Vertebral Synostosis: A Study in Dried Vertebrae of Western Odisha Population

*Mamata Sar¹, Srikanta Kumar Mishra², Sarita Behera³, Dibya Prabha Bara⁴, Manoj Kumar Dehury
(Department Of Anatomy, VSS Institute Of Medical Science And Research, Odisha, India,
Corresponding Author: Mamata Sar)

Abstract:
Aim: To study the magnitude of problem of vertebral synostosis in western Odisha population and to study its embryological significance and clinical implications.

Introduction: As vertebrae develop through a complicated process from the paraxial mesoderm, different types of vertebral anomalies may appear either in isolation or in association with other congenital anomalies. Vertebral synostosis or block vertebrae is a condition where incomplete segmentation of somites results in fusion of adjacent vertebrae.

Methods: All intact dried adult vertebrae preserved in osteology section of Anatomy department of our institute were examined. All the fused vertebrae were collected and a detailed morphological study of individual vertebra was undertaken to know the nature of fusion. The embryological and clinical significance of such anomaly was searched from literatures and discussed.

Results: Lumbosacral fusion was most common followed by cervical. Fusion was more complete in cervical region compared to other vertebrae. Degenerative changes like growth of osteophytes was common in lumbar block vertebrae.

Discussion: Vertebral synostosis can lead to compression and distortion of neural structures. It may also interfere with muscular movements. Cervical vertebral fusion is collectively termed Klippel Feil syndrome. Individuals with this syndrome are often otherwise normal, but association of this anomaly with other congenital defects is not uncommon. Therefore other visceral anomalies are to be excluded whenever we come across a case of block vertebra.

Keywords: Block vertebra, Unsegmented vertebra, Notochord, Somites.

Date of Submission: 23-08-2017  Date of acceptance: 04-09-2017

I. Introduction

Vertebral fusion or synostosis may occur due to congenital or acquired causes. Vertebra develops from sclerotome cells which surround the notochord and neural tube. The sclerotome undergoes second segmentation called resegmentation by the inducing effect of notochord and neural tube. Failure of resegmentation results in vertebral malformation like fusion of vertebrae. Vertebral fusion may also result from acquired causes like tuberculosis, juvenile rheumatoid arthritis and trauma. Vertebral synostosis leads to restriction of movement of spine and compression or distortion of neural structures. Premature degenerative changes occur in adjoining vertebrae due to increased biomechanical stress. Early detection and timely intervention can prevent these complications to develop.

II. Methods

All the dried vertebrae preserved in the osteology section of Anatomy, VSS Institute of Medical science and Research was taken as study material. All these bones were collected from population of western Odisha. All intact adult vertebrae were included for the study. Vertebrae with incomplete ossification and all broken vertebrae were excluded from our study. A total of 1662 number of vertebrae were examined, out of which 392 were cervical, 856 were thoracic, 399 lumbar and 15 were sacral vertebrae. We separated the fused vertebrae from them and looked for the type of fusion e.g. complete fusion, fusion of only anterior or posterior segment. We also observed any gross asymmetry or deformity affecting the fused vertebrae. Each fused vertebra, though multiple, was considered as single vertebra for our study purpose. To calculate the percentage of incidence, the thoracolumbar fused vertebrae were grouped under lumbar vertebrae. Similarly lumbosacral and sacrococcygeal fused vertebrae were grouped under sacral vertebrae. Thus we studied 392 cervical vertebrae, 856 thoracic, 399 lumbar and 15 sacral vertebrae. We calculated the percentage of fused vertebrae...
under each category, namely cervical, thoracic, lumbar, thoracolumbar, lumbosacral and sacrococcygeal synostosis. We compared our result with other authors.

III. Observations

Out of 392 intact cervical vertebrae 4 cases of cervical synostosis at different level were noticed (fig 1 to 8). One case of thoracic vertebral synostosis, two thoracolumbar, one lumbar, two lumbosacral and two sacrococcygeal synostosis were observed (fig 9 to 16). The details of their level of fusion, nature of fusion etc are described in a tabulated form in table 1 & table 2. We observed more or less complete fusion of vertebrae in case of all cervical and lumbar synostosis where as thoracic, thoracolumbar and lumbosacral synostosis were incomplete. In many of these block vertebrae fusion was not symmetrical leading to some or other form of deformities like kyphosis, scoliosis or lordosis.

Observation Table 1

<table>
<thead>
<tr>
<th>Vertebrae</th>
<th>Total Number Studied</th>
<th>Total Number Of Fused Vertebrae</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>392</td>
<td>4</td>
<td>1.02%</td>
</tr>
<tr>
<td>Thoracic</td>
<td>856</td>
<td>1</td>
<td>0.11%</td>
</tr>
<tr>
<td>Lumbar</td>
<td>399</td>
<td>3</td>
<td>0.75%</td>
</tr>
<tr>
<td>Sacral</td>
<td>15</td>
<td>4**</td>
<td>26.67%</td>
</tr>
</tbody>
</table>

*Includes 1 lumbar and 2 cases of thoracolumbar synostosis.
** Includes 2 lumbosacral and 2 sacrococcygeal synostoses.

Observation Table 2

<table>
<thead>
<tr>
<th>S</th>
<th>L</th>
<th>LEVEL OF SYNOSTOSIS</th>
<th>BODY SEGMENTS</th>
<th>LAMINA</th>
<th>ARTICULAR PROCESSES</th>
<th>TRANSVERSE PROCESSES</th>
<th>SPINOUS PROCESSES</th>
<th>SYMMETRICAL/ASYMMETRICAL</th>
<th>DEFORMITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C2+C3+C4+C5</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Not fused</td>
<td>Partially fused</td>
<td>Asymmetrical</td>
<td>KYPHOSIS</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C3+C4</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Not fused</td>
<td>Partially fused</td>
<td>Symmetrical</td>
<td>No deformity</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2 TYPICAL CERVICALS</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Ant roots are fused on right side</td>
<td>Completely fused</td>
<td>Symmetrical</td>
<td>No deformity</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2 TYPICAL CERVICALS</td>
<td>Fused on the right side</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>Scoliosis</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>T10+T11</td>
<td>Fused anteriorly</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>Kyphosis</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>T12+L1</td>
<td>Fused anteriorly</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>Kyphosis</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>T12+L1</td>
<td>Fused posteriorly</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>Lordosis</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>L5+Co</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Fused completely</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>Kyphosis</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>L5+S1</td>
<td>Fused on the left</td>
<td>Not fused</td>
<td>Fused completely</td>
<td>Lt side fused right side separate</td>
<td>Not fused</td>
<td>Asymmetrical</td>
<td>No deformity</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>L5+S1</td>
<td>Not fused</td>
<td>Not fused</td>
<td>Fused completely</td>
<td>Fused bilaterally</td>
<td>Not fused</td>
<td>Symmetrical</td>
<td>No deformity</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>S1+Co (2noss)</td>
<td>Fused completely</td>
<td>Cornua fused bilaterally</td>
<td>Not fused</td>
<td>Not deformation</td>
<td>Symmetrical</td>
<td>No deformity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DOI: 10.9790/0853-1608134448 www.iosrjournals.org 45 | Page
Vertebral Synostosis: A Study in Dried Vertebrae of Western Odisha Population

Fig 1- Anterior view of fused C_{2}+C_{3}+C_{4}+C_{5} showing complete fusion of vertebral bodies with an anterior concavity. (case 1)

Fig 2- Posterior view of same specimen showing fused laminae and fused articular processes, partially fused spinous processes. Transverse processes remain separate. (Case 1)

Fig 3- Fused C_{2}+C_{3} (anterior view) - bodies completely fused, independent transverse processes. (Case 2)

Fig 4- posterior view of same specimen. Completely fused laminae & articular processes but spines are partially fused. (case 2)

Fig 5- Fusion of two typical cervical vertebrae (anterior view) - Bodies completely fused, anterior roots of transverse processes fused on right side but remain separate on left. (case 3)

Fig 6- Posterior view of same specimen – laminae, articular processes and spines completely fused. (Case 3)

Fig 7- Fusion of two typical cervical vertebrae (anterior view) - Bodies are partially fused, independent transverse processes. (case 4)

Fig 8- Same specimen showing fused laminae and articular processes but spines are separate. (case 4)
Vertebral Synostosis: A Study in Dried Vertebrae of Western Odisha Population

Fig 9- Fusion of T₁₀ and T₁₁. Bodies partially fused only anteriorly. Laminae, articular processes, transverse processes and spinous processes remain separate. Anterior longitudinal ligament ossified. (Case 5)
Fig 10- Fusion of T₁₂ and L₁. Bodies partially fused only anteriorly. Laminae, articular processes, transverse processes and spinous processes remain separate. Osteophytic growths from margins of body. Anterior longitudinal ligament ossified. (Case 6)
Fig 11- Fusion of T₁₂ and L₁. Bodies partially fused only anteriorly. Laminae, articular processes, transverse processes and spinous processes remain separate. Osteophytic growths from the lower margin of body. (Case 7)
Fig 12- Fusion of L₁ and L₂. Complete fusion of body, laminae and articular processes. Transverse processes and spinous processes are separate. (Case 8)
Fig 13- Fusion of L₅ and S₁ (sacralisation of lumbar vertebra). Bodies and transverse processes fused on the left and remain separate on the right side. (Case 9)
Fig 14- Fusion of L₅ and S₁ (sacralisation of lumbar vertebra). Bodies are separated by a narrow disc space, transverse processes are bilaterally fused. (Case 10)
Fig 15 & 16- Fusion of S₁ with coccyx (case 11 & case 12)

IV. Results

Vertebral fusion was more common in the sacral region followed by the cervical region. It was also more frequent in transitional vertebrae e.g. thoracolumbar, lumbosacral and sacrococcygeal synostosis. Synostosis was more complete in the cervical region compared to other regions. Fusion was asymmetrical in 7 out of 12 cases leading to vertebral deformities like, kyphosis or scoliosis. Thoracolumbar and lumbar block vertebrae were found to have developed degenerative changes in the form of osteophytic growth from the margins of vertebral bodies and ossification of ligaments.

V. Discussion

5.1- Embryogenesis

Normal vertebrae develop from sclerotome cells which surround the notochord and neural tube. Then they pass through mesenchymal, cartilaginous and osseous framework of vertebral bodies and neural arches. The neural tube is found to have inducing roles in the formation of posterior neural arch whereas notochord has similar inducing control over vertebral bodies and their segmentation. Incomplete segmentation or block vertebra is common in cervical spine and most commonly involves axis and 3rd cervical vertebra.

The sclerotome undergoes second segmentation called resegmentation in which rostral and caudal half of somites segregate and refuse with their neighbouring somites to form vertebrae. The rostral compartment of the somite gives rise to caudal half of the vertebral body and intervertebral disc, whereas the caudal compartment generates the rostral half of vertebral body and pedicle of neural arch. The axial structures like notochord and neural tube are essential for resegmentation of the sclerotome. This has been shown by ablation studies, where surgical removal of notochord resulted in fused vertebral bodies and removal of neural tube resulted in fused neural arches. When both notochord and neural tube were removed, no segmentation appeared at all and a solid vertebral column is formed.

5.2- Genetics And Aetiology

Hox genes are a family of genes that regulates among other things, the differentiation process of the axial and appendicular skeleton. These genes regulate the embryonic differentiation of cranio caudal axis. Mutation of Homeobox genes may be responsible for congenital anomalies of spine. Takayuki Seki et al in their study on Ishibashi rat as animal model observed that fusion of adjacent primary ossification centres in embryonic period causes failure of segmentations. In these cases expression of Hox 10 and Hox 11 paralogs which regulates lumbar and sacral vertebrae was extremely low. They concluded that mutation and hyper- and hypox expression of genes is responsible for such skeletal malformation.

5.3- Clinical Implication

Vertebral synostosis may go undetected throughout life or may appear with serious clinical manifestations. Musculoskeletal, cardiovascular and urogenital anomalies are strongly associated with congenital spine deformities. Most of the studies showed higher incidence of fused vertebrae in the cervical region. But we observed highest percentage of segmentation abnormalities in sacral region followed by cervical. This is because other authors have not included sacral vertebrae in their studies. Congenital block vertebrae may be associated with other systemic anomalies. Tredwell et al reported that 19 (50%) out of 38 patients with foetal alcohol syndrome had congenital fusion of cervical vertebrae on radiographs of the neck. 16 of the 19 had fusion involving 2nd and 3rd cervical vertebrae. Klippel-Feil syndrome is a condition which is characterised by congenital cervical block vertebrae, shortness of neck, low hair line and restricted neck movement. Individuals
with this syndrome are often otherwise normal, but association of this anomaly with other congenital defects is not uncommon. Other syndromes associated with vertebral fusion are, VACTERL and MURC. VACTERL includes vertebral, anal, cardiovascular, tracheoesophageal, renal and limb abnormalities. MURC includes mullerian duct aplasia, renal aplasia, cervicothoracic somite dysplasia. Block vertebrae in cervical and thoracic areas as well as facial and ear deformities have been reported in patients with oculo-auriculo-vertebral dysplasia or Goldenhar syndrome. Observations from Adriamycin induced rat models suggest that an abnormal notochord may lead to the development of foregut malformation and cervicothoracic vertebral defect at its rostral end or hindgut malformation and lumbosacral vertebral anomalies at its caudal end. There is accumulating evidence that notochord serve as a key central organiser during early organogenesis. Vertebral abnormalities and some congenital gastro intestinal malformations follow abnormal development of notochord.

Kaur D et al reported that presence of lumbar block vertebrae is less common compared to other regions but when present, it results in premature degenerative changes owing to altered biomechanics. Erdil H. Et al also observed degenerative changes in nonsegmented cervical region both in x-ray and MRI. Other complications of synostosis includes spinal deformities, interference in muscular movements and compression or distortion of the neural structures.

VI. Conclusion

As vertebral synostosis is found to be associated with many serious clinical problems, an early diagnosis and timely surgical management can prevent complications. Degenerative changes are more pronounced in lumbar block vertebrae in contrast to other regions. Vertebral deformities in the form of kyphosis, scoliosis or lordosis was also a constant feature in most of the fused vertebrae.

References

[3]. Karen Colbjorn Larsen, Ernst-Martin Fuchbaker. The Neural Tube is required to maintain Primary Segmentation in the Sclerotome. Cell Tissue Organ. 2006; 182: 12-21