MORPHOMETRIC ANALYSIS OF AXIS VERTEBRA AND ITS IMPLICATIONS FOR INSTRUMENTATION

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CERTIFICATE

This is to certify that this dissertation titled **"MORPHOMETRIC ANALYSIS OF AXIS VERTEBRA AND ITS IMPLICATIONS FOR INSTRUMENTATION"** submitted by **DR. S. POONGODI** to the faculty of Neuro Surgery, The Tamil Nadu Dr. M.G.R. Medical University, Chennai, in partial fulfillment of the requirement in the award of degree of **MASTER OF CHIRURGIE IN NEURO SURGERY,** for the **August 2011** examination is a bonafide research work carried out by her under our direct supervision and guidance.

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DECLARATION

I, **Dr. S. POONGODI** solemnly declare that this dissertation **“MORPHOMETRIC ANALYSIS OF AXIS VERTEBRA AND ITS IMPLICATIONS FOR INSTRUMENTATION”** was prepared by me under the guidance and supervision of Professor and HOD, Department of Neurosurgery, Madurai Medical College and Government Rajaji Hospital, Madurai between **2007 and 2011.**

This is submitted to The Tamil Nadu Dr. M.G.R. Medical University, Chennai, in partial fulfillment of the requirement for the award of **MASTER OF CHIRURGIE, in NEURO SURGERY,** degree Examination to be held in **AUGUST 2011.**

Place : Madurai

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CONTENTS

INTRODUCTION

The anatomy of second cervical vertebra has been described in detail by various authors. Most authors [1-3] have concentrated on the dens and a few [4,5] have described the linear and angular characteristics of the pedicle or superior facets. Erosion of the lateral mass and pedicle of C2 vertebra by vertebral artery has been reported.[6,7,8]. This normal variation in anatomy has important implications for instrumentation of upper cervical vertebrae particularly the transarticular screw fixation at C1-C2 level that provides a rigid fixation. When grooves for vertebral artery were studied in dry specimens of C2 vertebra, they were often asymmetrical. In some specimens one of the grooves was deep enough to reduce the internal height of the lateral mass at the point of fixation of trans articular screws, thus placing the vertebral artery at extreme risk of injury during fixation and there is not enough bone to allow adequate fixation. Therefore before any decision is made concerning the type of fixation to be used at C2 it is recommended that a thin section CT be done with 3 dimensional reconstruction to show both the depth and any asymmetry of the grooves for the vertebral artery.

AIMS OF THE STUDY

1. To study the anatomical variations of the pedicle,the lateral mass, the vertebral artery groove and the transverse foramen parameters of axis vertebra in dry bone specimens of 25 individuals of the South Indian population with particular reference to the variations of the depth of groove for the vertebral artery and its implications in instrumentation.

2. To study the CT morphometry of axis vertebra in 25 individuals of the South Indian population with particular reference to the vertebral artery groove and its asymmetry.

3. To emphasize that high resolution CT with 3 dimensional reconstruction is mandatory before instrumentation to stabilise the C1 to C2 segment.

MATERIALS AND METHODS

25 dry specimens of the second cervical vertebra were obtained from the Department of Anatomy, Madurai Medical College Madurai. Nine parameters were measured and all were linear dimensions. The anatomical measurements focussed on the pedicle, the lateral mass, the groove for the vertebral artery and the transverse foramen. Paired structures were measured bilaterally using an electronic caliper accurate to 0.01 mm. The mean, standard deviation and range were calculated for all 25 specimens amounting to a total of 50 measurements for each observation. Right to left asymmetry was also analyzed by student's 't' test and One way ANOVA test. All mean values were expressed as the mean with confidence intervals of 95%. The following measurements were made:

1. Height of pedicle was measured from its superior surface to inferior surface in the transverse foramen.
2. Width of the pedicle was measured from the internal surface of pedicle to its external surface at the level of the transverse foramen.

3. Length of the pedicle was measured from the posterior most point in pedicle axis (bounded by the junction of lamina pedicle medially and the junction of the lamina to the inferior articular process posterolaterally) to the anterior most part of the pedicle axis (bounded by the junction of the pedicle to the axis body anteromedially and the junction of the pedicle to the lateral mass laterally)
4. External height of the lateral mass was measured from the midpoint of the superior facet to the lowermost point on the inferior surface of the lateral mass
5. Depth of vertebral artery groove was measured from the upper most point within the vertebral artery groove to its base on the inferior surface of the lateral mass.
6. Internal height of lateral mass was measured by subtracting the depth of vertebral artery groove from the external height of the lateral mass.
7. Length of vertebral artery groove was measured as the widest distance at the base in the antero posterior diameter on the inferior surface of C2

8. Height of the transverse foramen was measured at its maximal vertical diameter

9. Width of the transverse foramen was measured at the maximal horizontal diameter of the foramen.

Radiologic technique :

Data of patients undergoing CT of the neck in the Department of Radiology ,Government Rajaji Hospital,Madurai were used to define clinical guidelines. Thinly sliced 1 mm sections were obtained through the region of interest from the base of C3 to C1-C0 joint. Multiplanar reconstructions were obtained in the sagittal and coronal planes. The lateral mass height and the vertebral artery groove depth were measured bilaterally. The amount of bone mass above the roof of groove for vertebral artery (internal height)was measured. The pedicle length and the vertebral groove base length values were used. These five CT morphometric parameters were used to provide the surgeons the data regarding the lateral mass and the depth of the vertebral artery groove and to help them avoid an enlarged vertebral groove.

REVIEW OF LITERATURE

The axis, the 2nd cervical vertebra is a component of the cranio vertebral junction along with the basi occiput, foramen magnum and atlas.

The occipito atlanto axial joints, in their role as a stable but functionally mobile transition zone between the the axial skeleton and skull, compose the most anatomically and kinematically complex articulations of the spinal axis. [9,10,11,12] The geometry of the articular surfaces provides mobility at the cost of stability. The latter is provided by the ligamentous structures as well as by the cervical musculature.

A complete knowledge of the bony anatomy, embryology and biomechanics of the cranio cervical junction is necessary to understand the etiology of abnormalities in this area and thus their treatment.

ANATOMY OF AXIS VERTEBRA:

The axis is a pivot or axle for rotation of the atlas and head around its strong dens (odontoid process) projecting vertically from the body. A small oval anterior articular facet on the dens forms a synovial joint with a reciprocal facet on the back of the anterior atlantal arch. Posteriorly the dens has a groove formed by the Transverse Atlantal ligament. The dens is conical, about 1.5 cm long. . Its has a pointed apex and flat sides.

The body contains relatively less compact bone than the dens. It is obscured above by the dens and is flanked by two large oval facets, extending laterally onto adjoining pedicles and articulating with the inferior atlantal facets. The superior facets do not form a pillar with the inferior facets and are considerably anterior to these. In front the body is hollowed on each side by attachment of the vertical part of Longus colli.

The pedicles are thick with deep inferior vertebral notches, the superior being shallow. The laminae are thicker than in other cervical vertebra.They fuse posteriorly with the large spinous process which possesses an apical notch.

The axial transverse processes are small, blunt at their tips which are single tubercles and homologous with posterior tubercles at other levels. Small anterior tubercles are at or near the junctions of anterior parts of the transverse processes and the body as in the Atlas. Each axial transverse foramen inclines superolaterally because the vertebral arteries deviate laterally to traverse the more widely separated atlantal foramina. The inferior articular facets are at the pediculo laminar junctions facing anteroinferiorly as in typical cervical vertebra. The vertebral foramen is large. [13]

MUSCLES ATTACHED TO AXIS:

Longus colli(vertical part) is attached to the anterior surface of the body of axis.The inferior obliques arise from the lateral aspect of the spine and Rectus capitis posterior major is attached a little posterior to this.Semispinalis,Spinalis cervicis,Interspinalis and Multifidus are attached in the apical notch in the spine.Levator scapulae is attached to the tips of the transverse processes between Scalenus medius and Splenius cervicis.The intertransverse muscles are attached to the superior and inferior surfaces of the transverse processes.

The atlanto axial joints :

The articulation of the atlas and the axis comprises four synovial joints, two median ones on the front and back of the dens and paired lateral ones between the opposing articular facets on the lateral masses of the atlas and axis. Each of the median joints, situated on the front and back of the dens, has its own fibrous capsule and synovial cavity. The anterior one is situated between the anterior surface of the dens and the posterior aspect of the anterior arch of the atlas. The posterior one has an even larger synovial cavity and lies between the cartilage covered anterior surface of the transverse ligament of the atlas and the posterior surface of the dens.

The atlas and axis are united by the cruciform ligament, the anterior and posterior longitudinal ligaments and the articular capsules surrounding the joints between the opposing articular facets on the lateral masses. The cruciform ligament has transverse and vertical parts that form a cross behind the dens. The transverse part called the transverse ligament is a thick strong band that arches across the ring of the atlas behind the dens and divides the vertebral canal into a large posterior compartment containing the dura and the spinal cord and a smaller anterior compartment containing the odontoid process.

The vertical part is attached to the upper surface of the clivus between the apical ligament of the dens and the tectorial membrane. The lower band is attached to the posterior surface of the body of the axis.

Infront, the atlas and axis are connected by the anterior longitudinal ligament which is attached superiorly to the lower border of the anterior arch of the atlas and below to the front of the body of the axis. The posterior longitudinal ligament is attached below to the posterior surface of the body of the axis and above to the transverse part of the cruciform ligament and the clivus. Posterior to the spinal canal, the atlas and axis are joined by a broad, thin membrane in series with the ligamentum flavum that is attached above to the lower border of the posterior arch of the atlas, and below to the upper edges of the laminae of the axis. This membrane is paired laterally by the second cervical nerve.

Axis and Occipital bone :

Four fibrous bands, the tectorial membrane, the paired alar ligaments and the apical ligament connect the axis and the occipital bone. The tectorial membrane is a cephalic extension of the posterior longitudinal ligament that covers the dens and cruciform ligament. It is attached below to the posterior surface of the body of the axis, above to the upper surface of the occipital bone in front of the foramen magnum and laterally to the medial sides of the atlanto occipital joints.

The alar ligaments are two strong bands that arise on each side of the upper part of the dens and extend obliquely supero lateral to attach to the medial surface of the occipital condyles. The apical ligament of the odontoid process extends from the tip of the dens to the anterior margin of the foramen magnum and is situated between anterior atlanto occipital membrane and the superior prolongation of the cruciform ligament.

Vertebral Artery

The paired vertebral arteries arise from the subclavian arteries, ascend through the transverse processes of the upper 6 cervical vertebrae, pass behind the lateral masses of the axis, enter the dura mater behind the occipital condyles, ascend through the foramen magnum to the front of the medulla and join to form the basilar artery at the ponto medullary junction. Each artery is divided into intra and extra dural parts.

The extra dural part is divided into 3 segments. The 1st segment extends from the origin at the subclavian A to the entrance into the lowest transverse foramen usually at the C6 level.

The second segment ascends through the transverse foramen of the upper six cervical vertebrae in front of the cervical nerve roots.

This segment deviates laterally just above the axis to reach the laterally placed transverse foramen of the atlas.

The 3rd segment, the one most intimately related to the foramen magnum, extends from the foramen in the transverse process of the atlas to the site of passage through the dura mater.[14]

Embryology of C2

The axis is developed from four primary ossification centres. The dens is formed from C1 sclerotome, the two neural arches and the body of the axis are formed from the C2 sclerotomes, and the tip of the dens develops from the proatlas. The body of the atlas as such disappears and gives origin to the dens. The tip of the dens is fused with the body by the age of 12 years. The remainder of the segments ossify and are fused by the age of 3 years.[15]

ANATOMY AND BIOMECHANICS

Two separate groups of ligaments maintain the craniovertebral articulation. The articular capsular ligaments, the anterior and posterior alanto-occipital ligaments, and two lateral alanto-occiptal ligaments attach the cranium to the atlas (C1). The anterior atlanto-occipital ligament is a continuation of the anterior longitudinal ligament, and the posterior atlanto occipital ligament spans the posterior border of the foramen magnum and the posterior atlantal arch. The cruciate ligament also contributes to the stability of this articulation.

Stability across the craniovertebral junction is provided primarily by the apical dental ligament, the alar ligaments, the tectorial membrane, and the ligamentum nuchae.

The alar ligaments are paired structures, each of which has occipital and atlantal components. These ligaments connect the tip of the odontoid to the occipital condyles and the lateral masses of the atlas, respectively.[18] The alar ligaments are the main restraints for axial rotation with each ligament specifically restricting contralateral axial rotation. Axial rotation across the atlanto-occipital segment is minimal (4.4 to 5.9 degrees), compared with the atlantoaxial articulation (31 to 33 degrees). Isolated incompetence of the alar ligaments results in axial rotation of 10.5 degrees across O-C1 and 33 to 37 degrees across C1-2. This amounts to a 29% increase in axial rotation across O-C1. To a lesser degree, the alar ligaments also limit lateral flexion.[16]

The tectorial membrane also called the occipitoaxial ligament,resists hyperextension. If the tectorial membrane is incompetent, contact between the posterior arch of the atlas and the occiput will limit hyperextension.[19,20] Flexion is restricted by contact of the odontoid process with the anterior foramen magnum.

A variety of pathologic processes can compromise the structural integrity of the osseous elements, tethering ligaments or both, creating instability in this region as a consequence.

Method of approach :

The factors influencing specific treatment of instability of the craniocervical junction are the following:

1. Reducibility – whether the bony abnormality can be reduced to normal position and relieve compression of the cervicomedullary junction ; this implies restoration of anatomical relationships of the craniospinal axis.
2. The mechanics of compression and the direction of the encroachment

3. The etiology of the lesion (eg. Basilar invagination, rheumatoid arthritis) ; vascular abnormalities, syrinx and Chiari malformations fall within this category and
4. The presence of ossification centres and epiphyseal growth plates in certain congenital anomalies

The primary treatment for reducible craniocervical lesions is stabilization. Surgical decompression is performed when patients with irreducible lesions are encountered and the decompression is performed in the manner in which the encroachment occurs. If a ventral encroachment is present a transoral transpharyngeal decompression is done ; with dorsal compression a posterior decompression is mandated. If instability exists following either situation, posterior fixation is essential.[22]

Internal fixation of upper cervical spine:

The goal of internal fixation of an unstable spine is to immobilize the spine until a bony arthrodesis occurs, to reduce the deformity, to restore a stable spine, and to achieve neural decompression. Operative intervention in an unstable spine has the following advantages:

1. Providing the optimal mechanical environment for neurologic recovery.[23,24]

2. Facilitating early mobilization and avoiding adverse effects of prolonged bed rest.

3. Creating the opportunity for an earlier start of the rehabilitation process.

Practical applications of the biomechanics of spinal fixation :

White and Panjabi[25] cited four basic indications for spinal stabilization.

1. Restoration of stability when stability is compromised by trauma or degenerative changes.
2. Maintenance of alignment after alignment correction.
3. Prevention of further alignment deformities and
4. Alleviation of pain related to instability or pathologic movement.

Fixation techniques are used to provide the spine with temporarily rigid or semi rigid fixation until osseous fusion can occur. The basis of almost all internal fixation techniques is successful bone fusion. With continued repetitive loading in the absence of osseous fusion, all fixation methods eventually fatigue and fail.

Practical application of Bio mechanics of spinal fixation in the cervical spine:

Traditional C1 C2 fusion techniques use a posterior wiring technique(tension band)and an interspinous bone strut(simple distraction). The presence of an interpsinous bone strut counteracts the tendency for the posterior wiring technique to fail from narrowing of the inter anchor distance.

The interspinous bone strut also permits osseous fusion.The Gallie and Sonntag fusion techniques are examples.

The additional application of trans articular screws helps form a rigid construct that promotes osseous fusion by counteracting the system's tendency to fail because of its susceptibility to rotional stresses.

Either transarticular screws or a halovest is required to stabilize C1-2 adequately for most types of injuries.[26]

Prospective analysis has demonstrated that the regional anatomy (location of vertebral artery and width of pars inter anticularis) of almost 20% of patients contraindicates placement of a transarticular screw on atleast one side.[27]

If trans articular screw fixation is contemplated, the pre operative radiographic evaluation should include fine-cut computed tomographic images in the plane of the transarticular screw with sagittal reconstructions.[27]

When bilateral screw placement is contraindicated, unilateral posterior trans articular screw placement can provide valuable fixation for the treatment of atlantoaxial instability.[28]

An incompletely reduced AAD prevents transarticular screw placement because it is associated with a high risk of vertebral artery injury.[29]

When trans articular screw placement is impossible, limiting the position of the screw to the pars interarticularis provides a ‘next best’ fixation point for occipito cervical fusion construct.

An absent anterior tubercle of atlas has been associated with screw mal position. So preserving as much of this landmark as possible is attempted during anterior decompressive procedures.

Trans articular screw placement begins on the side of nondominant vertebral artery. Suspicion of a vertebral artery injury contraindicates placement of the contralateral trans articular screw but the alternative of pars interarticularis screw remains an option.

All screws are placed using imaging guidance (direct fluoroscopy or frameless stereotactic navigation).

Anterior vs posterior fixation:

Posterior fixation is used in cases where anterior odontoid fixation technique is contraindicated. The advantages of an anterior approach to C1 C2 stabilisation include immediate stabilisation via single screw placement, absence of bone graft requirement and no post operative halo immobilisation. In addition, anterior odontoid screw fixation is less technically demanding than C1 C2 transarticular screw placement.

Contraindications for surgery:

Anterior odontoid screw fixation is contraindicated in patients with osteoporosis or osteopenia, barrel chest from COPD or emphysema or with cervicothoracic kyphosis. Also odontoid screw fixation is not recommended in patients with nonreducible fractures, nonunion longer than 3 months, oblique fractures oriented from antero-inferior to postero-superior, fractures with associated transverse ligament rupture, or fractures that need flexion for reduction. These patients are best treated with a posterior C1-C2 fixation technique.

Contraindications for posterior fixation :

Posterior transarticular fixation of C1 –C2, on the other hand is contraindicated in patients with thoracic kyphosis, aberrant or ectatic vertebral arteries, nonreducible subluxation or severely dysmorphic C1, C2 anatomy or previous vertebral artery injury or occlusion.

Use of neuronavigation:

Neuro navigation is helpful for surgical planning. Thin slice CT scans from occiput to C3 are obtained and 3 dimensional reconstruction views are obtained through the stealth work station. Transarticular screws are then placed virtually on the 3 dimensional model. This useful exercise provides excellent pre operative visualization of the actual screw trajectory and confirms that a safe trajectory can be achieved with respect to the vertebral artery. Regular c –arm flouroscopy is most helpful for sagittal plane guidance during surgery.

Technique of posterior transarticular screw fixation:

With the patient positioned prone with crown halo traction and lateral flouroscopy being used throughout the procedure the C1 C2 facets are exposed. After exposing the C2 root,the C2 entry site is located about 3-4mm rostral and 3-4 mm lateral to the inferomedial edge of the C2-C3 facet joint. An awl or high speed drill is used to create a small trough for the k wire entry site. Reduction of C1-C2 subuxation must be performed before k wire drilling. This may be achieved using gentle C1-C2 manipulation under fluoroscopy or by first performing a posterior interspinous tension band construct. The k wire is drilled typically with a 5 to 15 degree medial angulation in the sagittal plane into the C2 pars, across the C1-C2 joint ,aiming at the anterior tubercle of C1. More medial angulations risk violation of the spinal canal. The tip of the k wire should ideally stop 3-4 mm posterior to the anterior C1 tubercle. Often the surgeon will perceive changes in drilling resistance as the k wire travels across the 4 cortical surfaces during drilling. These are the C2 entry cortex, the superior C2 articular surface, the inferior C1 articular surface, and the anterior cortex of the C1 ring. Screws are typically 34 to 44mm in length. The technique is repeated on the contralateral side. The ideal trajectory should cross the C1 - C2 joint and terminate at the anterior arch of C1. Screws that are misdirected can result in neurologic injury, inadequate fixation, vertebral artery injury and damage to pharynx.[29]

C2 pars screw:

The techniques of placement of C2 pars or pedicle screw have been described.[30,31,32] The C2 pars is the portion of the C2 vertebra between the superior and inferior articular surfaces. The C2 pars screw is placed using a starting point and in a trajectory similar to that of a C1-C2 transarticular screw, except that it is much shorter. The entry point is 3mm rostral and 3mm lateral to the medial C2-C3 facet joint. The screw follows a steep trajectory parallel to the C2 pars.(often 40 degrees or more). C2 pars screw is placed with a 10-degree medial angulation. The typical screw length is 16 mm, which often stops short of the transverse foramen. Because this is a unicortical screw ,we prefer to use a 4.0mm diameter screw, which affords increased purchase.

C2 pedicle screw:

The C2 pedicle is the portion of the C2 vertebra connecting the dorsal elements with the vertebral body. The starting point for the C2 pedicle screw is typically 2mm superior and 2mm lateral to the starting point for the C2 pars screw. The screw is placed with 15 to 25 degrees of medial angulation and 20 degrees upward angulation.

CONDITIONS CAUSING OCCIPITOATLANTOAXIAL INSTABILITY :

A variety of abnormalities which may be developmental, genetic, neoplastic or traumatic in origin may lead onto instability of occipitoatlantoaxial joints requiring surgical management.

Dysgenesis of odontoid process may encompass many congenital anomalies. Failure of the proatlas and dens to fuse results in ossiculum terminale. Os odontoideum represents failure of the odontoid process and axis body to fuse. Hypoplasia and agenesis of the dens is the result of developmental failure of the distal ossification centres. The common pathophysiology that produces neurological deficit with agenesis or hypoplasia of the dens is the instability between atlas and axis that results from incompetence of the cruciate ligament.

Basilar invagination is a developmental defect implying prolapse of the vertebral column into the skull base.[35,36,37] It is frequently associated with such developmental bony anomalies of the region such as occipitalization of the atlas, defective fusions of the spine, and blocked vertebral malformations. There is an increased incidence of neural dysgensis. The common neural malformations encountered are the Chiari malformation and syringohydromyelia. These have an incidence of 25 to 30 percent with basilar invagination.

Basilar impression refers to the secondary or the acquired form of basilar invagination due to softening of the skull. It may also occur due to erosion of the lateral mass of the atlas as with rheumatoid arthritis and in certain other syndromes such as spasmodic torticollis and osteomalacia. Other than this, basilar invagination due to softening of the skull is commonly seen with hyperparathyroidism, Paget’s disease, osteogenesis imperfecta, Hurler syndrome, rickets, and infection producing bone destruction with or without ligamentous instability. [34,38,39,40,41,42]

Platybasia refers to an abnormal, obtuse basal angle formed by the clivus and the anterior skull base planes.

The tip of the dens should not exceed more than 10 mm rostral to the bimastoid line. [40] The tip of the odontoid process should not be more than 2.5 mm above Chamber lain's line. Chamberlain's line joins the hard palate to the anterior aspect of the posterior rim of foramen magnum.

Cranial settling is usually associated with rheumatoid arthritis and implies a descent of the skull on the eroded lateral atlantal masses with resultant occipitoatlantoaxial instability. [43,44,45] There is an upward vertical subluxation of the odontoid process. The most common cause is rheumatoid arthritis, followed by diseases such as psoriasis, systemic lupus erythematosus, Ankylosing spondylitis, Juvenile Rheumatoid arthritis,Regional ileitis, pseudogout , infection (eg Grisel's syndrome) and chronic trauma such as that occurring with spasmodic torticollis.

Rheumatoid arthritis of the cervical spine was first described as a clinical entity by Garrod in 1890. One hundred and seventy eight of 500 patients had clinical involvement of the cervical spine. Subsequent investigators have found the cervical spine to be affected in 44 to 88 percent of patients with rheumatoid arthritis. [46,47] This ranges from minor degrees of subluxation without symptoms to total patient incapacitation secondary to cervical myelopathy or compression of the brainstem by a vertically subluxed odontoid peg. Mathews, [48] in a survey of 76 consecutive rheumatoid arthritis patients, found an abnormal separation between the odontoid process and the anterior arch of the atlas in 25 percent.

Rheumatoid cranial settling consists of vertical odontoid penetration into the foramen magnum, occipitoatlantoaxial dislocation, lateral atlantal mass erosion, downward telescoping of the anterior arch of the atlas onto the axis, and rostral rotation of the posterior arch of C1 producing both a dorsal and ventral cervi comedullary junction compromise.

Odontoid Fractures :

5% to 15% of all cervical spine fractures are odontoid fractures. The most frequently used classification to describe this injury was that put forth by Anderson and D' Alonzo in 1974, who classified odontoid fractures into three types based on the fracture line.[49]

Type I : fractures that occur through the tip of the dens

Type II : fractures that occur through the base of the odontoid process

Type III : fractures that occur through the body of C2.

Type IIa : described by Hadley and colleagues [50] involves a communition of the base of odontoid process.

Surgical fixation is considered as an option in cases of dens displacement of 5 mm or more, type iia odontoid fractures or inability to achieve or maintain fracture alignment with external immobilization. Options for posterior fixation include C1 C2 wiring techniques, C1, C2 transarticular fixation techniques or C1 lateral mass-C2 pedicle or C2 pars screw constructs.

Though posterior approaches have been proven to be effective in the management of acute type ii odontoid fractures, they usually require iliac crest graft and also lead to loss of C1, C2 axial rotation. C1-C2 wiring techniques as a sole treatment are not recommended , because patients must be immobilized in a halo to achieve an acceptable fusion rate.

Hangman's Fractures :

A C2 traumatic spondylolisthesis or Hangman's fracture involves a fracture of the isthmus or pars interarticularis of the C2 vertebra leading to varying degrees of instability depending on the nature and severity of injury. The most widely used classification of these injuries is that described by Levine and Edwards,[51] itself a modification of Effendi's original classification.

Levine and Edwards Classification of Hangmans fracture:

Type I fractures:

result from hyperextension and axial loading. They have no angulation and have less than 3mm of displacement. They are generally stable fractures and can usually be treated with collar bracing alone.

Type II fractures:

These occur secondary to severe flexion in addition to hyperextension and axial loading. On radiographs ,there is significant angulation, significant displacement (>3mm),or both. These fractures require closed reduction followed by immobilisation with a halo vest.

Type IIa Hangman's fractures represent a special class in which there is minimal displacement but severe angulation of C2. This type of injury is caused by flexion distraction and can sometimes be managed by gentle extension followed by halo vest immobilisation for extended periods of time. These fractures may require open reduction followed by posterior internal fixation in an uncooperative patient.

Type iii fractures are grossly unstable and require prompt recognition,because even minimal traction can lead to severe neurologic impairment. These are usually caused by flexion-compression injuries and involve bilateral facet dislocation in addition to fracture of the neural arch. Almost always these fractures require open surgical reduction followed by internal fixation. Because of the incompetence of the neural arch of C2, it may be necessary to perform an occiput to C3 fusion or C2-C3 fusion with lateral mass plates.

Late instability patterns resulting in kyphosis and translation at the C2-3 interspace may be managed by an anterior C2-3 discectomy and fusion with or without instrumentation.

Atlantoaxial Instability :

Traumatic instability of the atlantoaxial articulation is usually the result of significant flexion extension forces with or without an associated rotatory shear component. Fielding and Hawkins have described a useful classification for rotatory fixation patterns of this level. Traumatically induced instability patterns in the adult heal less predictably than their pediatric counterparts, and a posterior C1-2 stabilization procedure is generally recommended. Alternative approaches (lateral, anterior) are used selectively depending on the circumstance and integrity of the posterior bony elements. Acute axial distraction of the atlantoaxial articulation is treated by posterior C1 C2 fusion procedures.

Combination of C1-C2 fractures:

Combination fractures of the atlas and odontoid are more likely to be associated with greater morbidity and mortality compared with isolated fractures of the atlas or axis alone. The AANS/CNS joint section on disorders of the spine and peripheral nerves performed a detailed review of literature on combination C1-C2 fractures. Surgical fixation was recommended for fractures with atlanto dental interval of greater than 5 mm. Surgical stabilisation can usually be accomplished using posterior C1-C2 stabilization, although there have been reports of successful treatment of these fractures using anterior odontoid screw fixation.[38] In the presence of posterior arch incompetence ,posterior fixation can be accomplished using occipital cervical fixation or transarticular screw fixation originally described by Magerl or C1 lateral mass C2 pedicle screw fixation originally described by Harms, based on the pedicle screw fixation of C2 according to Robert Judet.

Occipitocervical dislocation:

is a highly unstable cervical spine injury that is frequently fatal. Immediate operative occiput to C2 or C3 fusion is advocated either with wire stabilisation or plating .Post operative halo bracing is recommended for 3 months. [52]

RESULTS

Table – 1

Height of the Pedicle

Height	No.of cases	Percentage
Below 8.0	7	14
8.1 – 9.0	11	22
9.1 – 10.0	14	28
10.1 – 11.0	10	20
Above 11.1	8	16
Total	50	100
Mean	9.50	
S.D.	1.31	

Mean height of the pedicle was observed to be 9.5 mm with minimum observation of 6.76mm and maximum observation of 12.7 mm. 70% of the specimens had the value of height of pedicle lying between 8 mm and 11 mm.

Table – 2

Width of the Pedicle

Height	No.of cases	Percentage
Below 7.0	3	6
8.1 – 9.0	3	6
9.1 – 10.0	18	36
10.1 – 11.0	16	32
Above 11.1	10	20
Total	50	100
Mean	9.17	
S.D.	1.29	

The Mean width of the pedicle was observed to be 9.17 mm with minimum observation of 6.06mm and maximum pedicle width as 11.75 mm. The pedicle width of 68% of the specimens had a value between 9 mm and 11 mm.

Table – 3

Length of Lateral Mass

Height	No.of cases	Percentage
Below 25	11	22
25.0 – 27.0	15	30
27.1 – 29.0	16	32
29.1 – 31.0	6	12
Above 31	2	4
Total	50	100
Mean	27.05	
S.D.	2.08	

The Mean length of lateral mass was calculated as 27.05 mm The minimum observation of lateral mass length in this study was 23.81 mm and maximum observation was 32.43 mm. 62% of the specimens had the value of length of lateral mass between 25 and 29mm.

Table – 4

External Height of Lateral Mass

Height	No.of cases	Percentage
Below 8.0	2	4
8.1 – 9.0	7	14
9.1 – 10.0	20	40
10.1 – 11.0	16	32
Above 11.0	5	10
Total	50	100
Mean	9.91	
S.D.	0.89	

The mean external height of lateral mass was calculated as 9.91 mm. The minimum observation of external height of lateral mass in this study was 7.9 mm and maximum observation was 11.9 mm. 72% of this specimens had the value of external height of lateral mass lying between 9 and 11mm.

Table – 5

Depth of Vertebral artery groove

Height	No.of cases		
	Left	Right	Total
2.0 – 3.0	6	5	11
3.1 – 4.0	10	10	20
4.1 – 5.0	3	7	10
5.1 – 6.0	5	2	7
6.1 – 7.0	1	1	2
Total	25	25	50
Mean			3.874
S.D.			1.12
p value	p = 0.929 Not significant		

Depth of vertebral artery groove in the present study was found to have no significant asymmetry between the right and left sides(p=0.929) with 6 specimens having vertebral artery groove depth > 5mm on the left side, and 3 specimens having measurements > 5mm on right side.

The minimum groove depth was 2.05 mm

The maximum groove depth was 6.73 mm

Table – 6

Internal Height of Lateral Mass

Height	No.of cases		
	Left	Right	Total
≤ 4.0	2	3	5
4.1 – 5.0	5	4	9
5.1 – 6.0	4	6	10
6.1 – 7.0	9	6	15
7.1 – 8.0	3	4	7
> 8.0	2	2	4
Total	25	25	50
Mean			6.03
S.D.			1.48
P value	‘p’ = 0.980 Not significant		

The mean internal height of lateral mass was calculated as 6.03 mm. The minimum observation of internal height of lateral mass in this study was 3.28 mm and maximum observation was 9.56 mm. 64% of the specimens had the value of internal height of lateral mass lying between 5 and 8mm. None of the specimens had an internal height < 2mm.

Table – 7

Length of VA Groove

Height	No.of cases		
	Left	Right	Total
< 5.0	3	3	6
5.1 – 6.0	6	11	17
6.1 – 7.0	8	8	16
7.1 – 8.0	5	2	7
> 8.0	3	1	4
Total	25	25	50
Mean			6.2
S.D.			1.06
‘p’ value	‘p’ = 0.060 Not significant		

The mean vertebral artery groove length was observed to be 6.2 mm with a minimum observation of 4.24 mm and a maximum observation of 8.63mm. 80% of the cases had a value of length of vertebral artery groove between 5 mm and 8 mm.

Table – 8

Height of transverse foramen

Height	No.of cases		
	Left	Right	Total
4.0 - 5.0	2	0	2
5.1 – 6.0	8	8	16
6.1 – 7.0	15	17	32
Above 7.0	0	0	0
Total	25	25	50
Mean			6.14
S.D.			0.503
‘p’ value	‘p’ = 0.343 Not significant		

The mean height of trasverse foramen was observed to be 6.14 mm with a minimum observation of 4.4 mm and maximum observation 6.8mm. 96% of the cases had a value of height of vertebral artery groove between 5 mm and 7 mm.

Table – 9

Width of transverse foramen

Height	No.of cases		
	Left	Right	Total
≤ 5.0	11	10	21
5.1 – 6.0	7	8	15
6.1 – 7.0	7	7	14
Above 7.0	0	0	0
Total	25	25	50
Mean			5.37
S.D.			0.85
‘p’ value	‘p’ = 0.343 Not significant		

The mean width of trasverse foramen was observed to be 5.37 mm with a minimum observation of 3.8 mm and maximum observation 6.9mm. 72% of the cases had a value of width of transverse foramen between 4 mm and 6 mm.

Table – 10

External Height of Lateral Mass (CT)

Height	No.of cases		
	Left	Right	Total
Below 8.0	5	2	7
8.1 – 9.0	5	5	10
9.1 – 10.0	5	9	14
10.1 – 11.0	9	4	13
Above 11.0	1	5	6
Total	25	25	50
Mean			9.476
S.D.			1.221
‘p’ value	P = 0.305 Not significant		

The mean external height of lateral mass was observed to be 9.476 mm with a minimum observation of 6.71 mm and maximum observation 11.9mm. The right to left asymmetry was not found to be significant.

Table – 11

Depth of Vertebral artery Groove (CT)

Height	No.of cases		
	Left	Right	Total
2.0 – 3.0	2	8	10
3.1 – 4.0	9	10	19
4.1 – 5.0	7	4	11
5.1 – 6.0	6	2	8
6.1 – 7.0	1	1	2
Total	25	25	50
Mean			3.814
S.D.			1.063
p value	p = 0.009 Significant		

20% of specimens were found to have vertebral artery groove depth > 5mm. Abnormal vertebral groove is found to be significantly frequent on the left side. (pvalue 0.009) indicating an unfavourable situation for transarticular screw fixation. The minimum observation by CT morphometry was 2.05mm and maximum observation was 6.03 mm.

Table – 12

Internal Height of Lateral Mass (CT)

Height	No.of cases		
	Left	Right	Total
$\leq$ 4.0	5	1	6
4.1 – 5.0	8	4	12
5.1 – 6.0	6	8	14
6.1 – 7.0	4	4	8
7.1 – 8.0	2	2	4
> 8.0	0	6	6
Total	25	25	50
Mean			5.663
S.D.			1.471
P value	‘p’ = 0.005 Significant		

The mean internal height of lateral mass was observed to be 5.663 mm with a minimum observation of 2.68 mm and maximum observation 8.5mm. 52% of the specimens had an observation of internal height of lateral mass lying between 4 and 6 mm.

Table – 13

Length of VA Groove (CT)

Height	No.of cases		
	Left	Right	Total
22 - 24	0	3	3
26.1 – 28.0	5	8	13
28.1 – 30.0	7	1	8
30.1 – 32.0	4	3	7
> 32	1	0	1
Total	25	25	50
Mean			27.271
S.D.			2.600
‘p’ value	‘p’ = 0.032 Significant		

The mean length of vertebral artery groove was observed to be 27.271 mm with a minimum observation of 22.94 mm and maximum observation 36.42mm.

Table – 14

Height of transverse foramen (CT)

Height	No.of cases		
	Left	Right	Total
4.0 - 5.0	7	4	11
5.1 – 6.0	7	7	14
6.1 – 7.0	8	8	16
Above 7.0	3	6	9
Total	25	25	50
Mean			5.958
S.D.			1.093
‘p’ value	‘p’ = 0.467 Not significant		

The mean height of transverse foramen was observed to be 5.958 mm with a minimum observation of 4.2 mm and maximum observation 7.98mm.

OBSERVATION AND RESULTS

There was a large variation in the dimensions of the 25 dry specimens of the axis vertebrae and in the symmetry of each specimen.

The mean width of the pedicle was 9.17 mm (6.06 – 11.75)and the mean height of the pedicle was 9.5 mm (6.76 – 12.7).

The lateral masses had a mean external height of 9.91 mm (7.9 – 11.9) and a mean internal height of 6.03 mm (3.28 – 9.56)and the mean depth of vertebral artery groove was 3.874mm (2.05 – 6.73).

The transverse foramen had a mean height of 6.14 mm (4.4 – 6.8) and a mean width of 5.37 mm (3.8 – 6.9).

The course of the vertebral artery through the lateral mass of C2 was very variable in shape, size, location and symmetry. An abnormal groove or erosion was found on both sides in none of these specimens, on the left side in 6 specimens and on the right side in 3 of the specimens.

In the study of dry bones, abnormal vertebral artery groove was noted in 20% of specimens.

Statistical analysis of the measurements of the lateral mass using the Students ‘t’ test and One way Anova test did not show significant asymmetry between the right and left sides for the depth of vertebral artery groove (p=0.929), internal height of lateral mass (p=0.98), length of Vertebral artery groove (p=0.06),the height of transverse foramen (p=0.343) and width of transverse foramen (p=0.343).The ratio of internal height to verterbral artery groove was < 1 in 6 specimens on the left side and 4 specimens on the left side. If this ratio is > 1, favourable circumstances for transarticular screw fixation exist.

CT Morphometery :

By CT morphometry, the mean external height of lateral mass measured was 9.476 mm (6.11 – 11.9), the mean depth of vertebral artery groove measured was 3.814 mm (2.05 – 6.03), the mean internal height of lateral mass was 5.663mm (2.68 – 8.5)and the mean length of vertebral artery groove was 27.271mm (22.74 – 36.4). The mean height of the transverse foramen was 5.958mm (4.2 – 7.98).

Statistical analysis of the measurements of the lateral mass and the transverse foramen parameters showed significant asymmetry between the right and left sides for the depth of the vertebral artery groove (p=0.009), internal height of the lateral mass (p=0.005), and the length of the vertebral artery groove (p=0.032). Significant asymmetry between right and left sides was not seen for the external height of the lateral mass (p=0.305) and the height of the transverse foramen (p=0.467).

Abnormal vertebral artery grooves were found in 12% of the specimens on the right and 28 % on the left. Asymmetry of the depth of vertebral artery groove which assumed significance (p value 0.009) showed deep vertebral artery grooves or erosions found mainly on left side (n=7).

DISCUSSION

This study has focussed on the anatomical features of the vertebra of C2 which are important in the instrumental stabilization of C1 to C2. Variations in the course of the vertebral artery through C2 has been described before in case reports, [6,8] in dried specimens, [3,53] by CT [54]and in cadavers.

At the level of the axis, angiographic studies[55] and observations on dried specimens[53] have shown that the transverse foramen is an angulated canal with inferior and lateral openings which cause the artery to deviate 45° laterally before continuing its ascent to enter the transverse foramen of the atlas. The dimensions of this canal appear to enlarge at the expense of the surrounding structures thus affecting the diameter of the pedicle and the internal height of the lateral mass. In these circumstances the internal height of the lateral mass and the width of the pedicle were thinned out. The shape and size of the canal itself were variable and asymmetrical in all the specimens. Thus, there is a considerable risk of injuring the vertebral artery if transarticular screw fixation of C1 to C2 is attempted. A plain radiograph will not provide sufficient information and it is mandatory to have CT scans of C1 and C2 to show the vertebral artery groove depth, lateral mass, pedicle and transverse foramen parameters before deciding whether to carry out transarticular screw fixation. Dull and Toselli[56] have recommended oblique axial CT of C2. These recommendations also apply when posterior transpedicular screw fixation of C1 to C2 is contemplated. As has been reported by Anderson and Shealy[57] a loop of the vertebral artery may erode the pedicle and compress the associated nerve root. A CT study by Paramore et al,[54] on 94 patients, described high riding of the transverse foramen on at least one side in 18%, which would prohibit the placement of transarticular screws. In their study, the left side was involved in nine patients, the right in five, and both sides in three. Taitz and Arensburg[3] reported a 33% incidence of erosion of the transverse foramen of C2 in 300 dried specimens, 21% with moderate and 12% with marked changes. Angiographically, both vertebral arteries were found to be symmetrical in only 40.8% of cases, with the right artery dominant in 23.4% and the left artery in 35.8%. In a study by Abou Madawi et al, 61 patients who had transarticular screw fixation, injury to the vertebral artery in its groove occurred in five, all on the left side. The depth of VA groove was 5.5 mm in 12% of their specimens.

. If the VA groove depth is more than 5 mm, then the screw trajectory must be planned with a larger superior angle to avoid injury to the vertebral artery, consequently further reducing the amount of C2 bony purchase. Similarly, if the pedicle width on the inferior surface is about 2mm, it may not provide adequate bone ‘grip’ for a 3.5 mm screw. [59]

CONCLUSION

Thinning of the lateral mass and the pedicle of axis vertebra may prevent adequate fixation by posterior transarticular screw placement. The agent responsible for this thinning is the axis groove for the vertebral artery, indicating the increased probability of vertebral artery injury. The range of variation of these and other measured parameters suggest the need to thoroughly evaluate them before operative planning when screw fixation is contemplated. High resolution thin section CT scanning is recommended for this purpose.

Vertebral artery injury can be avoided by improved understanding of the safety limits for transarticular screw fixation through the lateral mass by real time intra operative fluoroscopy control and by avoiding the procedure in anatomically unsuitable cases.

High resolution CT with 3–D reconstruction is mandatory before screw fixation is used to stabilize the C1 to C2 segment.

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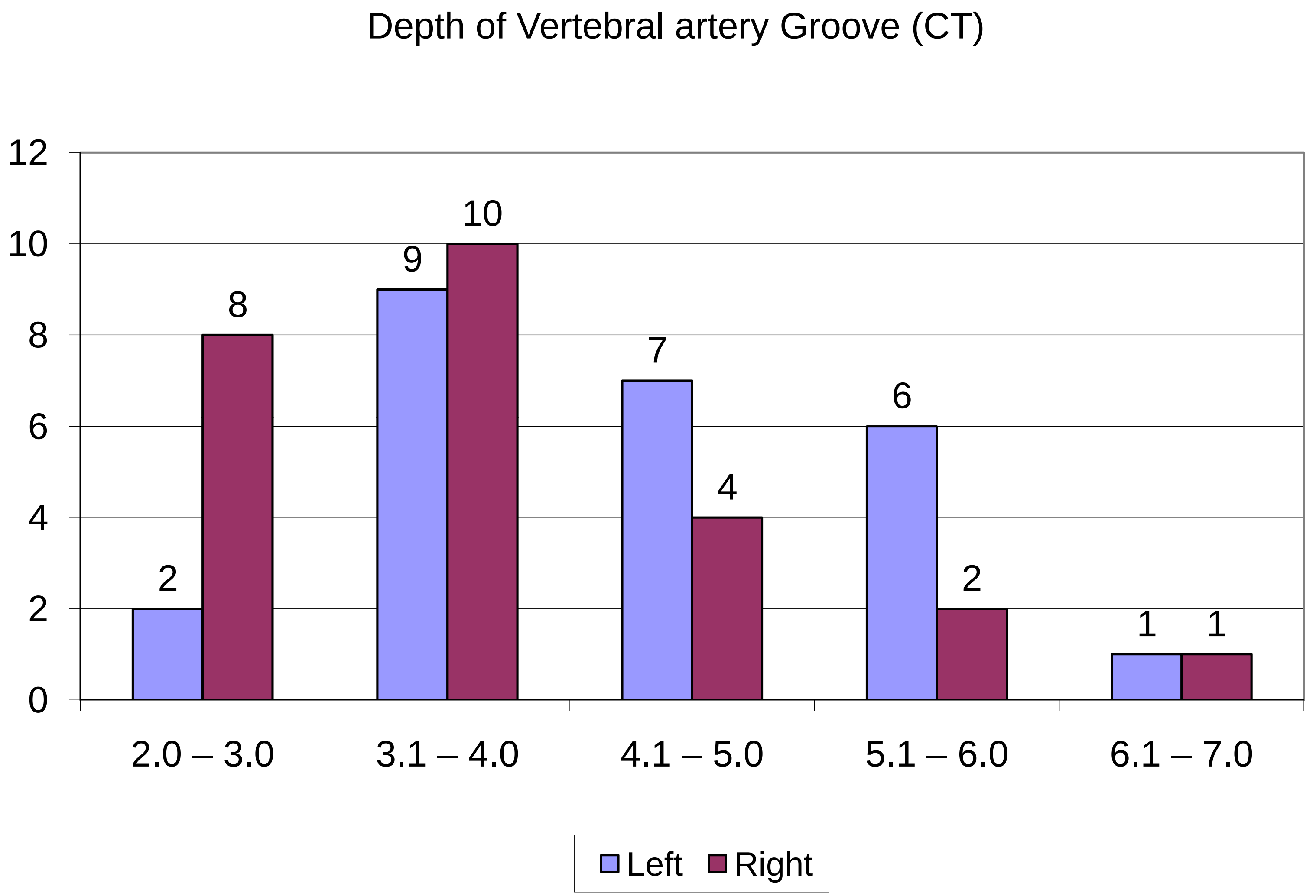
Depth of Vertebral artery Groove (CT)
12
10
8
6
4
2
0
2
8
9
10
7
4
6
2
1
1
2.0 – 3.0
3.1 – 4.0
4.1 – 5.0
5.1 – 6.0
6.1 – 7.0
Left
Right

MASTER CHART (CT MORPHOMETRY)

S. No.	Name	Age	Sex	IP No	Side	External Height of lateral mass	VA Groove	Internal Height	Pedicle Length	Length of VA groove
1	Mani kandan	39	M	1519	L	8.65	4.82	3.83	25.02	6.02
2					R	9.92	4.18	5.74	31.32	6.33
3	Saravanan	30	M	1520	L	10.82	6.01	4.81	36.42	7.2
4					R	9.36	6.03	3.33	27.04	7.54
5	Vel murugan	50	M	1591	L	8.82	4.12	4.7	28.72	5.66
6					R	11.2	5.16	6.04	27.09	5.43
7	Thirupathi	22	M	1594	L	10.92	5.42	5.5	24.58	4.92
8					R	10.04	5.6	4.44	26.82	4.86
9	Fiedel castro	34	M	1671	L	10.45	5.72	4.73	27.62	4.42
10					R	10.29	2.06	8.23	25.61	4.2
11	Dhinesh kumar	19	M	1672	L	11.9	4.4	7.5	29.03	5.92
12					R	8.56	2.05	6.51	24.38	6.02
13	Selvi	37	F	1674	L	9.28	3.62	5.66	28.26	6.36
14					R	9.3	3.32	5.98	27.82	7.02
15	Thirukan	50	M	1675	L	7.15	3.37	3.78	29.03	6.66
16					R	8.82	3.35	5.47	27.8	7.92
17	Baskaran	23	M	1676	L	9.21	5.76	3.45	26.83	5.92
18					R	10.35	2.24	8.11	31.44	5.36
19	Murugan	32	M	1678	L	10.15	3.1	7.05	30.01	5.54
20					R	11.02	2.56	8.46	31.66	5.46
21	Sundaresan	35	M	1681	L	6.71	3.72	2.99	30.72	4.42
22					R	8.83	3.35	5.48	25.41	4.26
23	Pandi	30	M	1683	L	7.72	3.63	4.09	24.86	4.55
24					R	11.04	3.02	8.02	27.09	4.92
25	Ramu	43	M	1729	L	10.48	4.14	6.34	28.06	5.07
26					R	10.22	2.41	7.81	26.67	6.08
27	Podhumani	25	F	1760	L	10.42	3.69	6.73	27.84	7.66
28					R	11.12	2.62	8.5	23.82	7.81
29	Dhana backiyam	33	F	1762	L	10.02	5.07	4.95	27.54	7.82
30					R	9.92	2.72	7.2	24.26	7.98
31	Kali muthu	46	M	1764	L	9.32	3.77	5.55	25.09	4.41
32					R	7.62	3.42	4.2	23.81	6.24
33	Thanga vel	32	M	1763	L	7.51	2.55	4.96	27.09	6.92
34					R	8.84	3.41	5.43	24.26	6.34
35	Subramanian	65	M	1765	L	9.32	3.52	5.8	31.02	6.31
36					R	9.14	4.42	4.72	22.94	6.81
37	Murugan	40	M	1766	L	6.85	4.17	2.68	25.02	6.94
38					R	9.54	3.22	6.32	26.01	6.56
39	Karuppaian	55	M	1767	L	10.62	5.02	5.6	27.56	6.42
40					R	11.81	3.72	8.09	28.62	6.33
41	Parakath Ali	55	M	1834	L	10.41	4.02	6.39	29.52	6.77
42					R	9.16	4.12	5.04	24.06	7.91
43	Kasimayan	43	M	1835	L	8.66	2.52	6.14	30.01	5.14
44					R	7.69	3.12	4.57	24.02	5.23
45	Murugan	25	M	1913	L	8.92	3.69	5.23	26.02	4.96
46					R	8.88	3.02	5.86	25.02	5.11
47	Nagaraj	16	M	1914	L	8.96	4.12	4.84	26.82	5.17
48					R	9.36	4.01	5.35	27.55	5.07
49	Vellaiyangiri	38	F	2018	L	9.16	5.02	4.14	28.66	4.92
50					R	9.35	2.56	6.79	27.66	5.01