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Neurosurgery

Computed Tomographic analysis of thoracic Spine for evaluation of safe parameters for anterior and posterior instrumentation

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ABSTRACT

Introduction : Instability of thoracic spine occurs due to many causes. Instability is stabilised by instrumentation of spine which provide spinal stability at unstable segment either anteriorly or posteriorly sometimes combined with screws along with rods or plate construct. During insertion of screws there are chances of screws violating the vertebral body or pedicle causing permanent and/or life threatening complication. Pre-operative planning with CT thoracic spine should be done for measurement of safe length and safe trajectory.The aim of this study is to evaluate safe placement of anterior and posterior screws by computed tomography analysis of length and trajectory for thoracic spine.

Materials and methods : The analysis was done on a cohort of 100 patients who had undergone CT thorax or thoracic spine imaging due to suspected thoracic injury and thoracic lesions during the period 2013-2014. Imaging of T1 to T12 was analyzed with axial views and multiplanar reconstruction. The length of the screw and the trajectory of screw insertion were analyzed with the measurement of transverse dimension and and vertebral angle for anterior instrumentation and pedicular chord length, extrapedicular chord length, pedicular angles and extrapedicular angles for posterior instrumentation was measured and the data analyzed for safe anterior and posterior instrumentation.

Results- The analysis of the various parameters of the thoracic vertebrae showed that the transverse diameter showed a gradual increase from T1 to T12 and that posterior safe angles decreased from T4 to T12. The pedicular chord length which is an indicator of maximum safe length of screw insertion showed a gradual increase from T1 to T9 and decrease from T10.The pedicular angle showed a decrease from T1 to T12 except at T9 level. The extrapedicular chord length showed a gradual increase from T1 to T9 and a decrease from T10 in males and from T9 in females and there was a uniform decrease in extrapedicular angle from T1 to T12 in both sexes.

Conclusions- This analysis of thoracic spine measurements showed that all the angles decrease from T1 to T12. Lengths increase from above downwards, but in posterior instrumentation there is a decrease in measurements in lower levels. This is virtual measurement of thoracic spine in transverse plane. This is useful in intraoperative guidance and also helps to emphasize the importance of pre-operative CT Thoracic spine scan for planning thoracic screw instrumentation.

KEYWORDS : Thoracic instrumentation, Vertebral measurements, CT imaging, Pedicular chord length, pedicular and extrapedicular angles.

INTRODUCTION

Instability is the abnormal response of spine caused by excessive motion of segments to applied load. Instability of thoracic spine occurs due to many causes. Instability is stabilised by instrumentation of spine. Spinal instrumentation is implantation of artificial devices which are attached to vertebral column. These implants provide spinal stability at unstable segment and promote bony fusion at unstable segment. Instrumentation of thoracic spine is done either anteriorly or posteriorly sometimes combined depending upon the columns of vertebra involved. Three column described by Denis et al, two column by Holdsworth, Anterior instrumentation first reported by Humphries and Hawk in 1958 for Pott's disease. Anterior instrumentation is done through thoracotomy or thoracoscopy. Instrumentation devices are screws with rods, plates or cables. Screws are inserted into vertebral body and are connected to construct. Posterior instrumentation uses wire-rod, hook-rod or screw-rod construct. Because of advantages such as stabilisation of all the columns, no need for intact posterior elements and biomechanically superior screw-rod constructs are popular. Posterior screw instrumentation techniques are pedicular described by Roy-Camille in 1970 and extrapedicular by Dvorak et al in 1993. In both anterior and posterior instrumentation screws are used along with rods or plate construct. During insertion of screws there are chances of screws violating the vertebral body or pedicle causing injury to surrounding neural, vascular structures and internal organs causing permanent and/or life threatening complication. During pre-operative planning CT thoracic spine should be done for measurement of safe length and safe trajectory. This study is an attempt to evaluate safe placement of anterior and posterior screws by computed tomography analysis of length and trajectory for thoracic spine in patients who underwent CT Thorax or thoracic spine in our institution.

AIM OF THE STUDY

Aim of the study is to determine the safe length and safe angle for anterior and posterior screw instrumentation in thoracic spine using CT Thorax / CT Thoracic spine in our population

MATERIALS AND METHODS

Totally 100 patients of which 50 male and 50 female patients were included in the study, who underwent CT thorax / CT thoracic spine for evaluation of suspected thorax / thoracic spine lesion due trauma, infections, malignancy or degenerative process. This study was conducted in Department of Neurosurgery and Department of Radiodiagnosis, Madurai Medical College, Madurai during 2013 – 2014.

Inclusion criteria:

- Age greater than 18 years
- Agreed to participate in the study and sign the consent form
- All CT Thorax / Thoracic spine studies done in patient with suspected thoracic injury / thoracic lesion

Exclusion criteria:

- Patient refuses to participate in the study
- Patient with thoracic spine spondylotic changes
- Patient with thoracic spine inflammatory changes
- Patient with thoracic spine fracture
- Patient with thoracic spine dislocation
- Patient with thoracic vertebral body destruction

All CT studies that satisfied inclusion criteria with slice thickness of

5mm were evaluated. CT scans were viewed with 32-bit research version Osirix application in Apple Macintosh computer. Thoracic spines from T1 to T12 were analysed from both sides for anterior instrumentation and both sides for posterior instrumentation. Axial views are analysed for measurement of length and angle. Multiplanar reconstruction mode is used to precisely locate the vertebral level. Instability of thoracic spine is stabilized by anterior, posterior instrumentation, or both. In both anterior and posterior instrumentation spinal cord, major vascular structures such as aorta and IVC are at risk due to close proximity to thoracic spine. So during instrumentation length and trajectory are important to avoid neurologic and vascular injury. In this study the aim was to define length of screw and angle of screw for safe anterior and posterior screw instrumentation. For anterior instrumentation, Transverse dimension and vertebral angle are measured.

Transverse dimension (figure 1):
Distance from rib head anterior border to vertebral body lateral cortex.

Posterior safe Angle (figure 2):
Angle subtended by line which connects anterior convex aspect of the rib heads with a line connect most concave antero-lateral aspect of vertebral canal to anterior convex aspect of the rib.

For posterior instrumentation, pedicular chord length, extrapedicular cord length, pedicular angle and extrapedicular angles are measured.

Pedicular Chord Length (figure 3):
Distance from transverse process lamina junction to anterior convex cortex of vertebral body along the long axis of pedicle

Extrapedicular Cord Length(figure 3):
Distance from costo-transverse joint to anterior convex cortex of vertebral body through rib-pedicle unit.

Pedicular Angle (figure 4):
Angle subtended by line bisecting vertebral canal in AP direction at its midpoint with line along pedicular chord length.

Extrapedicular Angle(figure 4):
Angle subtended by line bisecting vertebral canal in AP direction at its midpoint with line along pedicular chord length.

With these parameters, length of screw and angle of screw for safe anterior and posterior screw instrumentation were measured. The information collected regarding all the selected cases were recorded in a Master Chart and data analysis was done.

RESULTS
In this study, transverse diameters, posterior safe angle for anterior screw instrumentation and pedicular chord length, extrapedicular chord length, pedicular angle, extrapedicular angle were measured. Mean and Standard deviation and p-value results were computed and analysed for statistical significance. For this study there were a total of 100 patients with equal male and female distribution with male: female ratio of 1: 1. For males, minimum age was 22 years and maximum age was 76 years. The mean was 51.04 years with standard deviation of 10.26. For females, minimum age was 19 years and maximum age was 80 years. The mean was 44.80 years with standard deviation of 14.69.

Transverse Diameter:
The transverse diameter was measured from CT scan for placing anterior screw instrumentation on the right side and left side in males and in females (Table 1). The transverse diameter gradually increased from T1 to T12 for both right and left sides, males and females. For analysis of statistical significance, the transverse diameter measured from CT scan for placing anterior screw instrumentation on the right side in males was compared with the left side in males ,the transverse diameter on the right side in females was compared with the left side in females, the transverse diameter on the right side in males was compared with the right side in females and the transverse diameter measured on the left side in males was compared with the left side in females(figure 5)

Posterior Safe Angle:
The posterior safe angle was measured from CT scan for placing anterior screw instrumentation on the right side and left side in males and in females(table 2). The posterior gradually decreased from T1 to T12 for both right and left sides, males and females. For analysis of statistical significance, the posterior safe angle measured from CT scan for placing anterior screw instrumentation on the right side in males was compared with the left side in males, the posterior safe angle measured on the right side in females was compared with the left side in females, the posterior safe angle measured on the right side in males was compared with the right side in females, the posterior safe angle measured on the left side in males was compared with the left side in females.

Pedicular Chord Length:
The Pedicular Chord Length was measured from CT scan for placing posterior screw instrumentation on the right side and left side in males and in females (Table 3). The Pedicular Chord Length gradually increased from T1 to T9, then started to decrease from T10 for both right and left sides, males and females. For analysis of statistical significance, the Pedicular Chord Length measured from CT scan for placing posterior screw instrumentation on the right side in males was compared with the left side in males, instrumentation on the right side in females was compared with the left side in females, the Pedicular Chord Length measured posterior screw instrumentation on the right side in males was compared with the right side in females, the Pedicular Chord Length posterior screw instrumentation on the left side in males was compared with the left side in females.

Pedicular Angle:
The Pedicular Angle was measured from CT scan for placing posterior screw instrumentation on the right side and left side in males and in females(Table 4). The Pedicular Angle gradually decreased from T1 to T12 for both right and left sides, males and females. For analysis of statistical significance, the Pedicular Angle measured from CT scan for placing posterior screw instrumentation on the right side in males was compared with the left side in males, the Pedicular Angle measured on the right side in females was compared with the left side in females, the Pedicular Angle on the right side in males was compared with the right side in females, the Pedicular Angle measured on the left side in males was compared with the left side in females.

ExtraPedicular Chord Length:
The ExtraPedicular Chord Length was measured from CT scan for placing posterior screw instrumentation on the right side and left side in males and in females(Table 5). The Extra Pedicular Chord Length gradually increased from T1 to T8, then started to decrease from T9 for both right and left sides, males and females. For analysis of statistical significance, the ExtraPedicular Chord Length measured from CT scan for placing posterior screw instrumentation on the right side in males was compared with the left side in males, the ExtraPedicular Chord.Length measured on the right side in females was compared with the left side in females, the ExtraPedicular Chord Length measured on the right side in males was compared with the right side in females, the ExtraPedicular Chord Length measured on the left side in males was compared with the left side in females.

ExtraPedicular Angle:
The ExtraPedicular Angle was measured from CT scan for placing posterior screw instrumentation on the right side and left side in males and in females(Table 6). The ExtraPedicular Angle gradually decreased from T1 to T12 for both right and left sides, males and

females. For analysis of statistical significance, the ExtraPedicular Angle measured from CT scan for placing posterior screw instrumentation on the right side in males was compared with the left side in, the ExtraPedicular Angle measured on the right side in females was compared with the left side in females, the ExtraPedicular Angle measured on the right side in males was compared with the right side in females , the ExtraPedicular Angle measured on the left side in males was compared with the left side in females.

DISCUSSION

After computer software guided measurements of thoracic spines in 100 patients (50 males and 50 females) who underwent CT thorax / CT thoracic spine for suspected lesions in thorax / thoracic spine, the values are analysed and compared with previous studies conducted nationally and internationally.

Transverse diameter:

Present study showed there is gradual increase in transverse diameter from T1 to T12 due increase in size of vertebral body and there is statistical significant difference between males and females. This suggests that large length of screw can inserted into vertebral body ventrolaterally at lower thoracic level and larger screw for males. The upper level of thoracic spine that can be approached through thoracotomy is T3 or T4. There is no significant difference between the sides of screw insertion. The side of thoracotomy depends on surgeons preference because both sides have important vascular structures and internal organs. This study data is compared with X. H. Li et al which shows that transverse diameter increases from T4 to T12 and no statistical significance between right and left except at T8 level, but not mentioned male and female difference.

Posterior Safe Angle:

X. H. Li et al on their study concluded those posterior safe angles gradually decrease from T4 to T12. At lower levels T11 and T12 the angle become negative on measurement suggesting that vertebral canal is placed anterior to the line joining tips of corresponding ribs. The clinical implication of this finding during anterior screw instrumentation at ventrolateral aspect vertebral body is screw direction which should be directed anteriorly in T11 and T12 to avoid screw entering into spinal canal. The significant statistical difference between sides is seen at T5, T7and T8 level, but in present study there is no significant statistical difference, but not mentioned male and female difference. K. Papadimitriou et al. showed in their study, there was gradual decrease in distance between rib heads and spinal canal. At T11 and T12 the value became negative. This implies that posterior safe angle also become negative on measurement.

Pedicular chord length:

Zindrick et al first described pedicle morphometric analysis using CT scan Pedicular chord length is maximum safe length of screw that can be inserted during pedicle screw fixation without injuring structures at anterior aspect of vertebral body. In this study there gradual increase in length from T1 to T9 then from T10 started to decrease and there is no significant statistical difference between right and left side, but significant statistical difference between male and females. R. M. Kretzer et al did study on US trauma population, which showed pedicular chord length gradually increased from T1 to T9 and from T10 started to decrease. There was statistical significant difference between male and female in Pedicular chord length. Liau et al showed pedicular chord length gradually increased from T1 to T8 and from T9 started to decrease. There was statistical significant difference between male and female in Pedicular chord length at all levels. JH Kim, et al showed pedicular chord length gradually increased from T1 to T9 and from T10 started to decrease for males and gradually increased from T1 to T10 and from T11 started to decrease. There was statistical significant difference between male and female in Pedicular chord length except at T3, T4, T7, and T12. JH Kim, et al showed pedicular chord length gradually increased from T1 to T9 and from T10 started to decrease for males and gradually increased from T1 to T10 and from T11 started to decrease. There was statistical significant difference between male and female in Pedicular chord length except at T3, T4, T7, and T12. But Pai, et al in his study showed gradual increase of chord length from T1 to T12.

Pedicular Angle:

R. M. Kretzer et al, Liau et al, JH Kim et al, Pai et al showed there was gradual decrease of angle from T1 to T12 except at T9 level for R. M. Kretzer et al. For Liau et al no significant statistical difference between male and females, but for R. M. Kretzer et al and JH Kim et al at many level there was significant statistical difference between male and females. In Present study there is no significant statistical difference between right and left side, male and females and also gradual decrease of angle from T1 to T12.

Extrapedicular Chord Length:

Dvorak M et al first described extrapedicular approach for Posterior thoracic screw instrumentation. JH Kim et al extrapedicular chord length gradually increased from T1 to T9 and from T10 started to decrease for males and increased from T1 to T8 and from T9 started to decrease for females. There was statistical significant difference between male and female in ExtraPedicular chord length. This study has no significant statistical difference between right and left side, but significant statistical difference male and females and also gradual increase of extrapedicular chord length from T1 to T8 and decrease from T9 bilaterally.

Extrapedicular Angle:

JH Kim et al extrapedicular angle gradually decreased from T1 to T12 for males and females. There was no statistical significant difference between male and female. This study has no significant statistical difference between right and left side, male and females and gradual decrease of extrapedicular angle from T1 to T12 bilaterally.

Drawbacks of this study:

This study only included adult population, so measurements regarding length and angle are not useful for paediatric population

- The measurements are taken for virtual image that is constructed by computer by using matrix. So stimulation is not tested using values from this study. Pai et al showed difference between measurements taken from radiological and from cadaveric specimens.
- CT Thorax / CT Thoracic spine is taken in lying supine position. But the anterior screw instrumentation is done in lateral position and the posterior instrumentation is done in prone position. There is difference in thoracic kyphosis and relationship of surrounding structures with vertebra due to gravity.
- Intraoperative imaging is useful during instrumentation

CONCLUSION

This analysis of thoracic spine provides length and transverse angle for safe anterior and posterior screw instrumentation for thoracic spine which are evaluated using Computer software DICOM Viewer.

- These measurements show no significant statistical difference between sides for length and angle, no significant statistical difference between males and females for angle and significant statistical difference between males and females for length. Angles decrease from T1 to T12. Lengths increase from above downwards, but in posterior instrumentation there is a decrease in measurements in lower levels.
- This is virtual measurement of thoracic spine in transverse plane. This is useful in intraoperative guidance, while using C-arm AP and lateral views are possible.
- Pre-operative CT Thoracic spine scan has become important investigation for pre-operative evaluation in patients planned for thoracic screw instrumentation.

ILLUSTRATIONS AND TABLES

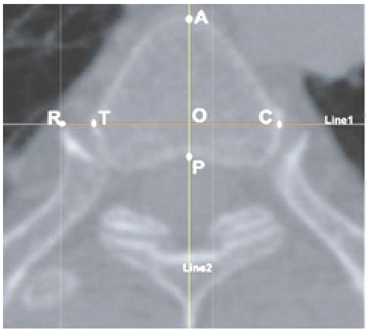

Figure 1-Transverse dimension

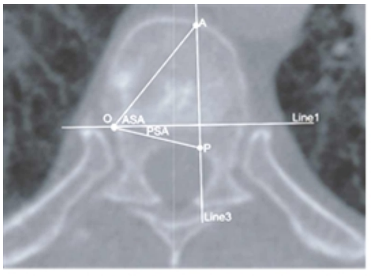

Figure 2-Posterior Safe Angle(PSA)

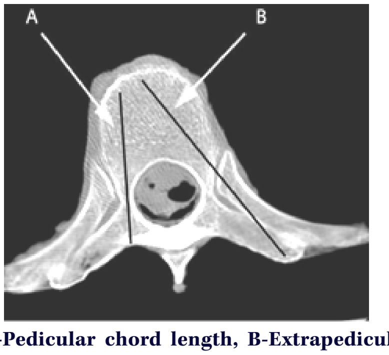

Figure 3-A-Pedicular chord length, B-Extrapedicular chord length

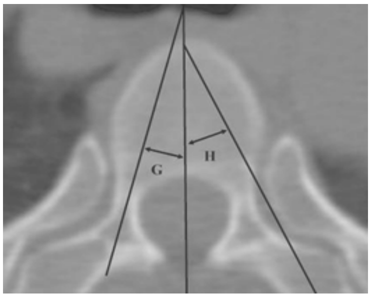

Figure 4-G-Pedicular angle, H-Extrapedicular angle

Table 1 Transverse diameter

	LEVEL	RIGHT		LEFT	
		Mean(mm)	SD	Mean (mm)	SD
Males	T1	23.81	2.56	23.50	2.52
	T12	38.60	3.10	38.92	3.40
Females	T1	21.34	2.48	21.14	2.51
	T12	35.37	2.90	35.12	3.10

Table 2-Posterior Safe Angle

	LEVEL	RIGHT		LEFT	
		Mean(in degrees)	SD	Mean (in degrees)	SD
Males	T1	31.80	4.13	31.63	4.01
	T12	-4.71	1.59	-5.10	1.86
Females	T1	30.62	4.20	31.51	4.16
	T12	-4.60	1.86	-4.95	1.65

Table 3- Pedicular Chord length

	LEVEL	RIGHT		LEFT	
		Mean(mm)	SD	Mean(mm)	SD
Males	T1	29.91	3.12	28.98	2.86
	T9	41.52	3.22	40.53	3.31
	T10	40.83	3.30	40.28	3.21
Females	T1	27.13	2.67	26.51	2.52
	T9	37.19	3.31	37.21	3.29
	T10	36.24	3.26	36.15	3.18

Table 4 –Pedicular angle

	LEVEL	RIGHT		LEFT	
		Mean (degree)	SD	Mean (degree)	SD
Males	T1	32.24	3.59	31.45	3.52
	T12	4.35	1.54	4.57	1.32
Females	T1	31.89	3.51	31.47	3.46
	T12	4.07	1.29	4.56	1.30

Table 5-Extrapedicular chord length

	LEVEL	RIGHT		LEFT	
		Mean(mm)	SD	Mean(mm)	SD
Males	T1	39.23	3.24	38.43	3.21
	T8	53.34	4.38	53.09	4.22
	T9	52.81	4.11	51.56	4.23
Females	T1	37.43	3.18	37.10	3.20
	T8	49.29	4.21	49.04	4.20
	T9	48.37	4.34	47.89	4.26

Table 6 –Extrapedicular angle

	LEVEL	RIGHT		LEFT	
		Mean (degree)	SD	Mean (degree)	SD
Males	T1	47.19	5.01	46.23	5.13
	T12	18.63	3.03	17.48	3.23
Females	T1	45.73	4.98	45.23	5.02
	T12	19.48	3.15	18.39	3.14

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