The anatomic and radiographic measurement of C2 lamina in Chinese population

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Abstract

Objective In this study, we performed anatomic and computed tomography (CT) measurements of C2 lamina in Chinese people in order to provide the anatomic and radiographic data, and to verify the clinical applicability of trans-lamina screws to this population.

Methods The anatomic and radiographic measurement was conducted on two separate groups, group A and group B. In group A, a total of 96 human adult (male 51, female 45) cadaver spines were included. The minimal height (H1), thickness (T), length (L1) of C2 lamina, height of the root of lamina (H2), distance from the entry point to the lateral rim of lamina (L2) and to the lateral rim of lateral mass (L3) were bilaterally measured using high precision calipers. The spino-laminar angles (angle A) were also included. In group B, a total of 112 volunteers (male 58, female 54) without upper cervical abnormality were enrolled. Angle A, H1, T, L1, H2, L2 and L3 were bilaterally measured using plain X-rays and reconstruction CT. All measurements were taken at the thinnest part of the lamina in the axial and coronal plane.

Results All the measurements (except angle A) in males were significantly higher than those in females ($P < 0.05$). There was no significant difference in the values of bilateral laminae between group A and group B ($P > 0.05$). The thickness of 45% specimens was less than 6 mm. The length of lamina in all specimens was less than 2.5 cm, while only 5% of the specimens had a length of >3 cm

from the entry point to the rim of lamina. The length from the entry point to the lateral rim of lateral mass was between 2.5 and 4.6 cm. In contrast, the length of only 5% specimens was longer than 4 cm.

Conclusions The preoperative radiographic evaluation is very important to determine the suitable size of screws. The diameter of screws is mainly restricted by the thickness of C2 lamina. It is safe to use screws with a length of 2.5–3.0 cm for Chinese people. The radiographic measurement method we used is simple, accurate and reliable for preoperative measurement.

Keywords C2 lamina · Anatomic measurement · Radiographic measurement

Introduction

Various techniques, e.g., Brooks method, Gallie method, Magerl and Harms technique [1, 4–8], can be used for internal fixation of upper cervical spine. However, the high frequency of pseudoarthrosis, high risk of injuring vertebral artery or spinal cord, and the anatomic size of C2 pedicle have limited the clinical application of these techniques. Wright et al. [16] first reported the clinical application of crossing C2 laminar screws for the internal fixation of cervical spine. Since then, anatomical, biomechanical and clinical series have been widely reported [8–16]. This technique can reduce the risk of injuries in the vertebral artery (VA), obtain similar biomechanical stability and is easy to insert without the assistance of navigation. However, as it is difficult to perform direct measurements in clinical practice, preoperative radiographic measurement must be conducted to determine whether this technique can be safely used in specific

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Fig. 1 Description of the anatomic measurement methods. The measurement of L1, L2, L3 and T (a), the measurement of angle A (b), the measurement of H1 (c), the measurement of H2 (d)

patients. In this study, we performed the anatomic and radiographic measurement of C2 lamina in Chinese population in order to provide the anatomical and radiographic data, verify the clinical applicability of trans-lamina screws in Chinese people, and to evaluate the efficacy of our radiographic methods.

Materials and methods

Anatomical measurement of C2 lamina

The anatomic specimens were provided by Anatomical Department of Medical School, Shandong University. A total of 96 cadaver spines from adults were included in this study (group A). To ensure that the C2 vertebrae were intact and free from osteophytes, deformity or tumors, all specimens were inspected before measurements. There were 51 males and 45 females. We measured 96 specimens bilaterally with a total of 192 measurements. The age and height of the subjects were 54.1 ± 15.6 years and 171.0 ± 10.0 cm, respectively. The minimal height (H1), thickness (T), length (L1) of C2 lamina, height of the root of lamina (H2), distance from the entry point to the lateral rim of lamina (L2) and to the lateral rim of lateral mass (L3) were bilaterally measured using high precision digital calipers (with 0.2 mm accuracy). All the data were measured at the narrowest or thinnest part of C2 lamina. The bilateral spino-laminar angles (angle A) were measured as described

by Cassinelli [2]. The methods of measurement are shown in Fig. 1.

Radiographic measurement of C2 lamina

A total of 112 volunteers (male 58, female 53) without upper cervical abnormality were enrolled in this study (group B). All volunteers were inspected to ensure that the vertebrae were free from osteophytes, deformity or tumors before measurements. This study was approved by the ethnic committee of Qilu Hospital of Shandong University. The age and height of the volunteers were 50.2 ± 10.1 years and 173.0 ± 9.4 cm, respectively. The radiographic measurement of C2 lamina was performed according to the methods described below (Fig. 2). First, a standard plain lateral radiograph was taken. The upper and lower boarder lines of lamina (white dotted lines) and two lines perpendicular to the plane with the ground were drawn. The line (line B) crossing the midpoint A and B of C2 lamina was defined as the longitudinal axis of C2 lamina, and the angle (angle B) between the inferior endplate of C2 (line A) and line B was calculated (Fig. 2a). Then, the upper cervical (C1–3) spine was scanned by CT (SOMATOM Definition, Siemens, German) and the thickness of slice was 0.75 mm. The cross-sectional images of C2 lamina were reconstructed according to the line B which can be calculated by line A and angle B (Fig. 2b). The bilateral thickness (T), length (L1) of C2 lamina, spino-laminar angles (angle A), distance from the entry

Fig. 2 Description of the radiographic measurement methods. A plain lateral radiograph was taken and the angle (angle B) between the inferior endplate of C2 (*line A*) and line along the longitudinal axis of C2 lamina (*line B*) was calculated (**a**), the cross-sectional images of C2 lamina were reconstructed according the *line B* (**b**), the

measurement of L1, L2, L3, T and angle A (**c**), the coronal images of C2 lamina were reconstructed according to perpendicular line of *line B* (**d**), the height of bilateral C2 lamina (H1) (**e**), the height of root of C2 lamina (H2) (**f**)

Table 1 The measurement data of C2 lamina in Chinese people

	N	Anatomical measurement		N	Radiographic measurement		P
		Mean	SD		Mean	SD	
L1 (cm)	192	1.81	0.51	224	1.79	0.32	0.66
L2 (cm)	192	2.55	1.56	224	2.48	0.41	0.12
L3 (cm)	192	3.22	1.27	224	3.32	0.45	0.80
T (cm)	192	0.62	0.52	224	0.66	0.15	0.43
Angle A (°)	192	45.0	5.0	224	46.9	4.89	0.37
H1 (cm)	96	1.21	0.16	112	1.18	0.33	0.79
H2 (cm)	192	1.36	0.69	224	1.41	0.43	0.10

point to the lateral rim of lamina (L2) and to the lateral rim lateral mass (L3) were measured, respectively (Fig. 2c). The lateral rim of the lamina of C2 was defined as the border between lamina and lateral mass. The coronal images of C2 lamina were reconstructed according to the perpendicular line of line B (Fig. 2d), and then the height of bilateral C2 lamina (H1) and the root of C2 lamina (H2) were measured, respectively (Fig. 2e, f). All the measurements were performed at the thinnest part of the lamina in the axial and coronal plane.

Data analysis

Each parameter was measured for three times and the average value was recorded. SPSS® 12.0 for windows (SPSS, Inc.) was used for statistical analysis. Unpaired *t* test was performed to determine the statistical significance. Pearson's correlation coefficients and partial correlation coefficients were used to evaluate the correlation between parameters. $P < 0.05$ was considered statistical significance.

Results

The results of all the anatomic and radiographic measurement are shown in Table 1. Comparison of each measurement between male and female populations is shown in Table 2. Comparison of each measurement between left and right sides is shown in Table 3. The distribution of lamina thickness and length is shown in Figs. 3 and 4, respectively. Radiographic measurement showed that angle B was 11.73 ± 5.13 .

There was no significant difference of each parameter between the left and right sides of lamina ($P > 0.05$).

Table 2 The data of C2 lamina in male and female

	Anatomical measurement		<i>P</i>	Radiographic measurement		<i>P</i>
	Male	Female		Male	Female	
L1 (cm)	1.85 ± 0.51	1.79 ± 0.58	0.04	1.92 ± 0.27	1.64 ± 0.29	0.00
L2 (cm)	2.57 ± 0.13	2.49 ± 0.16	0.02	2.55 ± 0.32	2.20 ± 0.34	0.01
L3 (cm)	3.29 ± 0.28	3.13 ± 0.23	0.04	3.45 ± 0.48	3.06 ± 0.31	0.00
T (cm)	0.62 ± 0.18	0.60 ± 0.12	0.04	0.69 ± 0.16	0.62 ± 0.14	0.02
Angle A (°)	44.9 ⁰ ± 6.9 ⁰	45.1 ⁰ ± 3.4 ⁰	0.23	47.9 ± 4.41	44.5 ± 3.83	0.05
H1 (cm)	1.23 ± 0.17	1.10 ± 0.12	0.02	1.28 ± 0.26	1.13 ± 0.22	0.02
H2 (cm)	1.46 ± 0.19	1.28 ± 0.12	0.00	1.62 ± 0.27	1.52 ± 0.17	0.01

Table 3 The data of C2 lamina in different side

	Anatomical measurement		<i>P</i>	Radiographic measurement		<i>P</i>
	Left side	Right side		Left side	Right side	
L1 (cm)	1.81 ± 0.30	1.80 ± 0.34	0.80	1.77 ± 0.30	1.80 ± 0.34	0.47
L2 (cm)	2.54 ± 0.37	2.51 ± 0.46	0.72	2.50 ± 0.37	2.48 ± 0.46	0.31
L3 (cm)	3.21 ± 0.46	3.23 ± 0.45	0.77	3.37 ± 0.46	3.27 ± 0.45	0.61
T (cm)	0.61 ± 0.15	0.62 ± 0.15	0.91	0.66 ± 0.15	0.65 ± 0.15	0.90
Angle A (°)	45.0 ⁰ ± 6.9 ⁰	45.1 ⁰ ± 3.4 ⁰	0.90	47.1 ⁰ ± 6.9 ⁰	45.1 ⁰ ± 3.4 ⁰	0.30
H1 (cm)	1.19 ± 0.17	1.22 ± 0.12	0.12	1.17 ± 0.17	1.18 ± 0.12	0.86
H2 (cm)	1.37 ± 0.19	1.36 ± 0.12	0.76	1.40 ± 0.19	1.39 ± 0.12	0.57

Fig. 3 The distribution of lamina thickness. Y axis indicates the percentage of patients and X axis indicates the lamina thickness

There was no significant difference of age and height between groups A and B. All the parameters in group B did not show significant difference compared to those in group A. All the parameters (except angle A) in males were significantly higher than those in females ($P < 0.05$). The thickness of 45% specimens was less than 6 mm (Fig. 3). The length of lamina in all specimens was less than 2.5 cm, while only 5% of the specimens had a length of >3 cm from the entry point to the rim of lamina. The length from the entry point to the lateral rim of lateral mass was between 2.5 and 4.6 cm. In contrast, the length of only 5% specimens was longer than 4 cm.

Fig. 4 The distribution of lamina length. Y axis indicates the percentage of patients and X axis indicates the lamina length

Discussion

Although many anatomic measurements and clinical application of trans-C2 lamina screws have been reported, there are only a few studies on radiographic measurement [3, 10, 12]. Nakanishi [12] examined the diameter of the vertebral arch using a navigation system. However, only the thickness of C2 lamina was reported. The height, length of C2 lamina, distance from the entry point to the lateral rim of lamina and to the lateral rim lateral mass were not included in that study. Dean et al. [3] performed CT and anatomic measurement of laminar thickness and estimated

the screw length and spino-laminar angle of C2 cadaveric vertebrae. CT scan measurements were found to be highly correlated with direct measurements for both left and right mean laminar thickness. However, screw lengths and spino-laminar angle determined by CT scan were significantly different from the direct measurements. It was concluded that CT scan can only accurately determine the laminar thickness. In our opinion, there is an angle between the inferior endplate of C2 (line A) and the line along the longitudinal axis of C2 lamina. Therefore, axial CT scanning without reconstruction along the longitudinal axis of C2 lamina may cause the incorrect measurement. In our study, radiographic measurements are not significantly different from the anatomical measurements, demonstrating that the radiographic measurement method we used is accurate and reliable. More importantly, this method is also very simple and we can obtain precise data of C2 lamina only according to the routine preoperative lateral X-rays and CT reconstruction of upper cervical spine without increasing exposures to X-rays. Thus, our method can be used in the preoperative assessment safely and effectively.

We measure minimal height, thickness, length of C2 lamina, height of the root of lamina, distance from the entry point to the lateral rim of lamina and to the lateral rim of lateral mass. Our results of main parameters are similar with those of with Cassinelli's reports [2]. We find that the thickness of lamina, distance from the entry point to the lateral rim of lamina and to the lateral rim of lateral mass are main factors that restricts the clinical application of the trans-C2 lamina screws.

The thickness of lamina is critical for safe placement of intra-laminar screws. The minimum thickness needed for safe placement of a screw varies in the literature. Nakanishi [12] reported that the thickness of the vertebral arch in C2 was the largest in the cervical spine, but individual differences ranging from 0.8 to 8.4 mm were found. C2 insertion of screws with a diameter of 3 mm was possible in 80% of males and 63% of females. Insertion of screws with a diameter of 4 mm was possible in 50% of the males and 24% of the females. A total of 70.5% of laminae had a thickness ≥ 5 mm, 92.6% of laminae had a thickness ≥ 4 mm, and 96.7% had a thickness ≥ 3.5 mm. Most of the studies used 4 mm screws for trans-C2 lamina fixation. However, our data suggested that not all laminae can accept 4 mm screws especially for Chinese patients. In our study, the height of C2 lamina and lamina root in all specimens is more than 10 mm, thus thickness is the most important factor restricting the screw diameter. Approximately, 15% lamina had a thickness of less than 5 mm, which is difficult to accept 3.5 mm screws; while 30% lamina had a thickness of less than 6 mm, which is not suitable to insert 4 mm screws (Fig. 2). Thus, preoperative radiographic evaluation is important to determine the suitable size of screws.

The length from the entry point to the lateral rim of lamina is an important factor that restricts the clinical application of the trans-C2 lamina screws. In literature, all the screws had a length of more than 20 mm. Wang et al. [15] reported that the average maximal screw length was 32 mm with a range of 27–37 mm. Moreover, the length from entry point to the lateral rim of lateral mass is less than 2 cm in 17.5% lamina. In such cases, it may cause injury of vertebral artery even if the 2 cm screws are used. In our study, all laminae had a length of less than 2.5 cm. However, the length from entry point to the lateral rim of lamina ranges from 2 to 3 cm in 77.5% lamina, thus, in most case, it is safe to use 2–3 cm long screws in Chinese patients. If longer screws are needed, the preoperative evaluation is very much necessary to avoid the injury of vertebral artery.

Similar with Cassinelli's reports [2], we also found that there were significant differences between lamina of males and females except the spino-lamina angle. The lamina size of males is much bigger than that of females. Therefore, for female patients, the preoperative evaluation of C2 lamina is very important to verify the suitability of this technique.

The results of our study show that the height of C2 lamina and lamina root is more than 10 mm in all specimens, which does not restrict the option of screw diameter. The spino-laminar angles are approximately 45° according to our radiographic and anatomic measurements; the screws can be inserted without breaking into spinal canal if the entry angle is more than 50°.

There are two limitation of this study. First, the anatomic and radiographic measurement was conducted on two separate groups; this may affect the final results. Second, we have used soft tissue fenestration of the CT-scans for the measurement, using a bone fenestration of the CT-scans may be more precise.

Conclusion

The preoperative radiographic evaluation is very much necessary to avoid injury of vertebral artery, especially for female patients. The diameter of screws is mainly restricted by the thickness of C2 lamina. It is safe to use 2.5–3.0 cm long screws in Chinese patients. The radiographic measurement method we used is simple, accurate and reliable for preoperative measurement.

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