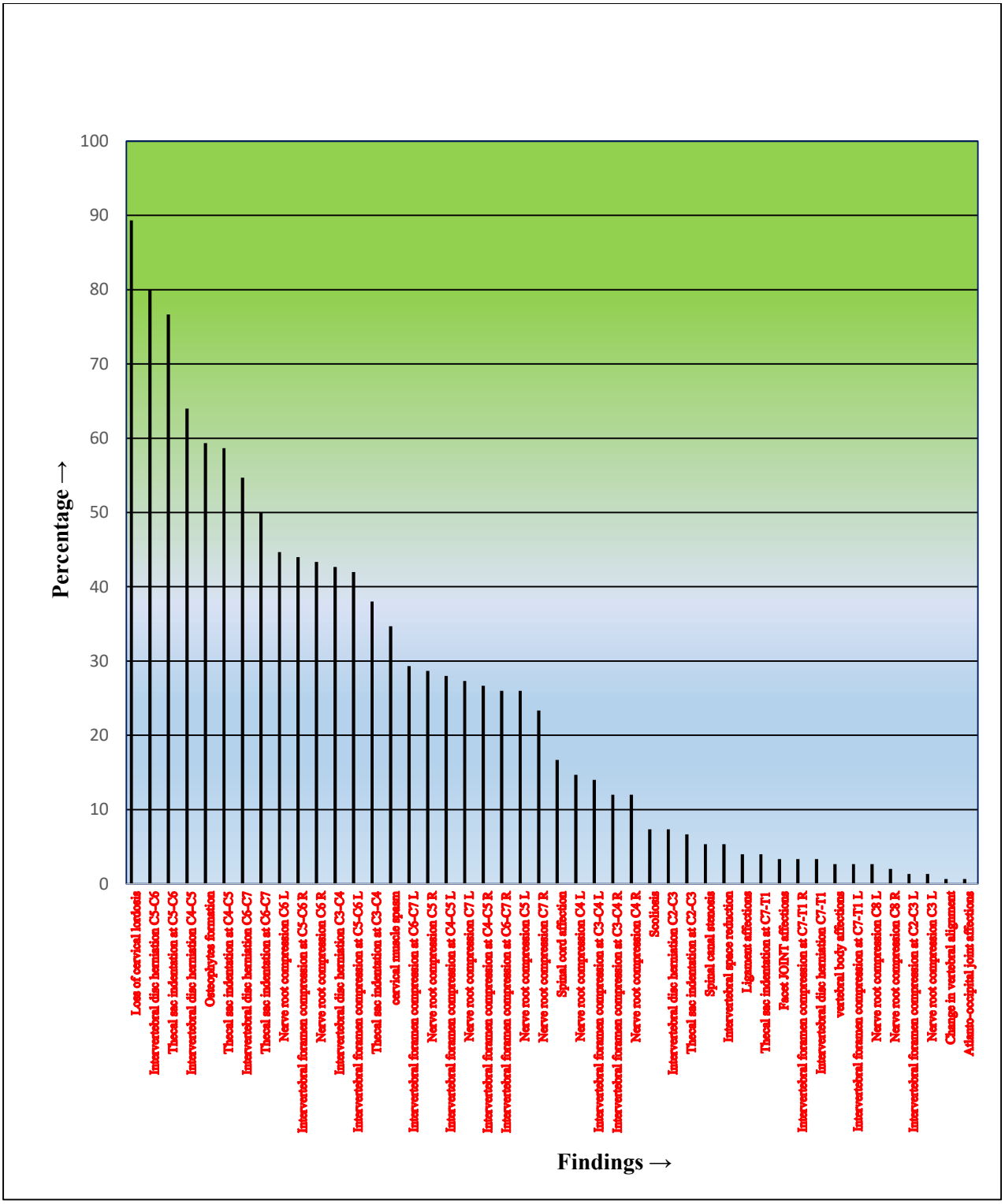
Statistical analysis

Percentage of the total cases for each finding are calculated and arranged in descending order. This gives a very good evidence regarding prone structure of cervical spine developing signs and symptoms of *manyāstambha.*

Table no. 32 Structural affections in all accessed structures in descending order

Sr. no	Findings	Total Cases	Percentage
1	Loss of cervical lordosis	134	89.33
2	Intervertebral disc herniation C5-C6	120	80.00
3	Thecal sac indentation at C5-C6	115	76.67
4	Intervertebral disc herniation C4-C5	96	64.00
5	Osteophytes formation	89	59.33
6	Thecal sac indentation at C4-C5	88	58.67
7	Intervertebral disc herniation C6-C7	82	54.67
8	Thecal sac indentation at C6-C7	75	50.00
9	Nerve root compression C6 L	67	44.67
10	Intervertebral foramen compression at C5-C6 R	66	44.00
11	Nerve root compression C6 R	65	43.33
12	Intervertebral disc herniation C3-C4	64	42.67
13	Intervertebral foramen compression at C5-C6 L	63	42.00
14	Thecal sac indentation at C3-C4	57	38.00
15	cervical muscle spasm	52	34.67
16	Intervertebral foramen compression at C6-C7 L	44	29.33
17	Nerve root compression C5 R	43	28.67
18	Intervertebral foramen compression at C4-C5 L	42	28.00
19	Nerve root compression C7 L	41	27.33
20	Intervertebral foramen compression at C4-C5 R	40	26.67
21	Intervertebral foramen compression at C6-C7 R	39	26.00
22	Nerve root compression C5 L	39	26.00
23	Nerve root compression C7 R	35	23.33
24	Spinal cord affection	25	16.67
25	Nerve root compression C4 L	22	14.67
26	Intervertebral foramen compression at C3-C4 L	21	14.00

27	Intervertebral foramen compression at C3-C4 R	18	12.00
28	Nerve root compression C4 R	18	12.00
29	Scoliosis	11	7.33
30	Intervertebral disc herniation C2-C3	11	7.33
31	Thecal sac indentation at C2-C3	10	6.67
32	Spinal canal stenosis	8	5.33
33	Intervertebral space reduction	8	5.33
34	Ligament affections	6	4.00
35	Thecal sac indentation at C7-T1	6	4.00
36	Facet JOINT affections	5	3.33
37	Intervertebral foramen compression at C7-T1 R	5	3.33
38	Intervertebral disc herniation C7-T1	5	3.33
39	vertebral body affections	4	2.67
40	Intervertebral foramen compression at C7-T1 L	4	2.67
41	Nerve root compression C8 L	4	2.67
42	Nerve root compression C8 R	3	2.00
43	Intervertebral foramen compression at C2-C3 L	2	1.33
44	Nerve root compression C3 L	2	1.33
45	Change in vertebral alignment	1	0.67
46	Atlanto-occipital joint affections	1	0.67
47	Intervertebral foramen compression at C1 R	0	0.00
48	Intervertebral foramen compression at C1 L	0	0.00
49	Intervertebral foramen compression at C1-C2 R	0	0.00
50	Intervertebral foramen compression at C1-C2 L	0	0.00
51	Intervertebral foramen compression at C2-C3 R	0	0.00
52	Nerve root compression C1 R	0	0.00
53	Nerve root compression C1 L	0	0.00
54	Nerve root compression C2 R	0	0.00
55	Nerve root compression C2 L	0	0.00
56	Nerve root compression C3 R	0	0.00
57	Nerve root compression T 1 R	0	0.00
58	Nerve root compression T 1 L	0	0.00

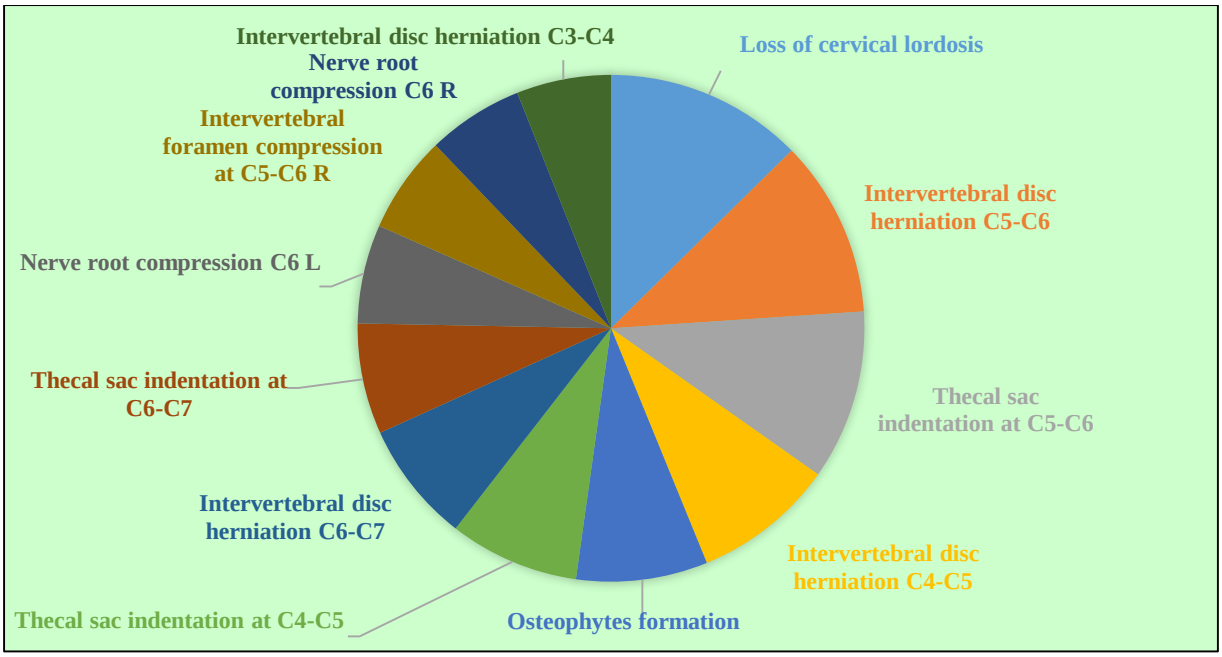


Graph no. 2 Percentage of affected Structures

Chi-square Test for each finding was applied. It has helped to form groups of findings according to their prevalence in the present study.

Table no. 33 Highly susceptible structures to produce *manyāstambha*

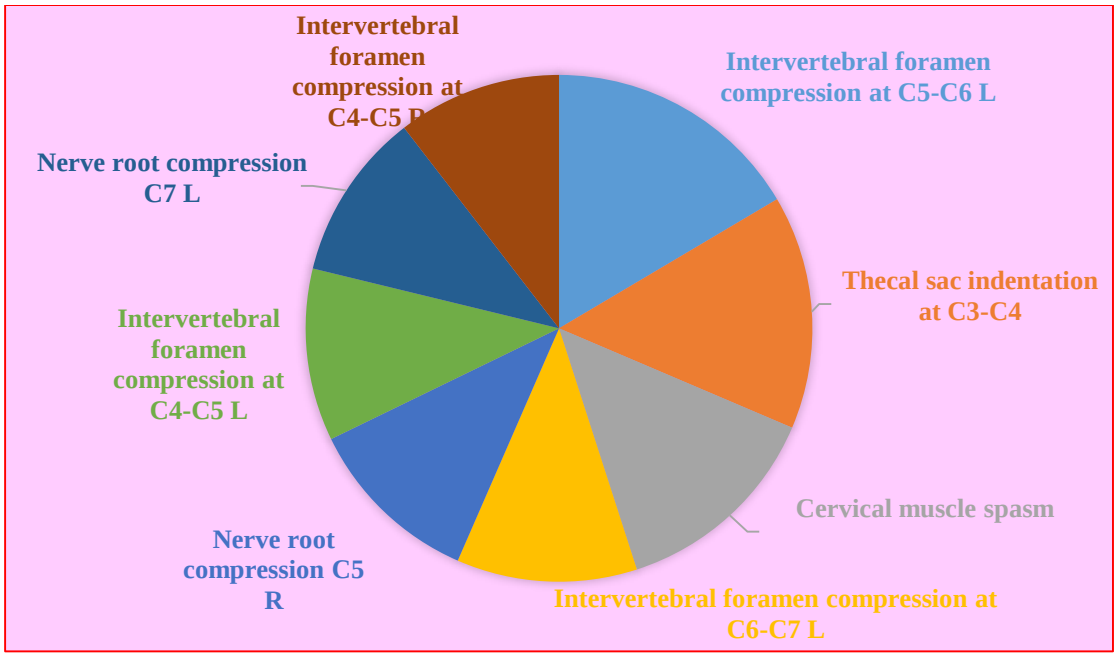
Sr.no.	Findings	P value	Total cases
1	Loss of cervical lordosis	0	134
2	Intervertebral disc herniation C5-C6	0	120
3	Thecal sac indentation at C5-C6	0	115
4	Intervertebral disc herniation C4-C5	0.001	96
5	Osteophytes formation	0.022	89
6	Thecal sac indentation at C4-C5	0.034	88
7	Intervertebral disc herniation C6-C7	0.253	82
8	Thecal sac indentation at C6-C7	1	75
9	Nerve root compression C6 L	0.191	67
10	Intervertebral foramen compression at C5-C6 R	0.142	66
11	Nerve root compression C6 R	0.102	65
12	Intervertebral disc herniation C3-C4	0.072	64



Graph No. 3 Highly susceptible structures to produce *manyāstambha*

Table no. 34 Moderately susceptible structures to produce *manyāstambha*

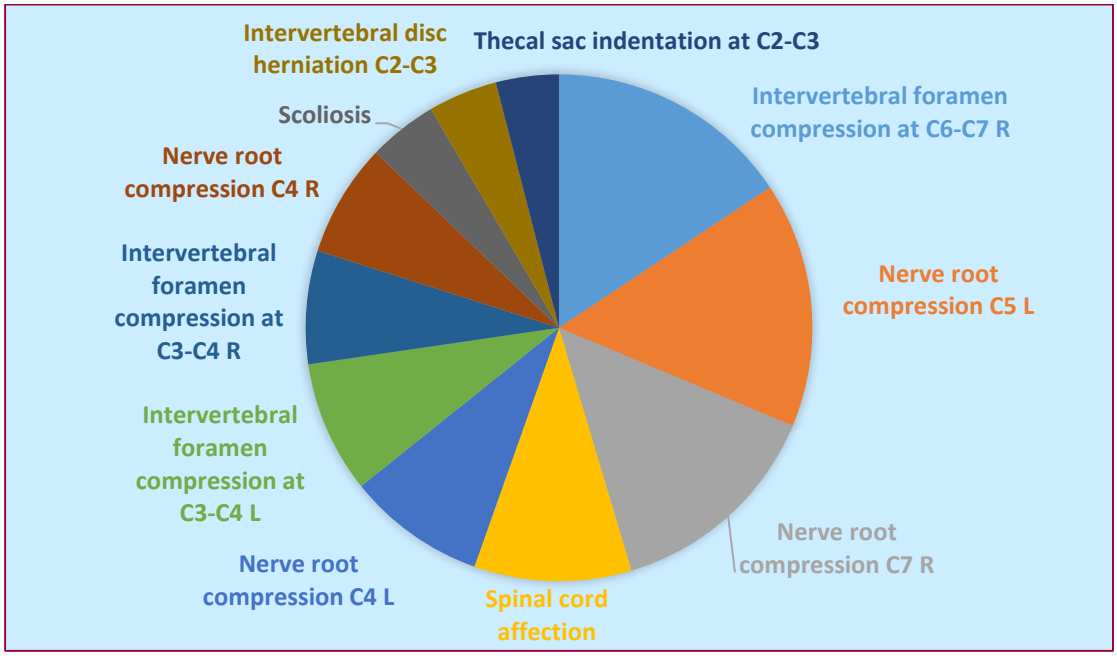
Sr.no.	**Findings**	**P value**	**Total cases**
1	Intervertebral foramen compression at C5-C6 L	0.05	63
2	Thecal sac indentation at C3-C4	0.003	57
3	Cervical muscle spasm	0	52
4	Intervertebral foramen compression at C6-C7 L	0	44
5	Nerve root compression C5 R	0	43
6	Intervertebral foramen compression at C4-C5 L	0	42
7	Nerve root compression C7 L	0	41
8	Intervertebral foramen compression at C4-C5 R	0	40



Graph No. 3 Moderately susceptible structures to produce *manyāstambha*

Table no. 35 Less susceptible structures to produce *manyāstambha*

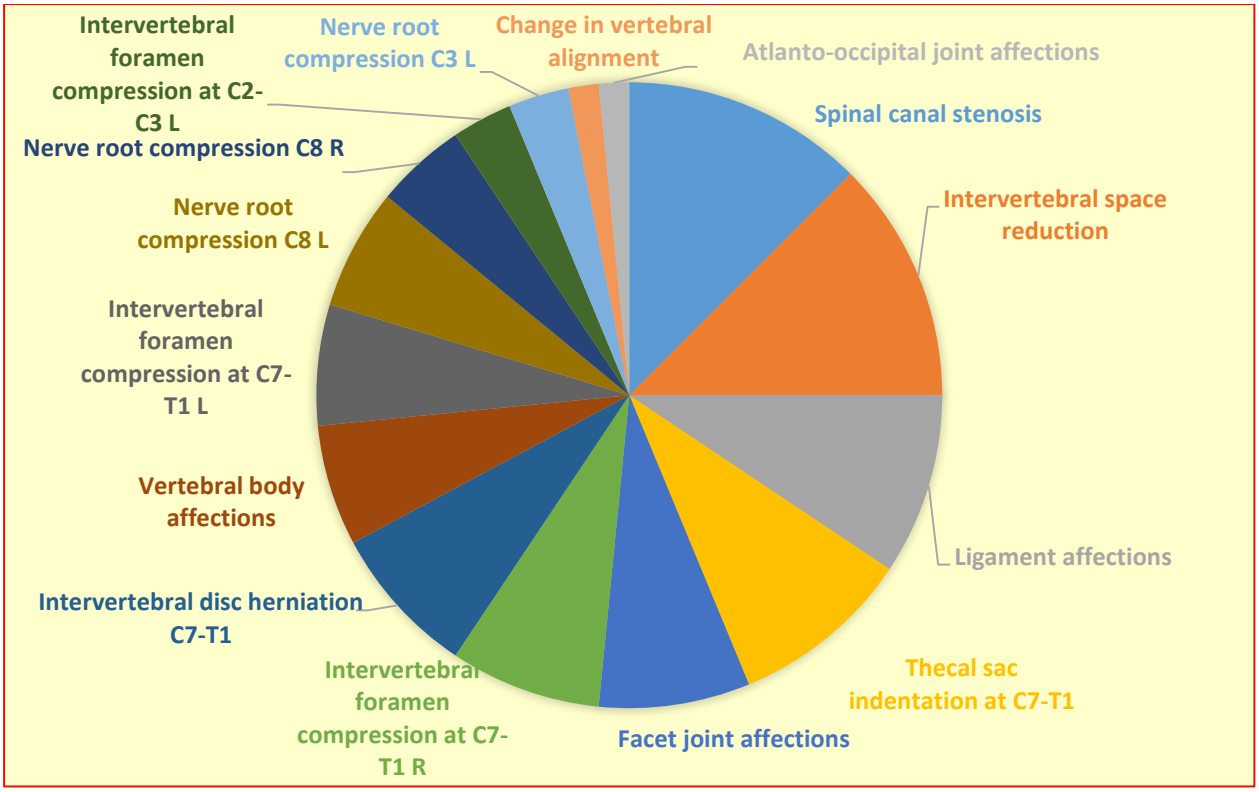
Sr. No.	Findings	P value	Total cases
1	Intervertebral foramen compression at C6-C7 R	0	39
2	Nerve root compression C5 L	0	39
3	Nerve root compression C7 R	0	35
4	Spinal cord affection	0	25
5	Nerve root compression C4 L	0	22
6	Intervertebral foramen compression at C3-C4 L	0	21
7	Intervertebral foramen compression at C3-C4 R	0	18
8	Nerve root compression C4 R	0	18
9	Scoliosis	0	11
10	Intervertebral disc herniation C2-C3	0	11
11	Thecal sac indentation at C2-C3	0	10



Graph No. 4 Less susceptible structures to produce *manyāstambha*

Table no. 36 Very less to non-susceptible structures to produce *manyāstambha*

Sr. No.	Findings	P value	Total cases
1	Spinal canal stenosis	0	8
2	Intervertebral space reduction	0	8
3	Ligament affections	0	6
4	Thecal sac indentation at C7-T1	0	6
5	Facet joint affections	0	5
6	Intervertebral foramen compression at C7-T1 R	0	5
7	Intervertebral disc herniation C7-T1	0	5
8	Vertebral body affections	0	4
9	Intervertebral foramen compression at C7-T1 L	0	4
10	Nerve root compression C8 L	0	4
11	Nerve root compression C8 R	0	3
12	Intervertebral foramen compression at C2-C3 L	0	2
13	Nerve root compression C3 L	0	2
14	Change in vertebral alignment	0	1
15	Atlanto-occipital joint affections	0	1
16	Intervertebral foramen compression at C1 R	-	0
17	Intervertebral foramen compression at C1 L	-	0
18	Intervertebral foramen compression at C1-C2 R	-	0
19	Intervertebral foramen compression at C1-C2 L	-	0
20	Intervertebral foramen compression at C2-C3 R	-	0
21	Nerve root compression C1 R	-	0
22	Nerve root compression C1 L	-	0
23	Nerve root compression C2 R	-	0
24	Nerve root compression C2 L	-	0
25	Nerve root compression C3 R	-	0
26	Nerve root compression T 1 R	-	0
27	Nerve root compression T 1 L	-	0



Graph No. 5 Very less susceptible structures to produce *manyāstambha*

Narrative of results

Based on observations in the terms of percentage

1) Cervical spine straightening due to loss of normal lordosis is found in maximum patients (89%). This is the most occurring structural change among all the findings of the present study. The reason developing the straightening of the cervical spine reported by the radiologist is cervical muscle spasm which is found in 34% patients.

2) The second structural change found is intervertebral disc herniation at the level of C5-C6 (80%), next to it is intervertebral disc herniation at C4- C5 level (64%), C6- C7 level (54%), C3-C4 (42%). The Uppermost level C2-C3 (7%) and lowermost level C7-T1

(3%) are least affected intervertebral disc in the form of herniation. this indicates the middle part of cervical spine is prone to disc herniation.

3) Bulging intervertebral discs compress meningeal covering around the spinal cord anteriorly. This is found 76% at C5- C6 level, 58% at C4-C5, 50% at C6-C7, 38% at C3- C4, 6% at C2-C3, 4% at C7-T1. These findings show similarity with the above findings of intervertebral disc herniation i.e. thecal sac indentation is maximum in the middle portion and decreasing at upper and lower ends of cervical spine.

4) Osteophyte formation is the fourth major structural change affecting the vertebral body and found in 59% patients of *manyāstambha.*

5) Intervertebral foramen compression and narrowing bilaterally at C5-C6 level and compressing bilateral roots of C6 nerves is almost similar and found in around 43% patients

6) Intervertebral foramen compression at left C6- C7 level is 29% and that at right side is 26%. whereas nerve root compression of left C7 is 27% and that of right side is 23% it shows that left side is percentage wise more affected

7) Intervertebral foramen compression at left C4-C5 level is 28% and that at right side is 26%. Whereas nerve root compression of left C5 is 26% and that of right side is 28% without much significant difference in affection.

8) Intervertebral foramen compression at left C3- C4 level is 21% and that of right side is 18% whereas nerve root compression of left C4 is 22% and that of right side is 18% here left side is found more affected

9) Intervertebral foramen compression at C7-T1 level bilaterally is almost 3% with similar percentage of bilateral nerve root compression of C8

10) Intervertebral foramen compression at left C2-C3 level was found in in 1% patients however right side of this level was not affected in any patient. Similarly, nerve root compression at left C3 was found in 1% patient and right C3 nerve root was not found affected in any patient

11) Other significant structural affections found are spinal cord compression in 16%, scoliosis 7%, spinal canal stenosis 5%, intervertebral space reduction 5%, ligament affections 4%, facet joint affection 3%, vertebral body affection 2%, change in vertebral alignment and atlanto occipital joint affection in one patient each.

12) No affections were found in bilateral intervertebral foramen at C1, C1-C2 level in any patient.

13) Nerve root compression was not found for bilateral nerve roots at C1, C2, T1 and left C3 nerves.

Based on observations in the terms of Chi-square test

1) It has been considered that 0.000 P value represents high or low prevalence rate of the findings at the same time P value more than 0.05 represents high prevalence rate. It should be noted that the structures found affected in many patients are also represented by P value 0.000. Therefore, in case of P value = 0.000, total number of finding is considered to decide low or high prevalence e.g. criteria 'loss of cervical lordosis' has P value = 0.000 and total number of findings 134, has been considered under highly susceptible structures to produce *manyāstambha*. Whereas criteria 'Atlanto-occipital joint affections' also has P value = 0.000 and total number of findings 1, has been considered under very less to non-susceptible structures to produce *manyāstambha*.

2) Based on P value and 58 criteria of assessment by MRI, the data is divided into highly susceptible, moderately susceptible, less susceptible, and very less to non-susceptible structures to produce *manyāstambha*.

a) **Highly susceptible structures to produce *manyāstambha*-** were found as loss of cervical lordosis as well as many structural abnormality i.e. intervertebral disc herniation, thecal sac indentation, osteophytes formation was found at C5-C6 and C6-C7 levels. Bilateral nerve root compression at C6 level, intervertebral foramen compression at C5-C6 level more at the right side were also found.

b) **Moderately susceptible structures to produce *manyāstambha*-** were found as intervertebral foramen compression at left C5-C6 and C6-C7 as well as at C4-C5 levels bilaterally, thecal sac indentation at C3-C4 level and cervical muscle spasm.

c) **Less susceptible structures to produce *manyāstambha*-** were found as intervertebral foramen compression at right C6-C7 and bilateral C3-C4 levels. Nerve root compression at left C5 and right C7 and bilateral C4 levels, intervertebral disc herniation and thecal sac indentation at C2-C3 level along with spinal cord affection and scoliosis.

d) **Very less to non- susceptible structures to produce *manyāstambha*-** were found with respect to spinal canal stenosis, intervertebral space reduction, ligament affections, facet joint affections, vertebral body affections, change in vertebral alignment, atlanto-occipital joint affections and the spinal structures at higher most levels C1-C3 and lowermost levels C7-T1.

Discussion

The neck is a very complex structure. Bones, their joints, ligaments, muscles, spinal cord, nerves, blood vessels along with larynx, trachea and oesophagus are very much compactly but systematically arranged in a small region. Functionally it is a very active region of the body as far as the movement of the head and neck itself is concerned. Reflections of other parts of the body are also observed on the neck. Muscles provided for the movements of head are present in neck. The weight of head is transferred to the cervical spine. Lifting of weight by hand affects the neck.

The degeneration starts early in the neck. Many degenerative changes are irreversible. The spinal structures show not only involvement in the diseases but also express foremost structural changes. The cervical spine is affected by genetical factors, age, nutrition, life style, occupation, other systemic disorders etc.

Anatomical view of cervical spine and neck from *Ayurvedic* point of view

Āyurveda has emphasized the study of human anatomy described under the topic *śārira* in ancient texts. It is said assuredly that physician should study the entire human body thoroughly to avoid faults while observing the disease and treating the patients. Hence the importance of anatomy is certainly for the seamless diagnosis and treatment.

To start with; it is very essential to understand the principle- Combination of five *mahābhūtas* create the body of organism. *Pṛithvī, āp, teja, vāyu, ākāśa* and *brahman* in the human body are characterized respectively by *mūrti*, *kleda*, *abhisantāpa*, *prāṅa* and *sushiratā* and *antarātmā*. Every body part has dominance of certain *mahābhūta*. This concept is very much essential for the study of disease as it is believed that abnormal changes developed in the *pāñcabhautika* form of any structure will surely lead to disease.

The spine is composed of *asthi* (bones). *Asthi* is fifth *dhātu.* According *Āyurveda,* providing support and firmness is the main function of *asthi*. The spine is formed by joining of all vertebrae. It provides axial strength and support to muscles and tendons. Delicate spinal cord is placed in the vertebral canal securely.

The spine is formed by the articulations among the vertebrae by joints between them. Movements of the cervical spine and head are possible due to the *cala* (movable) *pratara* type of *sandhi* (joints). The vertebrae are joined together by *pratānavati* (branching or ramifying) *snāyu* (ligaments and tendons). The joint needs lubrication to

prevent damage. Therefore, *śleshmadharā kalā* is present in movable joints. *Asthi* and *sandhi* are the roots of *majjāvaha srotas* for cervical spine as well.

In the neck; *Māṉsa* (flesh), *avayava* and *saṅghāta* (conjunction of structures) are separated by *peśī* from each other. The joints, bones, muscles and blood vessels are supported and reinforced by *peśī* (fascia). *Pelavā, anavah, vṛitta, rhswa, mṛidu ślakśna* types of *peśī* can be included into the neck. It has been described in *śārira* that there are four large *māṉsa rajjū* on either side of the cervical spine; outer and inner, each two and bind *peśī* together.

When *snāyu* are compared with ligaments and tendons; *pratānavatī* and *vṛitta* types of *snāyu* are correlated with the cervical spine.

Each type of *sirā i.e. vātvaha, pittavaha, kaphavaha* and *raktavaha* are existing in the neck.

2 kṛikātikā, 8 mātṛikā and 4 dhamanī marma are located in the neck.

8 *kaṇtha sirā* (*mātṛikā*) are *sadyaprāṇhara* (fatal) *marma*. *Manyā and nīlā* (two each), 2 *kṛikātikā,* are *vaikalyakara* (producing deformity) *marma.*

Marma is a site where collection of *māñsa, sirā, snāyu, asthi* and *sandhi* with the domination of *prāṇa* is present. This combination is also found in the cervical spine. Therefore, the cervical spine is very gentle and vital region. Severe pain, disability and death can take place after trauma to the cervical spine. Hence the cervical spine can be considered as a site of *marma* along with all its principles, e.g. complication of the spinal diseases and limitations in the success rate of the treatment.

Idā, pinglā and *sushumnā* and *nāḍicakra* are present in the cervical region. It is believed that these carry out the functions of body and mind.

Physiological view of cervical spine and neck from Āyurvedic point of view

The cervical spine is formed of many joints and *sandhi* is place of *kapha*.

Normal *kapha* flows in *kaphavaha sirā.* Its role is to develop

body smoothness and strength, lubrication, binding and stability of joints, functions of water i.e. filling, healing. This role is significant in the intervertebral disc (symphysis joints) and in the facet joints. Therefore, normal state of *kapha* is must for smooth functioning of *sandhi.* This is also controlled by *śleshmadharā kalā* in joints.

Normal *vāyu* flows in its *sirā*. It is useful for expansion, various movements of joints etc. Hence for standard functioning of cervical spine; normal state of *kapha* and *vāta* is an important condition.

Development of *Manyāstambha* due to the affections of cervical spine from Ayurvedic point of view

From the literature study it is possible to frame the probable process of affections to the cervical spine by the actions of vitiated *dosha* in its various parts.

Overall pathological view (*saṃprāpti*)

1) *Vāyu* aggravating reasons develop *laghutā*, *rukshatā*, *dāruṇatā*, *śītatā*, *viśadatā*, *sushiratā* and *kharatā* in the cervical spine. *Vāyu* gets favourable situation. Aggravated *vāta* fills up *srotas* in the cervical spine and develops diseases.

2) The deranged *vāyu* affects *vātvaha sirā* of cervical spine and develops diseases.

3) Morbid affection of *asthi* develops- *adhyasthi* (bone growing over another e.g. osteophytes) *asthibheda* (splitting pain in bone), *asthiśūla* (pain in the bones).

4) Synchronized vitiation of *asthi* and *vāta* leads to many types of bone related pathologies. According to the concept of *āṣraya āsrayi* relationship *asthi* is the only *dhātu* in which *vāta* resides with the authority. As *vāta* and *asthi* are closely related they can affect each other easily i.e. when *vāta* gets contaminated it causes bone related diseases.

5) Morbid affection of *majjā* in cervical spine; develops *parva rujā*, *bhrama*, *mūrchā*, *tamo darśana.*

6) Symptoms of joint injury are also applicable to the joint affections of cervical spine due to internal causes especially due to actions of vitiated *dosha*, i.e. stiffness, large swelling, loss of strength, severe joint pain and loss of joint functions.

7) The affections of many joints in the spine can also be caused due to loss of normal functions of *kapha dosha* i.e. *sneha* (lubrication), *bandha* (binding), *sthiratva* (firmness), *sandhisaṇṣleshaṇa.*

8) It can also be determined that *manyāstambha* is the disease of *marmāsthisandhi* (middle passage).

Understanding *Manyāstambha* and its symptoms from various diseases in *Āyurveda* and its correlation with degenerative spinal diseases

Manyāstambha

It is marked by stiffness/ rigidity of the neck. *Suśruta* has mentioned *Manyāstambha*. It is an acute illness caused due to the involvement of muscles and ligaments. *Āyurveda* has defined some disorders presenting symptoms of *manyāstambha;* including headache, radiating pain in upper limbs, other symptoms of compressed nerve roots etc. These symptoms are found in various degenerative changes of cervical spine. Although these diseases are not representing *manyāstambha* but they may help us to understand the pathology for the development of various symptoms of *manyāstambha.*

Ardhāvabhedaka and vātaj śiroroga

Some symptoms of *ardhāvabhedaka* are similar to that found in the degenerative disorders of upper cervical spine i.e. stiffness in neck, half or entire head ache, diseases of eyes, ear, nose and mouth (in the form of pain) and giddiness.

Some symptoms of *vātaj śiroroga* are also similar to that found in the degenerative disorders of upper cervical spine i.e. intense pain mainly in temporal and nape regions, forehead and middle part of eyebrow have feeling of burning and extreme pain. Patient suffers from dizziness and ear ache. Eyes and neck become stiff. Aggravated *vāyu* produces these symptoms in both the diseases.

Symptoms similar to radiculopathy according to *Āyurveda*

Hasta- pāda dāha

In the advance stages of *mañyastambha,* the herniated intervertebral disc compresses intervertebral foramen and exiting nerve roots. This produces radiculopathy which leads to burning sensation in the upper limb. This is comparable with *pāda dāha*. Here it can be labelled as *hasta dāha,* if the same pathology is applied for the upper limbs, caused due to vitiated vāta combining with vitiated *pitta* and *rakta*.

Hasta- pāda harsha

The tingling sensation is also developed in the nerve root compression. If the same pathology is applicable for the hands, that is because of action of deranged *vāta* and *kapha* in the leg; producing *pāda harsha,* it can be termed as *hasta harsha.*

It can also be considered that *ekaṅgavāta* if untreated leads to *sarvāṅgavāta* and develops loss of movements, loss of sensation, numbness etc. Alternative *samprāpti* can be applied here. When there is diminished *kapha,* the normal *pitta* is moved away

from its place by *vāyu*. It causes burning sensation, extreme tearing pain, fatigue and debility. In other form *pitta* produces burning sensation and pain obstructing *vāta*.

Antarāyāma and Bahirāyāma

The deranged *vāta* situated in the neck; afflicts *nādi* (channels, vessels and nerves). It develops *manyāstambha* (stiffness of neck). The sternocleidomastoid (anterior aspect of neck) becomes excessively stiff and causes neck to bend forward which is called *antarāyāma*.

The external *sirā* of neck posteriorly undergo shrinking due to deranged *vāta*.

The neck becomes stiff as well as the body bends to the backside. This is known as *bahirāyām. Antarāyām* and *bahirāyāma* are the affections of *vāta* to *snāyu*, *kandarā* and *sirā* of neck and back.

Disorders of *snāyu, sirā and kaṇḍarā*

Doṣas vitiated in ligaments, tendons, blood vessels (or nerves) and muscles cause stiffness, compression, severe pain in the limbs, bulging in *snāyu* and *sirā*, contraction throbbing and numbness.

From above description it can be stated that bones, joints, muscles, ligaments, tendons, blood vessels, nerves in the neck get affected by vitiated *vāta dosha* predominantly with accompanying *kapha* and *pitta* and develop *manyāstambha* and other symptoms. It is also stated in *Āyurveda* that, disorders of *snāyu* (ligaments, tendons) are most unfavourable to the body than any other structures.

***Manyāstambha* with reference to the modern anatomy of cervical spine and its correlation with activities of vitiated *dosha*.**

From the study of anatomy of cervical spine, it is clear that the structural arrangement of various parts though essential and suitable for normal functioning, is very much prone to develop diseases of spine. Such anatomical factors are discussed below

Bony structure- vertebra

Body

It provides support and is the main weight bearing and transferring structure of the cervical spine. It suffers from degeneration in the form of osteoporosis, osteophyte formation, fracture etc. According to Ayurvedic concepts this degeneration is caused due to *asthivṛiddhi*, *kaphakshaya* and action of vitiated *vāyu* in *asthi* and *majjā* by *ruksha* (roughness), *laghu* (lightness), *dāruṇa* (hardness), *khara* (coarseness) and

viśada (non-sliminess) properties. It produces *sushirata* (porosity), *śosha* (wasting) *bheda* (tearing) etc. in the vertebral body.

Articular processes

These have important role in spinal movement and also form weight bearing supports like pillars, bilaterally. Degeneration of the facet joints produces hypertrophy of articular processes that compresses dorsal nerve rootlets, root and root ganglion. The changes of articular process can be correlated with *adhyasthi* which is the manifestation of *asthivṛiddhi*.

Intervertebral foramina

Nerve root, arteries, veins, lymphatics in the intervertebral foramen get compressed mainly due to intervertebral disc herniation. Various additional structures can also affect these structures. These are- bone marrow of vertebral bodies, compact bone of the pedicles, facet joints, articular cartilage, fibro-adipose meniscoids, fat pads, synovial membranes, capsules, fibrocartilage of the anulus fibrosus, connective tissue rim, nucleus pulposus, and in the thoracic segment- costovertebral joints.

The intervertebral foramen stenosis happens as a result of degenerated disc, hypertrophy of ligamentum flavum, arthrosis of zygapophyses joint. The exiting spinal nerves along with other contents get compressed by bony tissue. It creates back pain and radiating pain into the libs.

This phenomenon can be considered as action of vitiated *vāta dosh* which causes *saṅgkocana* **(**compression, stenosis**)** of intervertebral foramen and also the manifestation of *asthivṛiddhi*.

Joints of the spine

Zygapophyseal joint (facet joint)

These joints allow movement and also limit it. They regulate the direction of the vertebral movement. The loss of movement or the unusual movement produce pain. This can be considered as action of vitiated *vāta dosh* which causes *stambha* (stiffness) and *vikṛiṭa ceshṭā* (abnormal movement) of *sandhi*.

Role of nerve supply of zygapophyseal joint

The joint capsule has multilevel nerve supply. Hence broad referral pain is developed. This indicates the affection of *vātavaha sirā* by *vāyu*.

Role of synovial folds (meniscus) of zygapophyseal joint

The synovial folds are sensitive to pain because they are provided with free nerve endings. The compression of synovial folds between the articular facets of the

joint generates pain. This is the act of vitiated *vāyu* in the form of *varta* (circumvention, entrapment).

Degeneration of cervical zygapophyseal joint

The changes occur significantly with age. These changes can be corelated with the effect of vitiated *vāyu.* The articular cartilage becomes yellow and thin. This is *śosha* (wasting). The cartilage becomes more brittle with irregularly thickened subarticular bone. Due to cracks, its surface becomes irregular. This effect is developed due to *kharatā* (coarseness) of vitiated *vāyu.* An injured, cartilage very slowly rebuilds. In about 4 weeks defect of 1 mm heals. It indicates reduced normal function of *kapha* i.e. *ropaṇa* (healing).

From the articular processes osteophytes protrude (Morbid affection of *asthi* develops- *adhyasthi*). Within the articular processes, bone sclerosis takes place. The sclerosis of bone can be developed due to *dāruṇa* (hardness) *vāta guṇā.*

The referred pain from the zygapophyseal joint

The referred pain arising from C2 to C3 facet joints can radiate to neck and head. And arising from C5 to C6 facet joints to neck and shoulder. This is also produced by *vāta*.

Intervertebral joints between the laminae, spines and transverse processes

These are supplied by adjoining spinal and sympathetic nerves. Hence their diseases can cause pain due to affection of *vāta*.

The ligaments of the spine

Ligaments can resist tensile forces. They buckle at compression. The ligaments transfer their tensile loads to the bone. Hence a heavy load may injure the bone or ligament. Here *bheda* (tearing) caused due to vitiated *vāyu* must be considered.

Ligamentum flavum

When suddenly heavy load is applied, ligamentum flavum undergoes tearing and scarring. This can cause pain in its region due to aggravated *vāta*.

Intervertebral discs

Each disc provides cushion like structure to absorb the shock and stress on the body and avoids the vertebral crushing against one another. The disc periphery only gets blood supply. whereas remaining part is avascular and gets diffusion through the trabecular bone of vertebrae. This limits the healing and repair of disc. One third part of the anulus fibrosus has sensory (nociceptive and proprioceptive.) and vasomotor

nerve supply. Hence disc disorders cause pain. Herniated disc can compress the exiting dorsal roots and spinal nerves. This will result in radicular symptoms.

Disc degeneration may result in necrosis, nucleus pulposus replacement and annulus fibrosus weakening in the form of *dhātukshaya*. Unequal joint tension produces muscle spasm and cause severe pain. In severe case a herniated nucleus pulposus compress nerve roots to produce referred pain.

Formation of Schmorl's node leads in rapid disc degeneration. This causes the vertebrae to come closer. These changes increase force on the anterior, posterior joints between the vertebrae and on the facet joints. It causes the degeneration of the anterior interbody joint. The posterolateral region of the disc is weak therefore, this part is susceptible to bulging and herniation. Tearing of lamellae results in the protrusion of nucleus pulposus into the vertebral canal. These are the effects of vitiated *vāta* in the form of *bheda, sraṇsa and bhraṇsa.* The permeability of the end plate declines with age and formation of bone inside the cartilaginous end plate can lead to disruption of internal disc and degeneration of disc indicating *dhātukshaya.*

Osteophytes without disc prolapse produce pure motor weakness with atrophy. The volume of intervertebral disc tissue becomes smaller, following the intervertebral disc degeneration. It reduces the intervertebral space. This is *śosha* due to *vāta* and loss of *sthairya* (stability) property of *kapha*.

The cervical pain is produced due to the coming together of vertebral bodies. This causes slacking of all longitudinal ligaments, loadbearing increasing at margins of vertebral body, and at zygapophysial joints, intervertebral foramina narrowing and retrolisthesis (*sraṇsa* due to *vāta*).

Curvatures of the vertebral column

The straightening of cervical spine (loss of normal lordosis) can indicate a deformity. This points out reduced *dhāraṇa karma* of *asthi*.

Vertebral canal

At the C1 level, spinal cord occupies less than 50% of vertebral canal. Whereas at the level of C6, 75% of the vertebral canal is occupied by spinal cord. Therefore, the lower cervical cord is mostly prone to suffer diseases.

Vertebral canal stenosis

This is developed as a result of antero-posterior or the transverse diameter narrowing of the vertebral canal. It may be because of prenatal and perinatal growth

disturbance. With advanced aging the vertebral dimensions and size of canal change. Vertebral canal narrowing is compared with the action of vitiated *vāta* that is *saṅgkoca.*

Clinical anatomy of spinal cord

Compression of spinal cord due to spinal elements develops myelopathy or myelomalacia. It suggests action of vitiated *vāta* in the form of *saṅga* and *saṅgkoca.*

Vertebral artery

It can generate pain. The nociceptive sensation afferents course with the autonomic fibres. The spur formation of the upper cervical joint of Luschka or facet joints may cause irritation of these fibres which lead to headaches.

The vertebral canal width can be reduced due to osteophytes on the uncovertebral joint. It develops stricture in the vessel. Because vessel in foramen cannot slide laterally.

Generally, the artery may be compressed earlier due to the osteophyte than the nerve root as it present anterior to the nerve root.

Neck muscles

When a load is applied to the arms, the muscles of the arms transfer the weight to the cervical spine. Therefore, the workers suffer early degeneration of cervical spine due to heavy manual work.

Atishrama (extreme work), *ativicheshṭana* (unusual movements), *bhāraharaṇa* (carrying weight on head) are recognised as the causative factors for aggravation of *vāta*.

The cervical para-spinal muscle spasm may produce loss of cervical lordosis and straightening of cervical spine. In many of the MRI reports of cervical spine this is usually stated. This can be correlated with vitiated *vāta* affecting *māṉsa* and *meda* producing *veshṭana*.

Cervical stiffness and pain with reference to spinal nerves and the structures to whom they supply

The following abnormalities of nerves can be considered as the affections of *vātavaha sirā by* vitiated *vāta.*

C1 rootlets irritation create vertex pain (lower rootlets of C1), orbital pain (upper rootlets), and frontal pain (middle rootlets).

The anterior rami and the structures innervated by them

The neck muscles and the upper limb are supplied by the anterior primary divisions. Neck pain and stiffness is developed due to strain or spasm of these muscles.

Bruise to periosteum of transverse processes develop pain as it is supplied by the anterior primary divisions.

The dorsal rami and the structures innervated by them

Dorsal rami supply sensory nerves to many parts of the neck that can cause pain. The strained muscles or affected by areas of myofascial tenderness, the sprained ligaments, fractured or inflamed zygapophyseal joint as a result of arthritic changes and fractured spinous processes produce pain. The facet joint articular capsule or synovial fold compressed between the articular surfaces as well as articular cartilage erosion develop inflammatory substance that irritates the articular capsule nociceptors and cause discomfort. Inactivity of spinal joints may cause pain.

C1-C3 dorsal rami

These produce pain in head

1) Upper cervical spine abnormality and irritation to the greater occipital nerve or the C2 ganglion can produce headache.

2) The osteoarthritis of the cervical spine affects intervertebral foramen at C2-C3 level. Third occipital nerve is closely related with it which gets stimulated producing headache.

3) Dorsal rami of the upper three cervical nerves if irritated, can cause referred pain to the occipital regions and to the head.

The recurrent meningeal nerves and the structures innervated by them

Affections of meningeal branches due to diseases of the upper cervical spine can cause occipital headache. The periosteum of a vertebral body affected by fracture of the body, the affected basivertebral veins, vertebral body crush fractures or neoplasms cause pain.

The internal disc disruption posteriorly, bulging of the nucleus pulposus through the annulus fibrosus, tearing of the anulus fibrosus and posterior longitudinal ligamental sprain can cause pain.

The epidural veins affected by venous engorgement, the dura mater indented anteriorly by herniated disc, irritation due to the chemical released from internal disc distraction can generate pain.

Nerves associated with the sympathetic nervous system and the structures innervated by them

Disorders like fracture, osteomyelitis and neoplasm of the periosteum of the antero- lateral parts of the body that are supplied by sensory fibres associated with gray

rami develops pain. Anterior longitudinal ligament sprain, the outer layers of the antero-lateral aspect of the annular fibres causes pain; conducted by nerves which run along with the gray communicating rami.

Additional structures creating cervical region pain

1) Stimulations of the nerves around the vertebral artery.

2) Nociception receiving from uncovertebral joints and any structure supplied by the upper four cervical nerves may radiate to the head, initiating headaches.

4) Pain arising from the basi-occiput and occipital condyles commonly spreads to the frontal and orbital regions.

5) Disorders of the suboccipital and upper cervical spine can generate autonomic symptoms e.g. variations of pulse, pallor, nausea, sweating etc. This suggests abnormality produced due to *prāna vāyu* covered by *pitta* and alternatively *samāna vāyu* mixed with *pitta*.

Radicular pain

Activation of sensory fibres at the site of dorsal root ganglia develops radicular pain.

A thin band of piercing pain at the nerve distribution is felt. Compression of the dorsal root ganglion marks reduced blood flow to bodies of sensory nerve. This develops neural ischemia. It is experienced as radicular pain.

Causes of radicular pain

Intervertebral disc herniation, diseases of disc, stenosis of vertebral canal, space occupying lesion like abscess and tumours of the canal, vertebral canal defects, spondylolisthesis, spinal nerve root deformity, various bone diseases, chemicals like histamine produced from intervertebral disc degeneration. These can generate radicular pain.

When there is compression of dorsal nerve root, other sensory and motor functions are also affected. Thus, radicular pain frequently goes with paraesthesia, hypesthesia and decreased reflexes. Both the dorsal and ventral nerve roots are together; hence usually both roots get compressed. The ventral root compression leads to motor weakness. Thus, radicular pain may go together with motor weakness.

Vyathā (aching pain), *toda* (piercing pain), *supti* (numbness), *harsha* (tingling sensation) these symptoms found in radiculopathy are produced by vitiated *vāta.*

Consideration of *Manyāstambha* in the cervical spine disorders; described in modern science.

Degenerative disorders of spine

Cervical spondylosis

It is an age-related degenerative disorder of the cervical spine. The cervical segment of the vertebral column has the highest movement. Hence it is highly prone not only to functional stress but also to the trauma. Therefore, very commonly we find cervical spondylosis. It mainly affects the intervertebral discs and facet joints (as described above in degeneration of cervical zygapophyseal joint) producing cervical pain and stiffness. It is associated frequently with referred pain in the upper extremities.

Degeneration (*dhātukshaya*) of intervertebral disc is the main orthopedic cause of cervical spondylosis. After the age of thirty the process of disc degeneration accelerates. Its constitution modifies along with peripheral osteophyte formation. (*asthivṛiddhi*). And the adjacent vertebral bodies become sclerotic (becoming rigid) (effect of *dāruṇa vātaguṇā*). The discs also sink (*sraṇsa*) gradually into the adjacent vertebral bodies. The posterior intervertebral joints get affected especially the facet joint degeneration (due to *sandhigata vata*) takes place due to resultant loading causing neck pain. Radiating pain in the upper limb is developed by the impinging (*varta*) osteophytes on the nerve roots. Cord compression can also take place due to impinging osteophytes. The lowest three cervical intervertebral joints are more prone to the cervical spondylosis. C5-C6 level is the most common level. The damaged intervertebral disc cannot be repaired (loss of *ropaṇa karma* of *kapha*).

The nucleus can protrude centrally (*sraṇsa*) to develop Schmorl's nodes. When the centre of rotation is placed in the posterior one third of the disc, nucleus can prolapse postero-laterally.

Clinical features are stiffness and pain in the neck, radiating pain in the upper limb, giddiness and audible crepitation on movement.

This can be correlated with disorders produced by vitiated *vāta dosha* as, many of its symptoms are seen in the cervical spondylosis. The symptoms are *stambha*, *vyathā* (aching pain) in neck and in the upper limb, giddiness (*bhrama*) and audible crepitations on movement. Radiating symptoms in the upper limb are *vyathā* (aching pain), *toda* (piercing pain), *supti* (numbness), *harsha* (tingling sensation).

This disorder is developed due to affection of zygapophyseal joint by vitiated *vāta* as described above in the form of *śosha* and *adhyasthi* with reduced normal *ropaṇa* function of *kapha*. *Vāta guṇā, kharata and dāruṇa* also produce degeneration.

Disc herniation

Disc herniation is defined with respect to the grade of displacement of the disc beyond its limits. Disc herniation can happen along with other degenerative changes. Degeneration of the disc results in nucleus softening and fragmentation, breakdown of the annulus posteriorly before displacement of the nuclear material (*bheda karma* of vitiated *vāta*). The nucleus displacement takes place in the steps of disc protrusion, disc prolapse (*sraṉsa*), disc extrusion and disc sequestration (*bhraṉsa*).

At the fibrosis stage, remaining nucleus pulposus becomes fibrosed. The squeezed-out nucleus pulposus becomes calcified. At the same time osteophytes (bony spurs) are developed at the site of separation of the posterior longitudinal ligament form the vertebral body (stage of developing *adhyasthi*). The posterior herniation develops compression on the nerve roots or the structures in the spinal canal. *Schmorl's* nodes are produced by upward or downward herniation into the adjoining vertebral bodies.

As this is the abnormal modification in the disc structure it develops symptoms i.e. stiffness and pain in the neck, radicular pain etc.

All the above destructions in the disc is due to the affection of deranged *vāta* as well as *dhātu kshaya*.

Spondylosis deformans

The tear in the periphery of the annulus anteriorly (*bheda* by vitiated *vāta*) leads to anterolateral herniation of disc (*sraṉsa*). The anterior longitudinal ligament tearing by the intervertebral disc encourages osteophytes development (*adhyasthi*). Mostly this takes place along the antero-lateral part of the vertebral column. Symptoms include dysphagia, neck stiffness and pain.

Osteochondrosis

Osteochondrosis happens due to distraction in the end plate in the form of microfractures of cartilage (*bheda*), calcification of the cartilage (increased *kharatā* and *parushatā*), development of blood vessels resulting into endochondral ossification. It results into herniation of disc into the adjoining vertebral body (*sraṉsa*). Consequently,

the other parts of disc undergo an advanced degeneration (*śosha and kshaya*), in the form of necrosis, calcification, tearing of the annulus fibrosus replaced by fibrous tissue. Huge horizontal fissures are developed in the disc tissue centrally (*vyāsa*).

The disc tissue degeneration leads to disc space narrowing (*saṅgkoca*) and formation of osteophytes takes place at disc periphery (*adhyasthi*). The disc becomes irregular and sclerotic (effect of *ruksha and daruṇa property of vāta*). In the end stage there is an abrupt fusion of the adjacent bodies (*saṅga*). The above pathological process refers severe destruction by vitiated *vāta* along with *dhātu kshaya*.

Degenerative spondylolisthesis

It is a degenerative disc disease where one vertebral body gets displaced on another. The intervertebral disk space narrowing causes facet joint degeneration that leads to degenerative spondylolisthesis. Bony erosions (*śosha and kshaya*) of the articular surfaces of the facet joint also results. The effect of degenerative spondylolisthesis is spinal stenosis (*saṅgkoca*). Degenerative spondylolisthesis alternatively suggests reduced normal functions of *kapha* hampering *bandha* and *sthiratva*.

Spinal canal stenosis

The stenosis is produced by soft-tissue changes such as disc herniation, ligamentous hypertrophy, fibrous scar, tumour or owing to modifications in bones. The decreased volume and narrowed shape of the spinal canal (*saṅgkoca*) cause compression of spinal cord and nerves. In the cervical spine this can cause symptoms of myelopathy or myelomalacia in severe cases. Lateral recess stenosis can cause radicular symptoms.

Symptoms of cervical spondylotic myelopathy

Clumsiness (poor coordination, movement or action), alteration in gait, neck pain, fine motor skills of hands are lost, radiculopathy of upper limb, muscle atrophy of extremities and loss or alteration of bowel and bladder function.

This indicates reduced normal smooth functioning of *vāyu* affecting *ceshṭā, dhātugati, samomoksho gatimatām* (normal elimination of excreta). This also points out symptoms when there is reduced *kapha* and aggravation in *vāta* and *pitta* producing *bhrama, udveshṭana, toda, dāha, vepana, aṇgamarda, parīṣosha, dūyana*. Similar symptoms are also observed when *vyāna vāyu* gets covered by *pitta* which produces *dāha, gatravikshepaṇa, klama, sarvagātragaurava, asthiparvastambha.*

Neuropathic (charcot) spine

Pain (*vyathā*) is the usual presentation of this condition. It is marked by narrowing of one of disc space (*saṅgkoca*), vertebral end plates sclerosis (effect of *dāruṇa property of vāta*) and osteophytes formation (*adhyasthi*).

Inflammatory disorders of spine

Inflammatory spondyloarthropathies

The spine is formed of many articulations therefore many diseases of the spine affect these joints resulting in arthritis.

Sero-negative inflammatory spondylitis

Ankylosing spondylitis

This spinal disease progressively affects the thoracic and cervical vertebrae. Early affections of ankylosing spondylitis are inflammation of sacroiliac joints, affected facet joints, lower bone density of the vertebrae, changes in the shapes of vertebral bodies and calcifications inside the spinal ligament. In the early phase of the illness, the discs are usually normal but in the advanced stage they are entirely bridged in the centre with bone tissue. In the advanced stage, facet joints are wholly fused with intervertebral foramina narrowing.

The cancellous bone becomes increasingly porotic and the cortices of the vertebrae become more prominent. This together with the ossification along the peripheral parts of the disc transforms the spine into a tube-like osseous rod called a bamboo spine.

This disorder indicates severe aggravation of *vāta* affecting *asthi dhātu* and sandhi irreversible destruction of spine develops structural changes.

Ankylosing hyperostosis of the spine

It is the ankylosis of vertebral column, in which there is ossification of ligaments with normal discs. That is marked by normal vertebral end plates and intervertebral disc height. But crucial spinal ankyloses, ossification of the anterior longitudinal ligament and sometimes of posterior longitudinal ligament. The disc spaces may be mildly narrowed with disc calcification. This disease shows *vimārgagaman* of *asthi dhātu* due to vitiated *vāta dosha*.

Metabolic disorders of spine

Osteoporosis of the spine

Osteoporosis develops from an inequity in the normal process of remodeling of the bone. This causes decreased bone strength. Generalized or localized back pain is

associated with loss of height due to vertebral compression. It can also cause progressive kyphosis or scoliosis. It is also noted that the spine is frequently first region of the skeleton suffering osteoporosis. Osteoporosis causes marked loss of trabecular bone tissue and vertebral strength is lost. This indicates vitiated *vāyu* causing *asthi dhātu kshaya* due to reduced *poshaṇa* and regeneration of *asthi dhātu* due to *srotovikṛiti*. It develops *sushiratā* and loss of *dhārana karma* of *asthi dhātu.*

The spinal deposition diseases

In children mostly cervical spine suffers intervertebral disc calcification with affection of nucleus pulposus associated with neck pain. In the adult the frequent site of calcification of disc is thoraco-lumbar spine. The calcification of the intervertebral disc rarely may cause symptoms with spinal cord or nerve root compression due to herniated disc. This deposition interferes disc nutrition and mechanical function and may cause disc degeneration. The facet joints and paraspinal ligaments also show calcification.

This suggests *asthi dhātu vimārgagamana* in the other structures which causes structural changes developing loss of normal functioning.

Ochronosis

The signs and symptoms are back ache, stiffness, loss of sagittal alignment of spine and restricted movement. The intervertebral discs present black brown pigmentation as an earliest finding of ochronosis. It is marked by decreased disc space height with subchondral sclerosis, osteophytes at the vertebral bodies and bridging of the bodies.

In the morbid affection of *asthi* its discoloration is produced. Vitiated *vāta dosh* develops greyish, blackish discoloration in *dhātu*. It develops *kharatā* in *asthi dhatu* and *adhyasthi*.

Genetic factors in *manyāstambha*

Genetic features are believed to cause the structural degeneration in the cervical spine e.g. Spondylolisthesis, scoliosis etc.

Āyurveda has described *anuvānṣika siddhānta* (laws of heredity) and verified that *bīja* of each creature contains both normal and abnormal factors. Which produce bodily and psychological features. It is proved that factors producing abnormality are likewise moved from the parents to the next generations.

Caraka says in this respect- in the unit of reproduction of individual, the body part that is damaged in the genetic source progresses abnormality; else not. It is stated

that these inherited diseases are usually incurable. Hence if we find family history of *manyāstambha* we may face difficulty in successful treatment.

Findings from observational study in the patients of *manyāstambha*

Assessment of *manyāstambha* with the help of goniometer.

Goniometer reading provides a broad idea about the restriction in the various neck movements. The neck movements included for the observations are combined movements of many joints i.e. between head and neck and intervertebral joints among their various parts. It is difficult to find out a very precise range of movement for individual joints.

The angle of movement was recorded at that point up to which the patient can turn the head/ neck comfortably. Beyond this point the patient can turn but he will start suffering discomfort in the form of resistance and pain. This resistance and pain together indicate stiffness. As this is a subjective finding there are chances of possible error. But it is useful when before and after treatment goniometer readings are taken to decide the efficacy of treatment.

Other symptoms found in the patients of *manyāstambha*

Though chronic neck stiffness was considered as the cardinal symptoms to diagnose and include the patients in the present study, other symptoms were also found in the patients. These are referred pain in head, neck, shoulder and upper limbs, burning and tingling sensation in hands etc.

Assessment of *manyāstambha* with the help of MRI of the cervical spine

MRI is a very useful modality in the patients of *manyāstambha* to find out anatomical involvement and structural changes in the cervical spine. With some limitations it gives a fair idea of the condition of the cervical spine in *manyāstambha.* All the findings are helpful to understand the disease better. It will help to decide the direction of treatment. For example, MRI can detect reduction in the water contents of disc confirming the disc desiccation. This finding can be helpful to understand the disc degeneration and the precise Ayurvedic treatment can be given.

Observations and results of the clinical study

Cervical spine straightening due to loss of normal lordosis is found in 89 %

patients. This is the most affected parameter among all the others. It is developed due to cervical muscle spasm in 34% patients. The characteristic shape of the intervertebral disc i.e. higher disc height anteriorly develops normal lordosis. This

arrangement of discs must be suffering modification due to their degeneration resulting into loss of normal lordosis.

The second structural change is found in the form of intervertebral disc herniation posteriorly at the level of C5-C6 in 80% patients. Although less frequently, compared to C5-C6 level; intervertebral disc herniation is also found in C3-C4, C4- C5, C6-C7 levels. The intervertebral disc above and below the middle segment has shown less tendency of herniation. The intervertebral disc of the middle segment might be suffering most disturbances and easily undergoing degeneration. This specific anatomical position of these disc decides the severity of their degeneration.

Posterior bulging of intervertebral discs compresses anterior meningeal covering around the spinal cord. This occurrence is comparable to the above findings of disc herniation. The severity of thecal sac indentation is maximum in the middle portion and decreasing at upper and lower ends of cervical spine.

fourth major structural change affecting the vertebral body is the osteophyte formation found in the patients of *manyāstambha.* Osteophytes represent the degeneration of cervical spine.

Posterior bulging of intervertebral disc produces not only the thecal sac indentation but it also causes intervertebral foramen compression and narrowing. This structural change is affecting critically the intervertebral foramen at C5- C6 level bilaterally and compressing bilateral roots of C6 nerves as the discs at this level is most affected among all cervical discs as per the above statements.

Intervertebral foramen compression at C6- C7, C4-C5 and C3- C4 levels and bilateral nerve root compression are observed with decreasing percentage of occurrence.

Intervertebral foramen compression bilaterally at C7-T1 and left C2-C3 level with bilateral nerve root compression of C8 and left C3 nerves was found only in 2-3 patients.

Other important structural affections found in decreasing order are spinal cord compression, scoliosis, spinal canal stenosis, intervertebral space reduction, ligament affections, facet joint affection, vertebral body affection, change in vertebral alignment and atlanto occipital joint affection. No affections were found in bilateral intervertebral foramen at C1, C1-C2 level in any patient. Nerve root compression was not found for bilateral nerve roots at C1, C2, T1 and left C3 nerves.

Based on observations in the terms of Chi-square test the data has been divided depending on their P value into highly susceptible structures, moderately susceptible structures etc. to produce *manyāstambha*. This classification is also useful for a clinician to presume the structural involvement and changes in the cervical spine in the patient of *manyāstambha;* during clinical examination.

Conclusion

Degenerated intervertebral disc herniating significantly at the level of C5-C6 is found along with indentation of thecal sac, intervertebral foramen compression and nerve roots compression. These structural modifications accompanied by cervical muscle spasm leading to loss of cervical lordosis develop signs and symptoms of *manyāstambha*.

Summery

The neck is a multipart structure. As far as *manyāstambha* is concerned the anatomy of cervical spine formed by the vertebrae, their joints, attached ligaments, muscles, spinal cord, nerves, blood vessels play a significant role. Functionally cervical spine is a very dynamic region of the body for the movement of the head and neck.

The degeneration starts much earlier in the neck. During the study many patients having age group of 20 years were found suffering from *manyāstambha* with degenerative changes in the cervical spine; observed in their MRI reports.

Various principles in *Āyurveda* like *mahābhūtas and dosh-dushya* as well as concepts of *sārir* e.g. *asthi, sandhi, snāyu, māmsa, peṣī kala, srotas, sirā, dhamanī, avayava etc.* are very important and useful to understand *manyāstambha.*

literature study for *manyāstambha*

From the literature study the effort has been made to border the possible progression of affections to the cervical spine by the actions of vitiated *dosha* in its various parts. The factors vitiating *vāta* produce *rukshatā, kharatā, laghutā, sushiratā* etc. in the cervical spine.

According to the concept of *āṣraya āsrayi* relationship when *vāta* gets contaminated it causes *asthi* related diseases. *Vāyu* finds favourable environment in *asthi* and *majjā. Vāyu* gets aggravated and filling up the channels and *vātavaha sirā* of cervical spine produces disorders.

Morbid affection of *asthi* and *majjā* in cervical spine develops- *adhyasthi, asthibheda, asthiṣūla, parva rujā, bhrama, mūrchā, tamo darśana* etc. The affection of many joints in the spine can also be caused due to loss of normal functions of *kapha dosha* i.e. *sneha, bandha, sthiratva, sandhisanṣleshaṇa.*

The muscles, ligaments, tendons, blood vessels, nerves in the neck get affected by vitiated *vāta dosha* predominantly with accompanying *kapha* and *pitta* and develop *manyāstambha* and other symptoms.

Different *samprāpti* can also be considered.

In the state of reduced *kapha, vata* emigrates the normally located *pitta.* It develops *bheda, dāha, śrama* and *daurbalya*. In other form *pitta* produces *dāha* and *śūla* obstructing *vāta*.

Manyāstambha and its symptoms are found in various diseases described in *Āyurveda.* Their study helps us to understand the pathology of *manyāstambha* and its

symptoms. *Manyāstambha* described by *Suṣruta* is a disorder in which muscles and ligaments are involved with stiffness or rigidity of the neck. But *manyāstambha* in the present study is a chronic disease.

Study of these symptoms helps us to understand the pathology for the development of various symptoms of *manyāstambha.* These are *ardhāvabhedaka, vātaj shiroroga, hasta- pāda dāha, hasta- pāda harsha, ekaṅgavāta, sarvāṅgavāta, antarāyām and bahirāyām.*

We get structural details of cervical spine from the modern anatomy texts. Study of anatomy is the first step in the comprehensive study of *manyāstambha.* Various disorders of cervical spine are sorted out from the modern medicine text according to our inclusion criteria e.g. cervical spondylosis, spondylosis deformans etc. From that we get the detail description of anatomical structural involvement, affections and structural changes in each part of the cervical spine.

This knowledge helps us to understand how each affected and transformed structure is responsible to develop *manyāstambha* and its symptoms e.g. degeneration in the intervertebral disc is found in cervical spondylosis. Understanding of these pathological processes and their effects developed in the anatomical structures help us to corelate them with Āyurvedic concepts of *samprāpti*. It helps us to understand contributory factors, which properties of *dosha* and *dhātu* have affected and suffered modifications, how actions of vitiated *doshas* have taken place in *dhātu* and the structures. For example, due to heavy physical works early degeneration starts in the cervical spine affecting mainly intervertebral disc in the form of desiccation (loss of water contents and drying up), tearing of annular fibres of disc and causing disc herniation. This modern pathology helps us to understand *hetu* for the vitiation of *vāta dosha* and *dhātu kshaya*, due to increase in its *ruksha, laghu, dāruṇa, khara, viśada guna.* And it confirms destructions made by *vāta* in the form of *sraṉsa, bhraṉsa, saṉga, bheda, śosha, saṅgkoca etc*. Thus, it produces symptoms of *manyāstambha* i.e. *stambha, vyathā, toda, supti, harsha* etc.

Various parts of the cervical spine suffer affections of vitiated *vāta* and undergo structural changes these are vertebral body, articular processes, intervertebral foramina zygapophyseal joint (facet joint), synovial folds (meniscus) of zygapophyseal joint intervertebral joints between the laminae, spines and transverse processes the ligaments of the spine, intervertebral discs, curvatures of the vertebral column, vertebral canal, spinal cord, vertebral artery, neck muscles and spinal nerves. The structural

arrangement of various parts listed above is important and appropriate for normal functioning. But these are much susceptible for the progress of spinal diseases. Such anatomical factors are affected due to the actions of vitiated *doshas*; especially *vāta* and develop *manyāstambha*.

The modern science of medicine has described many diseases of cervical spine. Most of these spinal diseases are developed due to degeneration of the spine i.e. intervertebral disc, articular processes, body etc. These are cervical spondylosis, disc herniation, spondylosis deformans, osteochondrosis, degenerative spondylolisthesis spinal canal stenosis cervical spondylotic myelopathy and neuropathic (charcot) spine. Few inflammatory disorders of spine are also described i.e. sero-negative inflammatory spondylitis, ankylosing spondylitis and ankylosing hyperostosis of the spine. Metabolic disorders of spine are described like osteoporosis of the spine deposition diseases affecting the spine and ochronosis.

Various causes to bring about the degeneration of the spine are described in the above listed diseases. Certain parts of the cervical spine get involved and undergo structural changes is very well elaborated by the modern science. Cervical pain is the main symptom in all these diseases along with neck stiffness, cervical radiculopathy and so on. Using the clinical history, clinical examination, laboratorial investigation and imaging technics one can very well understand and diagnose these conditions in the patient.

This description of spinal disorder helps us to understand *manyāstambha* and corelate it with the various Ayurvedic aspects like *racanā* and *kriyā śārira*, activities of *dosha* and *dhātu* to produce *manyāstambha* (in the form of *samprāpti*), other symptoms of *mañyastambha*, *upadrava* and *sādhyāsadhyatva*.

The main symptom of *manyāstambha* is the neck stiffness which is found in all the above diseases together with cervical pain referred pain in head, radiating pain in upper limbs etc. The peculiar anatomical structure of cervical spine is the definite source to develop these diseases. Hence the anatomy of cervical spine must be given at most importance while considering all aspects of *manyāstambha.* There are limits to find out minute changes in many parts of the cervical spine precisely in the patients of *manyāstambha* with the help of MRI. But the physician should always consider whole anatomical structure of cervical spine in *manyāstambha.*

Degeneration in the cervical spine may take place due to genetic factors. Family history is found in scoliosis, spondylolisthesis, Schmorl's nodes etc. Therefore, family

history of *manyāstambha* must be well thought while determining prognosis of this disease in the patient.

Observational study of *manyāstambha*

Goniometer reading is an objective parameter to observe the restriction in the various neck movements. The reading is recorded at the comfortable range of neck movement. The accuracy of reading depends on the patient's ability to identify exact demarcation point between comfortable Goniometric measurements and neck stiffness causing discomfort. It has a limited significance to represent neck stiffness in the present study.

Chronic neck stiffness was considered as the cardinal symptoms to diagnose to include the patients in the present study, other symptoms were also found in the patients while taking the history. These are referred pain in head, neck, shoulder and upper limbs, burning and tingling sensation in hands etc.

Assessment of *manyāstambha* with the help of MRI of the cervical spine

MRI is a very useful investigation in the patients of *manyāstambha* to find out anatomical involvement and structural changes in the cervical spine. With some limitations it gives a fair idea of the condition of the cervical spine in *manyāstambha.* All the findings are helpful to understand the disease better. It will help to decide the direction of treatment. For example, MRI can detect reduction in the water contents of disc confirming the disc desiccation. This finding can be helpful to understand the disc degeneration and the precise Ayurvedic treatment can be given.

Observations and results of the clinical study

Cervical spine straightening due to loss of normal lordosis is found in maximum patients. This most affected parameter is developed due to cervical muscle spasm and modification in the shape of disc. Then comes the place of degenerated disc. The degenerative changes in the disc is observed in the form of various stages of disc herniation posteriorly. The disc between C5-C6 vertebrae is found to be herniated in maximum patient as compared to the other cervical intervertebral discs. The vertebrae near the skull and thorax are comparatively express less movements than the vertebrae between them hence their disc might be suffering degeneration less frequently. Postero-central bulging of intervertebral disc indents anterior meningeal covering around the spinal cord. Postero-lateral bulging narrows intervertebral foramens abutting nerve roots. Both these conditions are developed due to the disc herniation hence found at the levels where there is severe disc herniation. This structural change is affecting severely

the intervertebral foramen at C5- C6 level bilaterally and compressing bilateral roots of C6 nerves.

Fourth major structural change affecting the vertebral body is the osteophyte formation found in the patients of *manyāstambha.* Osteophytes represent the degeneration of cervical spine. These osteophytes are also found compressing the nerve roots.

Other important structural affections found in decreasing order are spinal cord compression, scoliosis, spinal canal stenosis, intervertebral space reduction, ligament affections, facet joint affection, vertebral body affection, change in vertebral alignment and atlanto occipital joint affection. No affections were found in bilateral intervertebral foramen at C1, C1-C2 level in any patient. Nerve root compression was not found for bilateral nerve roots at C1, C2, T1 and left C3 nerves.

With the Chi-square Test P value is determined to indicate highly susceptible structures, moderately susceptible structures etc. to produce *manyāstambha*. This sorting provides presumption to a clinician about the structural involvement and changes in the cervical spine in the case of *manyāstambha.*

Conclusions

The symptoms of *manyāstambha* are developed by the structural abnormalities of cervical spine. The degenerated intervertebral disc produces herniation posteriorly which indents the thecal sac, compresses intervertebral foramens and the nerve roots departing through them along with loss of cervical lordosis. In maximum patients, the finding was posterior intervertebral disc herniation at C5-C6.

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Abbreviations

च. सू.	चरक संहिता सूत्रस्थान
च. शा.	चरक संहिता शारीरस्थान
च. वि.	चरक संहिता विमानस्थान
च. नि.	चरक संहिता निदानस्थान
च. चि.	चरक संहिता चिकित्सास्थान
चक्र.	चक्रपाणिदत्त टिका
सु. सू.	सुश्रुत संहिता सूत्रस्थान
सु. शा.	सुश्रुत संहिता शारीरस्थान
सु. नि.	सुश्रुत संहिता निदानस्थान
सु. उ.	सुश्रुत संहिता उत्तरतंत्र
नि. सं.	निबंध संग्रह टिका
न्या. च.	न्याय चन्द्रिका टिका
का. शा. पृ. क्र.	काश्यप संहिता पृष्ठ क्रमांक
अ. सं. शा.	अष्टांग संग्रह संहिता शारीरस्थान
अ. सं. नि.	अष्टांग संग्रह संहिता निदानस्थान
अ. ह्र. शा.	अष्टांग ह्रदय संहिता शारीरस्थान
अ. ह्र. सू.	अष्टांग ह्रदय संहिता सूत्रस्थान
अ. ह्र. नि.	अष्टांग ह्रदय संहिता निदानस्थान

Nāgarī Letters with their Indo-Romanic Equivalents

Vovels		Consonants		Consonants	
अ	a	क्	k	द्	d
आ	ā	ख्	kh	ध्	dh
इ	i	ग्	g	न्	n
ई	ī	घ्	gh	प्	p
उ	u	ङ्	ṅ	फ्	ph
ऊ	ū	च्	c	ब्	b
ऋ	ṛi	छ्	ch	भ्	bh
ॠ	ṛī	ज्	j	म्	m
ऌ	lṛi	झ्	jh	य्	y
ॡ	lṛī	ञ्	n̆	र्	r
ए	e	ट्	ṭ	ल्	l
ऐ	ai	ठ्	ṭh	ळ्	ḷ
ओ	o	ड्	ḍ	ळ्ह्	ḷh
औ	au	ढ्	ḍh	व्	v
अं	n̲	ण्	ṇ	श्	ś
अः	ḥ	त्	t	ष्	sh
		थ्	th	स्	s
				ह्	h

Consent form

रुग्ण संमती पत्रक

बाह्य रुग्ण क्र.

रुग्ण नाम: वय: लिंग:

पत्ता– फोन नं.–

Anatomical Significance of Cervical Spine in *manyāstambha*

१] मी या पत्रकाद्वारे असे नमुद करतो/करते की, मी दिनांक रोजी या प्रक्रिये संदर्भातील सर्व माहिती वाचली असून त्याबद्दल उपस्थित झालेल्या सर्व शंकांचे समाधान करण्यासाठी प्रश्न विचारण्याची संधी मला मिळाली आहे. त्यामुळे सर्व मुद्दे मला समजले असून शंकांचे पूर्ण समाधान झाले आहे.

२] तसेच माझ्या घेण्यात येणाऱ्या शारीरीक व प्रयोगशालेय तपासण्यां विषयी सर्व माहिती मला देण्यात आली असून त्या करून घेण्यास मी स्वखुशीने तयार आहे.

३] तसेच मी हे देखील जाणून आहे की ह्या प्रक्रिये मधला माझा सहभाग मी कोणत्याही क्षणी रद्द करु शकतो/शकते. त्याकरीता मला कोणतेही कारण देण्याची गरज नाही व त्यामुळे माझी कोणतीही वैद्यकिय सेवा किंवा कायदेशीर न्यायविषयक अधिकार यांचे हनन होणार नाही.

४] अभ्यासक, अभ्यासासाठी काम करणारे इतर लोक व परीक्षक या सर्वांना, माझे संबंधित नोंदी पहाण्यासाठी माझी संमती घेण्याची आवश्यकता नसेल. मी प्रक्रियेमधून माझा सहभाग काढून घेतल्यानंतर देखील या प्रबंधासाठी किंवा इतर सबंधित अभ्यासासाठी माझ्याशी संबधित नोंदी माझ्या संमती शिवाय पडताळल्या जाऊ शकतात याची मला जाणीव असून माझी पूर्ण संमती आहे.

५] तसेच मला याची कल्पना आहे की, माझी ओळख पूर्णता गोपनीय राखली जाईल. माझ्या नोंदी इतर कोणत्याही अभ्यासविषयक कामासाठी किंवा प्रकाशनास देताना माझी ओळख पूर्णत: गोपनीय राखली जाईल. या नोंदी कोणत्याही शास्त्रीय दृष्टिकोनातून वापरण्यास मी विरोध करणार नाही. वरील सर्व गोष्टी मला समजल्या असून मी स्वखुशीने संमती देत आहे.

रुग्णाची/ तज्ञाची सही–

Patient's information sheet

रुग्ण माहिती पत्रक

रुग्ण नाव:– वय:–

विषय :–Anatomical Significance of Cervical Spine in *manyāstambha*.

परिचय:–

तुमचे, या संशोधनात्मक प्रयोगात भाग घेण्यासाठी स्वागत आहे. त्यासाठी तुम्ही या संशोधनात्मक प्रयोगाची माहिती वाचून, तुम्हाला या अभ्यासाचे स्वरुप व पद्धत तसेच सहभागी झाल्यावर तुमचे हक्क पुर्णपणे समजल्यावर तुम्ही या प्रयोगात सहभागी होऊ शकता.

संशोधनात्मक प्रयोगाचा उद्देश:–

To Study the anatomical significance of Cervical Spine in *manyāstambha*.

संशोधनात्मक प्रयोग करण्याची पद्धत:–

संशोधनात्मक प्रयोगामध्ये वैद्य आपली शारीरिक तपासणी करुन आपल्या MRI (cervical spine) या तपासणी चा अभ्यास करतील.

संशोधनात्मक प्रयोगात भाग घेण्याचे संभाव्य फायदे:–

या प्रयोगाने तुमच्या व्याधीची तपासणी व परीक्षण होणार आहे. त्यामुळे व्याधीची अधिकची माहीती प्राप्त होऊन पुढील उपचाराची दिशा निश्चित करण्यास फायदा होईल. तुमचा या प्रयोगातील सहभाग हा आयुर्वेदात संशोधन व मानवतेच्या हिता साठी महत्त्वाचा आहे.

संशोधनात्मक प्रयोगात भाग घेण्याचा मोबदला:–

या संशोधनात्मक प्रयोगात भाग घेण्याचा मोबदला दिला जाणार नाही.

या संशोधनात्मक प्रयोगात सहभाग मध्येच सोडून देण्यासंबंधी : –

या संशोधनात्मक प्रयोगातील सहभाग पुर्णपणे ऐच्छिक आहे, प्रयोगात सहभागी न होण्याचा, किंवा प्रयोगातील सहभाग केव्हाही रद्द करण्याचा तुम्हाला हक्क आहे.

या संशोधनात्मक प्रयोगातील गुप्तता:–या संशोधनात्मक प्रयोगातील तुमच्या नावाची माहिती गरजेनुसार कायद्या व्यतिरीक्त कोठेही प्रकट केली जाणार नाही.

या संशोधनात्मक प्रयोगातील माहिती वाचण्यासाठी/ ऐकण्यासाठी वेळ दिल्याबद्दल धन्यवाद.

CASE RECORD FORM

Anatomical Significance of Cervical Spine in *manyāstambha.*

General information:-

I.P.D.no. - O.P.D.no.-

Name: – Age: - Gender:–

Address: - Contact no:-

Diagnosis:-

Rugna parikshana

According to *trividh pariksha (darshan, sparshan, prashna.)* And using the measurements of Goniometry of the Cervical Spine.

gradation	range of restriction of neck movement
grade 1	1 % to 25%
grade 2	26 % to 50%
grade 3	51 % to 75%
grade 4	76 % to 100%

Sr. No.	Neck movement	Standard range of neck movement	Goniometric measurements	Restriction of neck movement	Gradation
1	Forward flexion	40˚ to 60˚			
2	Backward extension	45˚ to 70˚			
3	Right lateral flexion	45˚			
4	Left lateral flexion	45˚			
5	Right rotation	60˚ to 80˚			
6	Left rotation	60˚ to 80˚			

Findings from MRI of cervical spine

No.	Structure	Findings
1	Cervical muscles	
2	Vertebral alignment	
3	Curvature of cervical spine	
4	Ligaments	
5	Atlanto-occipital joint	
6	Vertebral body	
7	Osteophytes	
8	Facet joints	
9	Spinal canal	
10	Thecal sac	
11	Spinal cord	
12	Intervertebral foramen	
13	Nerve root compression	
14	Intervertebral disc	
15	Inter vertebral spaces	
16	Other findings	

Signature of research worker.....**Signature of the guide**.....

Master Chart

SR	AGE	GEN	CMS	VA	LCL	SCOLI	LIG	AOJ	VB	OPT	FJ	SCS	TSC2-C3	TSC3-C4	TSC4-C5	TSC5-C6	TSC6-C7	TSC7-T1	SPC	IVFOC-C1R	IVFOC-C1L	IVFC1-C2R	IVFC1-C2L	IVFC2-C3R	IVFC2-C3L	IVFC3-C4R	IVFC3-C4L	IVFC4-C5R	IVFC4-C5L
1	30	M	N	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
2	30	M	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
3	30	F	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N
4	30	F	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
5	30	F	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
6	30	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
7	30	F	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N
8	31	M	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
9	31	F	N	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
10	31	F	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N
11	31	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y
12	31	M	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N
13	31	F	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
14	32	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
15	32	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
16	32	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y
17	32	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
18	32	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
19	32	F	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
20	32	F	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
21	32	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N
22	32	M	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
23	32	F	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
24	33	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
25	33	M	N	N	N	Y	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
26	33	F	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
27	33	F	Y	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
28	34	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
29	34	M	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
30	34	M	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N	N	N	N	N	N	N	N	Y	Y
31	34	M	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
32	34	F	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
33	34	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
34	34	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
35	35	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
36	35	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
37	35	F	Y	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N
38	36	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
39	36	M	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
40	36	M	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
41	36	M	Y	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
42	36	M	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N
43	37	M	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	N	Y	Y	Y
44	37	M	Y	N	Y	Y	N	N	N	Y	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
45	37	M	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
46	38	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
47	38	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
48	38	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
49	38	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
50	38	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N

SR	IVFC5-C6R	IVFC5-C6L	IVFC6-C7R	IVFC6-C7L	IVFC7-T1R	IVFC7-T1L	NC1R	NC1L	NC2R	NC2L	NC3R	NC3L	NC4R	NC4L	NC5R	NC5L	NC6R	NC6L	NC7R	NC7L	NC8R	NC8L	NCT1R	NCT1L	IVDC2-C3	IVDC3-C4	IVDC4-C5	IVDC5-C6	IVDC6-C7	IVDC7-T1	IVS
1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
2	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N
3	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
4	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
5	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
6	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
7	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
8	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	Y	N	N	N	N	N	N	N	Y	Y	N	N
9	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	N	Y	N	N	N
10	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	Y	N	N	N	N	N	N	Y	Y	Y	N	N
11	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
12	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
13	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
14	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
15	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
16	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N
17	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	Y	Y	N	N
18	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	Y	N	N
19	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
20	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
21	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
22	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
23	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	Y	Y	N	N
24	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N
25	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	Y	N	N
26	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
27	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N
28	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
29	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
30	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N
31	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
32	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
33	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
34	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
35	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
36	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
37	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N
38	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N
39	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	Y	N	N	N	N	N	N	N	Y	Y	N	N
40	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
41	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
42	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
43	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
44	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
45	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
46	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	N	N
47	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N
48	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N
49	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
50	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N

SR	AGE	GEN	CMS	VA	LCL	SCOLI	LIG	AOJ	VB	OPT	FJ	SCS	TSC2-C3	TSC3-C4	TSC4-C5	TSC5-C6	TSC6-C7	TSC7-T1	SPC	IVFOC-C1R	IVFOC-C1L	IVFCI-C2R	IVFCI-C2L	IVFC2-C3R	IVFC2-C3L	IVFC3-C4R	IVFC3-C4L	IVFC4-C5R	IVFC4-C5L
51	38	M	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
52	38	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
53	38	M	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N
54	38	M	Y	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
55	39	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
56	39	M	N	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	N	N
57	39	M	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N
58	40	M	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
59	40	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
60	40	M	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
61	40	F	Y	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
62	40	m	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
63	41	F	N	N	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
64	42	F	Y	N	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y
65	42	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
66	42	M	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	N	Y	Y	Y
67	42	M	Y	N	Y	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N
68	42	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
69	42	F	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N	N
70	42	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
71	42	F	Y	N	Y	N	Y	N	N	Y	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N
72	42	F	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N
73	43	F	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
74	43	F	N	N	Y	N	N	N	N	Y	N	N	Y	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
75	43	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
76	44	F	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
77	44	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
78	44	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y
79	45	F	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
80	45	F	Y	N	Y	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
81	45	F	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
82	46	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y
83	46	M	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
84	47	F	N	N	Y	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
85	47	F	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
86	47	F	Y	N	Y	N	N	N	N	Y	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
87	48	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
88	48	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
89	48	F	N	N	Y	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
90	49	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
91	49	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	Y	N	N	N	N	N	N	Y	N	Y	N
92	49	F	Y	N	Y	N	N	N	N	Y	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y
93	49	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N
94	49	F	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
95	49	F	N	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
96	50	F	N	N	Y	N	N	N	N	Y	Y	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
97	50	F	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
98	50	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y
99	50	F	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
100	50	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y

SR	IVFC5-C6R	IVFC5-C6L	IVFC6-C7R	IVFC6-C7L	IVFC7-T1R	IVFC7-T1L	NC1R	NC1L	NC2R	NC2L	NC3R	NC3L	NC4R	NC4L	NC5R	NC5L	NC6R	NC6L	NC7R	NC7L	NC8R	NC8L	NCT1R	NCT1L	IVDC2-C3	IVDC3-C4	IVDC4-C5	IVDC5-C6	IVDC6-C7	IVDC7-T1	IVS
51	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
52	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
53	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
54	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N
55	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
56	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	Y	N	N
57	Y	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N
58	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
59	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N
60	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N
61	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	N	Y
62	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	N	N	N	N
63	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N
64	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
65	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N
66	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	N	N
67	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	Y	N	Y	Y	N	N
68	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
69	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
70	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
71	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
72	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N
73	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
74	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
75	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
76	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
77	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N
78	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
79	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
80	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	Y
81	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
82	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
83	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
84	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N
85	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
86	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N
87	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	N	N
88	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
89	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	N	N
90	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
91	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	Y
92	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	Y
93	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
94	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
95	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
96	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N
97	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	N	N	N
98	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
99	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
100	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N

SR	AGE	GEN	CMS	VA	LCL	SCOLI	LIG	AOJ	VB	OPT	EJ	SCS	TSC2-C3	TSC3-C4	TSC4-C5	TSC5-C6	TSC6-C7	TSC7-T1	SPC	IVFOC-C1R	IVFOC-C1L	IVFCI-C2R	IVFCI-C2L	IVFC2-C3R	IVFC2-C3L	IVFC3-C4R	IVFC3-C4L	IVFC4-C5R	IVFC4-C5L
101	50	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	N	Y	N	Y	N	N	N	N	N	N	N	N	N	Y
102	50	F	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
103	50	M	Y	N	Y	N	Y	N	N	Y	Y	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	Y	Y
104	51	M	N	N	Y	N	N	N	N	Y	N	N	Y	Y	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N
105	51	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
106	52	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
107	53	M	N	N	N	N	N	N	N	Y	N	Y	N	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
108	54	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y
109	54	F	Y	N	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y
110	54	M	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
111	55	M	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	Y	Y
112	55	M	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
113	56	M	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
114	56	M	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
115	56	M	N	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
116	56	M	Y	N	Y	N	N	N	N	Y	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
117	58	M	Y	N	Y	Y	N	N	N	Y	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	Y
118	58	M	Y	N	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
119	58	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y
120	58	M	N	N	Y	N	N	Y	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
121	59	M	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
122	60	F	N	N	Y	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y
123	60	F	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	Y	Y
124	62	F	N	N	Y	N	N	N	N	Y	Y	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
125	64	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
126	64	M	Y	N	Y	Y	N	N	N	Y	N	N	Y	Y	Y	Y	N	N	Y	N	N	N	N	N	N	Y	Y	N	N
127	65	F	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
128	65	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
129	65	F	N	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N
130	65	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
131	66	M	N	N	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
132	68	F	N	N	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
133	68	F	N	Y	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	Y	Y	Y	Y
134	68	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y
135	68	F	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
136	68	F	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
137	69	M	Y	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
138	69	M	N	N	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
139	69	M	N	N	N	N	Y	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
140	69	M	N	N	Y	N	Y	N	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N
141	69	M	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
142	70	F	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y
143	70	M	N	N	Y	N	N	N	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y
144	70	M	N	N	Y	N	N	N	N	Y	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
145	70	M	N	N	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y
146	70	F	Y	N	Y	N	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N
147	70	F	Y	N	Y	N	N	N	N	Y	N	N	N	Y	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	Y
148	70	F	N	N	N	Y	N	N	N	Y	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	N	Y	N	N
149	70	M	N	N	Y	N	N	N	N	Y	N	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
150	70	M	N	N	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y	N	N	N	N	N	N	N	N	N	N

SR	IVFC5-C6R	IVFC5-C6L	IVFC6-C7R	IVFC6-C7L	IVFC7-T1R	IVFC7-T1L	NC1R	NC1L	NC2R	NC2L	NC3R	NC3L	NC4R	NC4L	NC5R	NC5L	NC6R	NC6L	NC7R	NC7L	NC8R	NC8L	NCT1R	NCT1L	IVDC2-C3	IVDC3-C4	IVDC4-C5	IVDC5-C6	IVDC6-C7	IVDC7-T1	IVS
101	Y	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
102	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
103	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N	N	N	Y
104	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N	N
105	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	N	N
106	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
107	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	Y	N	N
108	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	Y	N	Y	N	N
109	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N
110	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
111	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	Y
112	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
113	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
114	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
115	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	Y
116	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
117	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	N	N	N	Y	Y	Y	Y	Y	N
118	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N
119	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
120	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
121	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N
122	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	Y	N	N	N	N	N	N	Y	Y	Y	N	N
123	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
124	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N
125	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
126	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N
127	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
128	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
129	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
130	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N
131	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	N	N
132	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
133	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
134	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	N	N
135	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
136	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
137	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
138	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
139	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
140	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N
141	N	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	N	N
142	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	N
143	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N
144	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
145	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N
146	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N
147	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N	N
148	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N
149	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	Y
150	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	N

Abbreviations used in Master Chart and their meaning

Sr. No.	Abbreviation	Meaning
1	CMS	Cervical muscle spasm
2	VA	Change in vertebral alignment
3	LCL	Loss of cervical lordosis
4	SCOLI	Scoliosis
5	LIG	Ligament affections
6	AOJ	Atlanto-occipital joint affections
7	VB	Vertebral body affections
8	OPT	Osteophytes formation
9	FJ	Facet joint affections
10	SCS	Spinal canal stenosis
11	TSC2-C3	Thecal sac indentation at C2-C2
12	TSC3-C4	Thecal sac indentation at C3-C4
13	TSC4-C5	Thecal sac indentation at C4-C5
14	TSC5-C6	Thecal sac indentation at C5-C6
15	TSC6-C7	Thecal sac indentation at C6-C7
16	TSC7-T1	Thecal sac indentation at C7-C8
17	SPC	Spinal cord affection
18	IVFOC-C1R	Inter vertebral foramen compression at C1 R
19	IVFOC-C1L	Inter vertebral foramen compression at C1 L
20	IVFCI-C2R	Inter vertebral foramen compression at C1-C2 R
21	IVFCI-C2L	Inter vertebral foramen compression at C1-C2 L

22	IVFC2-C3R	Inter vertebral foramen compression at C2-C3 R
23	IVFC2-C3L	Inter vertebral foramen compression at C2-C3 L
24	IVFC3-C4R	Inter vertebral foramen compression at C3-C4 R
25	IVFC3-C4L	Inter vertebral foramen compression at C3-C4 L
26	IVFC4-C5R	Inter vertebral foramen compression at C4-C5 R
27	IVFC4-C5L	Inter vertebral foramen compression at C4-C5 L
28	IVFC5-C6R	Inter vertebral foramen compression at C5-C6 R
29	IVFC5-C6L	Inter vertebral foramen compression at C5-C6 L
30	IVFC6-C7R	Inter vertebral foramen compression at C6-C7 R
31	IVFC6-C7L	Inter vertebral foramen compression at C6-C7 L
32	IVFC7-T1R	Inter vertebral foramen compression at C7-T1 R
33	IVFC7-T1L	Inter vertebral foramen compression at C7-T1 L
34	NC1R	Nerve root compression C1 R
35	NC1L	Nerve root compression C1 L
36	NC2R	Nerve root compression C2 R
37	NC2L	Nerve root compression C2 L
38	NC3R	Nerve root compression C3 R
39	NC3L	Nerve root compression C3 L
40	NC4R	Nerve root compression C4 R
41	NC4L	Nerve root compression C4 L
42	NC5R	Nerve root compression C5 R
43	NC5L	Nerve root compression C5 L
44	NC6R	Nerve root compression C6 R
45	NC6L	Nerve root compression C6 L

46	NC7R	Nerve root compression C7 R
47	NC7L	Nerve root compression C7 L
48	NC8R	Nerve root compression C8 R
49	NC8L	Nerve root compression C8 L
50	NCT1R	Nerve root compression T 1 R
51	NCT1L	Nerve root compression T 1 L
52	IVDC2-C3	Intervertebral disc herniation C2-C3
53	IVDC3-C4	Intervertebral disc herniation C3-C4
54	IVDC4-C5	Intervertebral disc herniation C4-C5
55	IVDC5-C6	Intervertebral disc herniation C5-C6
56	IVDC6-C7	Intervertebral disc herniation C6-C7
57	IVDC7-T1	Intervertebral disc herniation C7-T1
58	IVS	Intervertebral space reduction

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