Research Article

Fusion of thoracic vertebrae: An anatomical study and clinical analysis

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Abstract

Among all the vertebral synostosis or fusion, fusion of thoracic vertebrae is documented as less frequently present in comparison to sacral, cervical and lumbar vertebrae. It has got value for physicians, surgeons, radiologists, orthopaedics, anaesthetists, rheumatologists, pathologists, paediatricians and for forensic medicine also. Total 45 vertebral columns containing 540 thoracic vertebrae of unknown age and sex were studied by macroscopic examination and by Digital Vernier calliper. We found 13.33% fused thoracic vertebrae out of which four sets were of two fused thoracic vertebrae (8.88%), one set of three (2.22%) and one set of four fused thoracic vertebrae (2.22%). Their features were studied macroscopically and discussed. The calcification of anterior longitudinal ligament was present in 3 sets of fused thoracic vertebrae. In one set of 2 fused atypical thoracic vertebrae T11-T12 the ossification was present on sides of the body of vertebrae. The length of calcification ranged between 38.68mm- 86.33mm. As fusion of thoracic vertebrae can lead to stenosis of intervertebral foramen causing root pain and can lead to other complications also, measurements in the form of maximum length and width in the middle of intervertebral foramen of fused thoracic vertebrae were taken. The possible causes for the fusion of thoracic vertebrae can be congenital vertebral malformation, DISH, or other rheumatological, degenerative diseases, or infective disease like TB. In present study, the result of the study and its possible clinical significance is discussed.

Keywords: congenital vertebral malformation, DISH, fusion of vertebrae, spinal fusion, vertebral synostosis.

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INTRODUCTION

The adult vertebral column usually consists of 33 vertebral segments. The functions of the column are to support the trunk, to protect the spinal cord and nerves, and to provide attachments for muscles. Vertebral column morphology is influenced externally by mechanical, occupational and environmental factors and internally by genetic, metabolic and hormonal factors. These all affect its ability to react to the dynamic forces of everyday life, such as compression, traction and shear.[17] Fusion of vertebral bodies is called as vertebral synostosis or Spinal fusion or Block vertebrae. In present study, the 2 sets of fused thoracic vertebrae were identified as acongenital defect and4sets of fused thoracic vertebrae as an acquired cause.

MATERIAL AND METHOD

Total 45 vertebral columns i.e. 540 thoracic vertebrae of unknown age and sex were examined from collection of Anatomy Department, GMERS Medical College, Gotri, Vadodara, and Gujarat. The features were macroscopically observed and measured by Pia International Digital vernier calliper 150mm/6inch having accuracy of +/- 0.03 mm/o.oo1 mm. In thoracic vertebrae features observed were fused thoracic vertebrae, type of thoracic vertebrae typical or atypical, site of fusion at-body, costal facets, articular processes, transverse process, lamina, and spine. Measurements of intervertebral foramen of fused thoracic vertebrae were taken i.e. Maximum length and width at middle of the intervertebral foramen. Cervical, lumbar vertebrae and sacrum were excluded as they were already studied by other authors in the department.

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RESULT

Among 45 vertebral columns i.e. 540 thoracic vertebrae, four sets of two fused thoracic vertebrae found, one set of three and one set of four fused thoracic vertebrae found.

CDF= costal demifacet, ZPJ= zygapophysial joint

Figure 1(a)

Figure 1(a)

Figure 2

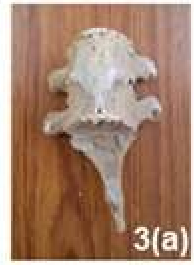

Figure 3(a)

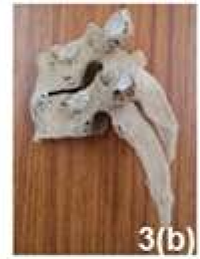

Figure 3(b)

Figure 4(a)

Figure 4(b)

Figure 5(a)

Figure 5(b)

Figure 5(c)

Figure 6(a)

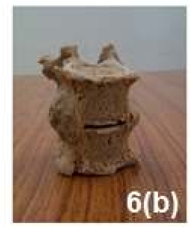

Figure 6(b)

Legend

Figure 1(a): Shows right lateral aspect**; Figure 1(b):** Shows posterior aspect of fusion of 2 thoracic vertebrae
Figure 2: Right lateral aspect of fusion of 2 thoracic vertebrae
Figure 3(a): Shows anterior aspect; **Figure 3(b):** Shows left aspect of fusion of 2 thoracic vertebrae
Figure 4(a): Shows anterior aspect; **Figure 4(b):** Shows right lateral aspect of fusion of 3 thoracic vertebrae
Figure 5(a): Shows anterior aspect; **Figure 5(b):** Shows right lateral aspect; **Figure 5(c):** Shows left lateral aspect of fusion of T7, T8, T9, T10
Figure 6(a): Shows right lateral aspect; **Figure 6(b):** Shows anterior aspect of fusion of 2 atypical thoracic vertebrae

Table 1: Measurements of intervertebral foramen of all fused thoracic vertebrae noted as per below

No.	Type of vertebrae fused		Intervertebral foramen (mm)	
			Right	Left
1	2 typical thoracic vertebrae Fig: 1 (a) and (b)	Length	9.43	7.31
		Width	6.58	5.50
2	2 typical upper thoracic vertebrae, Fig: 2	Length	13.32	12.84
		width	7.42	7.44
3	2 typical thoracic vertebrae Fig: 3 (a)and (b)	Length	11.20	11.69
		width	8.23	7.89
4	3 typical thoracic vertebrae Fig: 4 (a) and (b)	Length	14.74	14.05
			13.70	14.86
		Width	8.08	7.75
			8.38	7.30
5	4 thoracic vertebrae (T7,T8,T9,T10) Fig: 5 (a), (b) and (c)	Length	12.71	11.24
			11.96	11.75
			13.87	14.13
		Width	4.66	6.68
			6.81	6.69
			8.93	7.11
6	Fusion of atypical thoracic vertebra T11-T12 Fig: 6 (a) and (b)	Length	13.02	11.65
		width	5.90	5.54

Length difference between right and left side intervertebral foramen ranged 0.21-2.12mm and width difference ranged – 0.02-2.02mm. According to our study we found presence of four sets of two fused thoracic vertebrae – 8.88%, one set of three fused thoracic vertebrae – 2.22%, one set of four fused thoracic vertebrae - 2.22%. Out of 45 sets of vertebral columns we got 6 sets of fused thoracic vertebrae 13.33%. 3 sets of fused thoracic vertebrae presents ossification of anterior longitudinal ligament.

DISCUSSION

The frequency of fusion of vertebrae decreases as the level descends as follows: cervical 70- 75%, thoracic 15-20% and lumbar 10%.[9] In present study fusion of thoracic vertebrae is present in 13.33%. Considering the development of vertebrae, during the fourth week of development, cells of the sclerotomes shift their position to surround both the spinal cord and the notochord. The caudal portion of each sclerotome segment proliferates extensively and proceeds into the subjacent intersegmental tissue and binds the caudal half of one sclerotome to the cephalic half of the subjacent sclerotome. Hence, by incorporation of the intersegmental tissue into the precartilaginous vertebral body, the body of the vertebra becomes intersegmental. Patterning of the shapes of the different vertebra is regulated by HOX genes. It is possible to have two successive vertebrae fuse asymmetrically or have half a vertebra missing, a cause of scoliosis (lateral curving of the spine). A typical example of these abnormalities is found in patients with Klippel-Feil anomaly. These patients have fewer than normal cervical vertebrae, and often other vertebrae are fused or abnormal in shape.[16] The causes of fusion of vertebrae can be congenital, acquired or surgical. Congenital Vertebral Malformation is caused by genetic and environmental influences that occur during somitogenesis around the third week after fertilization. Occurrence of Congenital Vertebral Malformation in animal models and humans has been associated with various maternal exposures during pregnancy, including alcohol use(Treadwell *et al.* 1982), anticonvulsant medications including valproic acid (vorhees,1987; Menegola *et al.*,1996; Holmes *et al*., 2001),hyperthermia (Bree, *et al*., 1999),maternal insulin-dependent diabetes mellitus, and gestational diabetes (Passarge and Lenz, 1966; Aberg *et al.*,2001; Martinez- Frias *et al.*, 1998)[5].The process of spinal formation can result in vertebral anomalies such as hemivertebrae, block vertebrae butterfly vertebrae, transitional vertebrae, and in extreme cases spina bifida. These defects can cause compression of the spinal cord due to deformation of the vertebral canal, spinal curvature, and alterations of the shape and number of vertebrae referred to as congenital vertebral defect. Block vertebrae also occur when there is improper segmentation of the somites during the period of differentiation leading to fusion of parts of or entire vertebrae. Physicians are able to detect congenital block vertebrae in vivo, but it is difficult to determine whether the defect is congenital, acquired, or both. Vertebral anomalies are also associated with kidney problems because the precursor cell population that creates the spine is the same population that migrates to form the mesonephros.[1]Although prior estimates indicate prevalence between 0.13–0.5 1/1000 live births, more recent information indicates that the incidence of CVM in the general population is unknown as many people who are asymptomatic do not present for medical care (Wynne-Davis, 1975;Brand, 2008). In present study we got 2 sets of fused typical thoracic vertebrae out of which one is having complete fusion of zygapophysial joint, fusion of root of transvere process and spine (fig: 1) while another is having partial fusion of zygapophysial joint and laminae (fig: 2) indicating probability of congenital malformation (0.44%). According to Chandraraj *et al.* the anatomy of fused vertebrae indicates the embryological time of occurrence of synostosis: Independent pedicle and transverse process suggests normal initial development followed by fusion. Absence of the joint between articular facets in the fused vertebrae suggests failure of normal development and differentiation of vertebrae i.e. Fusion at the precartilaginous stage of vertebral development (Chandraraj *et al.*, 1987).Congenital vertebral malformation (CVM) in humans are associated with significant health problems including kyphosis, scoliosis, neck and back pain, disability, cosmetic disfigurement, pulmonary compromise, and functional distress. They can also lead to muscle weakness and/or atrophy, and neurological sensory loss.[1]

Acquired fusion of vertebrae can be due to diseases such as Tuberculosis, Juvenile rheumatoid arthritis and trauma[2] (Erdil *et al*., 2003) or due to Forestier's disease, also known as diffuse idiopathic skeletal hyperostosis (DISH), Ankylosing spondylitis, Spondylocostaldysostosis or as part of other syndromes. Forestier,s disease is an idiopathic rheumatological abnormality in which exuberant ossification occurs along ligaments throughout the body, but most notably the anterior longitudinal ligament of the spine can also lead to vertebral synostosis. The axial skeleton is often involved in Forestier's disease particularly the thoracic spine, but involvement of peripheral joints can also be present. DISH was termed as senile ankylosing hyperostosis and described for more than 50 years ago[13]. The main target of the disease process is within the enthesis, an organ rich in collagen fibers, fibroblasts and other mesenchymal cells, fibrocartilage, and calcified matrix that penetrate the bone cortex at its attachment. The lower thoracic spinal segment is usually the first to be involved, with subsequent extension into the upper thoracic segments and the lumbar spine. The ossification pattern of DISH involves the anterior ligament, the lateral portion of the annulus fibrosis, and the adjacent vertebral bodies[14] comparable with fig: 3, 4, 5,6.

The classification criteria set by Resnick and Niwayama requires involvement of at least 4 contiguous vertebrae of the thoracic spine, preservation of the intervertebral disc space, and absence of apophyseal joints or sacroiliac inflammatory changes.[14] We found such finding in one set of fused thoracic vertebrae T7,T8,T9,T10. Nagaraj Mallashetty *et al.*[9] observed that the bodies of upper ten thoracic vertebrae were fused due to ossification of anterior longitudinal ligament. DISH has no genetic link and no organ involvement. Foresteir's disease most commonly affects obese men who are more than 40 years old. The prevalence of the disease has been estimated to range between 12 and 22% in men and 12 to 13% in women. In present study we got 4 sets of thoracic vertebrae having ossification of anterior longitudinal ligament indicating 8.88%. Most patients have mild to moderate restriction of spine movements, low back pain and stiffness in the lumbosacral region.[6] Mechanical factor, dietary and long term use of antidepressants may be correlated with DISH.It can explain some clinical, otherwise unclear rheumatologic manifestations, and can avoid or change the attitude toward presence of future complications attributable to DISH such as dysphagia, unstable spinal fractures, spinal stenosis, postsurgical heterotropic ossifications, difficult intubation, difficult gastroscopy, aspiration pneumonia, myelopathy, and others.[8,10,12]

The disease is not fatal however some complications may lead to death such as paralysis, dysphagia and pulmonary infections due to fusion of rib cage. Ossification of posterior longitudinal ligament has been well recognized as Japanese disease and it is a well-documented cause of cervical spine stenosis.[9]

According to Forestier the cacification and ossification is most common in right side of spine than left. We got the same result having ossification of anterior longitudinal ligament more on right side. In patients with dextrocardia this calcification occurs on left side, which confirms the role of the descending thoracic aorta in preventing the physical manifestation of DISH on one side of spine.[9]

In comparision with other causes of fused vertebrae, Ankylosing spondylitis is a genetic disease with identifiable marks and involvement of organs[4]. More than ten contiguous vertebral fusion can be due to Spondylocostaldysostosis. The Forestier's disease is diagnosed and differentiated from ankylosing spondylitis, on the basis of certain radiological criteria.[13] Pathological causes of fusion of vertebrae are Fibrodysplasia, Progressive Juvenile Rheumatoid arthritis, Postinfectious, Postsurgical, Ossification of posterior longitudinal ligament of cervical spine, Posttraumatic etc. (Clarke *et al.*, 1995).

Amonginfectious diseases e.g tuberculosis which frequently affects thoracic and lumbothoracic vertebrae can be a cause of fused vertebrae. Many syndromes are associated with congenital spinal deformities. These include Down syndrome, cervico-oculo-acoustic syndrome, VACTERL association etc. but are mainly associated with cervical vertebral defects.[1]

Because of their construction, contents and susceptibilities to multiple disorders, the intervertebral foramina are loci of great biomechanical, functional and clinical significance. Nerve compression and irritation may be caused by bony entrapment as the size of the foramen decreases as a result of facet joint osteoarthritis, osteophyte formation or disc degeneration, all of which may lead to lateral or foraminal spinal stenosis.[17] Within its boundaries is an intricate network of ligaments that divide the intervertebral foramen into multiple sub-compartments containing specific anatomic structures. The height of the foramen is critical to allow safe passage of vital neurovascular structures to and from the spinal canal. Compromise of these neurovascular structures in the foramen is frequently responsible for the radicular pain patterns seen in elderly patients.[11] The measurenments of intervertebral foramina presented here may be significant for clinical aspect.

During medicolegal investigations, some congenital abnormalities are of vital importance in identification, especially when antemortem records are available.[7] Due to lack of references related to morphometric study of intervertebral foramen of thoracic vertebrae, this needs to be further compared and correlated.

CONCLUSION

In present study we found 13.33% fused thoracic vertebrae, 2 sets of 2 fused thoracic vertebrae due to congenital reason, 4 sets of fused thoracic vertebrae due to acquired reason in 45 vertebral column. Morphometric analysis of interverbrebral foramen is to be further evaluated. Recognition of fused thoracic vertebrae at an early age can prevent many disabilities and complications or it can identify other hidden pathologies also. Although fusion of thoracic vertebrae is a rare finding but it can highlight many clinical aspects.

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