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Morphometric Analysis Of Axis Vertebra And Its Implications For Instrumentation

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ABSTRACT

INTRODUCTION-

The anatomy of second cervical vertebra and its normal variation in anatomy and thin section CT analysis has important implications for instrumentation of upper cervical vertebrae particularly the transarticular screw fixation at C1-C2 level that provides a rigid fixation. The aims of this study is to 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 and to study the CT morphometry of axis vertebra and further 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 mainly of the pedicle, the lateral mass, the groove for the vertebral artery and the transverse foramen were measured and all were linear dimensions. The mean, standard deviation and range were calculated for all 25 specimens amounting to a total of 50 measurements for each observation. The data of patients undergoing CT of the neck with thinly sliced 1 mm sections and MPR in sagittal and coronal planes were obtained through the region of interest from the base of C3 to C1-C0 joint and 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.

RESULTS

The morphometric analysis and measurement of the mean height of the pedicle, width of the pedicle, length of the lateral mass, external height of lateral mass,depth of vertebral artery groove, internal Height of Lateral Mass, length of VA Groove, height of transverse foramen ,width of transverse foramen, external height of lateral mass (CT) ,depth of Vertebral artery Groove (CT) ,internal Height of Lateral Mass (CT), length of VA Groove (CT) ,height of transverse foramen (CT) was done and tabulated. 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, in dried specimens, by CT and in cadavers.

CONCLUSIONS

Thinning of the lateral mass and the pedicle of axis vertebra due to the vertebral artery may prevent adequate fixation by posterior transarticular screw placement. High resolution thin section CT scanning to analyze vertebral artery to prevent vertebral artery injury is recommended for this purpose which can be further improved by intraoperative flouroscopy and 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.

KEYWORDS : C2 (axis) vertebra, morphometry,CT 3D reconstruction, vertebral artery, transarticular fixation.

INTRODUCTION

The anatomy of second cervical vertebra has been described in detail by various authors. Most authors have concentrated on the dens and a few 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. 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.

RESULTS

Height of the pedicle

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 1)

Width of the Pedicle (Table – 2)

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.

Length of Lateral Mass(Table – 3)

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.

External Height of Lateral Mass (Table – 4)

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.

Depth of Vertebral artery groove (Table – 5)

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
Internal Height of Lateral Mass (Table – 6)

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.

Length of VA Groove (Table – 7)

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.

Height of transverse foramen (Table – 8)

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.

Width of transverse foramen(Table – 9)

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.

External Height of Lateral Mass (CT) (Table – 10)

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.

Depth of Vertebral artery Groove (CT) (Table – 11)

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.

Internal Height of Lateral Mass (CT) (Table – 12)

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.

Length of VA Groove (CT) (Table – 13)

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.

Height of transverse foramen (CT) (Table – 14)

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, in dried specimens, by CT and in cadavers.

At the level of the axis, angiographic studies55 and observations on dried specimens 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 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 a loop of the vertebral artery may erode the pedicle and compress the associated nerve root. A CT study by Paramore et al, 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 Arensburg3 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.

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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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).

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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.

TABLES AND FIGURES

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	

Table 2

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	

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	

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	

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		

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		

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		

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		

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		

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		

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		

Table – 12 Internal Height of Lateral Mass (CT)

Height	No.of cases		
	Left	Right	Total
< 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		

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		

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		

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