

# Morphometric Analysis of Atlas and Its Clinical Significance: An Anatomical Study of Indian Human Atlas Vertebrae

Mohd Salahuddin Ansari<sup>1</sup> Mukesh Singla<sup>1</sup> Kumar Satish Ravi<sup>1</sup> Prabhat Goel<sup>2</sup> Raj Kumar<sup>3</sup>

<sup>1</sup>Department of Anatomy, All India Institute of Medical Sciences (AIIMS) Rishikesh, Uttarakhand, India

<sup>2</sup>Department of Anatomy, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

<sup>3</sup>All India Institute of Medical Sciences (AIIMS) Rishikesh, Uttarakhand, India

Address for correspondence Mohd Salahuddin Ansari, MD, Department of Anatomy, All India Institute of Medical Sciences (AIIMS) Rishikesh, Veerbhadra Marg, 249201, Uttarakhand, India (e-mail: msalahuddin.ansari12@gmail.com).

Indian J Neurosurg 2015;4:92–97.

## Abstract

The morphometry of atlas is very important for surgeries in the occipitocervical region. There are studies explicitly differing in the results concerning some key anatomic measurements, mandating an additional evaluation of anatomic landmarks of atlas. Therefore, this study was aimed to evaluate the various dimensions of the atlas quantitatively relevant for various surgeries. A total of 30 adult atlas vertebrae of Indian origin were studied. The distances were measured by digital vernier calliper. The transverse diameter and maximum anteroposterior dimension of vertebral canal of atlas had a mean of  $27.31 \pm 2.74$  and  $29.44 \pm 2.54$  mm, respectively. The vertebral artery groove thickness on atlas is  $3.79 \pm 1.08$  mm on right and  $4.05 \pm 0.86$  mm on left, respectively. The mean distance from sagittal midline to the innermost edge of the vertebral artery groove is  $10.73 \pm 2.92$  mm on right side and  $9.72 \pm 2.56$  mm on left side. Overall, 74% of superior articular facets were found to be oval in shape and 26% in kidney shape. On the basis of these findings, we concluded that the thickness of the vertebral artery groove is satisfactory for surgical fixation techniques and the dissection on the posterior arch of atlas can be extended to 12 mm from the midline through the posterior approach.

## Keywords

- ▶ atlas
- ▶ vertebral artery groove
- ▶ posterior screw placement
- ▶ lateral mass
- ▶ superior articular facet

## Introduction

Atlas and axis are having unique anatomical features as compared with the rest of the cervical vertebrae. A large number of different surgical techniques such as interlaminar clamp, interspinous wiring, plates, and screw fixation have been currently employed to correct the instability of the atlantoaxial complex or occipitocervical junction caused by numerous traumatic and nontraumatic conditions. Recently, transarticular and transpedicular screws fixation have been widely used in stabilizing the cervical column.<sup>1–6</sup> In spite of

the benefits conferred by transpedicular screw fixation in the cervical column, controversy exists regarding its potential risks. Incorrect insertion of pedicle screws can cause damage to adjacent vital structures such as the spinal cord, nerve roots, cranial nerves, and vertebral arteries. Fusion of occipitocervical or atlantoaxial spine is an accepted treatment option in upper cervical instability caused by trauma or various disorders.<sup>7–12</sup> Clinically, iatrogenic injury to the vertebral artery during an approach to the atlantoaxial region is rare, but it has a potential hazard.<sup>13</sup> Posterior screw placement techniques to the atlas lateral

received  
September 10, 2014  
accepted  
May 25, 2015  
published online  
July 28, 2015

DOI <http://dx.doi.org/10.1055/s-0035-1558967>.  
ISSN 2277-954X.

© 2015 Neurological Surgeons' Society of India

License terms



mass have been recently introduced to avoid the inevitable loss of occipitocervical motion in occipitocervical fusion and to enable posterior C1-C2 fusion in patients who are not suitable for transarticular screw fixation due to anatomic variations, as for instance, of the vertebral artery.<sup>8,9,12,14</sup> To further improve posterior C1-C2 fusion techniques, some recent publications evaluated the application of screws to C1 via the posterior arch.<sup>15-18</sup> Two of these studies focused on a morphometric characterization of the atlas to minimize intraoperative malposition of the so-called C1 pedicle screws.<sup>16,18</sup> However, these studies explicitly differ in the results concerning some key anatomic measurements, necessitating an additional evaluation of anatomic landmarks and safe zone for the screw placement through the posterior arch of C1. Therefore, this study was aimed to evaluate the various dimensions of the atlas quantitatively and analyze their relationship with the vertebral artery foramen, in addition to determining the safe sites for different surgical approaches.

## Materials and Methods

This study was performed on 30 adult atlas vertebrae of Indian origin, from the department of Anatomy. All samples were examined to ensure that the vertebrae were intact and free from any other bony abnormalities

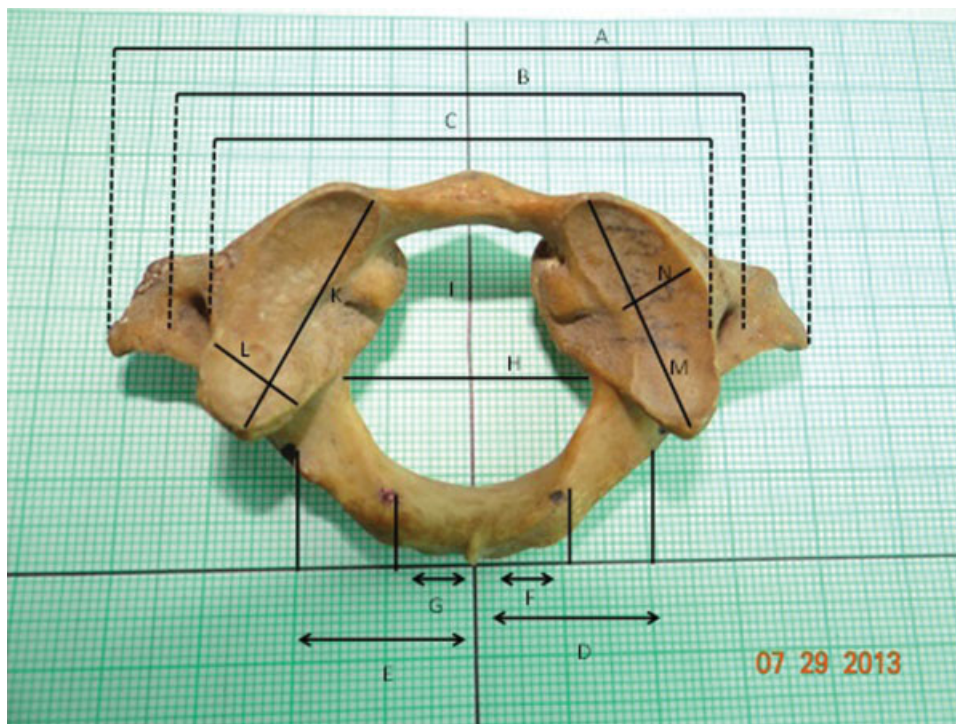
before measurements were made. All distances were measured by digital vernier caliper, accurate to 0.1 mm for linear measurements. In this study, we have taken the following measurements. All the atlases studied belong to adult cases which were measured with digital vernier caliper, accurate to 0.1 mm for linear measurements. The different anatomical parameters measured have been shown in **►Figs. 1 and 2.** (**►Table 1**)

## Observations and Results

The observations and results have been recorded in **►Table 2.**

## Discussion

As surgical techniques and instrumentation for the treatment of unstable cervical spine as a result of traumatic, congenital, or neoplastic disorders continue to evolve, more knowledge about bones and surrounding anatomy is required.<sup>19</sup> The relationship between the vertebral arteries, atlas, and axis vertebrae have a determining role in planning an operative approach. Various techniques such as interlaminar clamp and hook plating, lateral screw and plate fixation, and interspinous wiring have been described for treating cervical instability.<sup>19</sup>



**Fig. 1** (Showing the measured distances A–N) (A) Distance between both tips of transverse process; (B) distance between both lateral most edge of transverse foramen, Tf–Tf; (C) distance between medial edge of transverse foramen, Tf–Tf; (D) distance from midline to medial most edge of vertebral artery groove outer cortex (right); (E) distance from midline to medial most edge of vertebral artery groove outer cortex (left); (F) distance from midline to medial most edge of vertebral artery groove on inner cortex (right); (G) distance from midline to medial most edge of vertebral artery groove on inner cortex (left); (H) Max transverse diameter of vertebral canal; (I) AP dimension of vertebral canal, maximum; (K) superior articular facet length (left); (L) superior articular facet breadth (left); (M) superior articular facet length (right); and (N) superior articular facet width (right).



**Fig. 2** (Showing the measured distances W, X, U, and V). (U) Foramen transversarium anterior posterior diameter (right); (V) foramen transversarium transverse diameter (right); (W) foramen transversarium anterior posterior diameter (left); and (X) foramen transversarium transverse diameter (left).

Transpedicular screw fixation is one of the most sophisticated procedures currently in use to treat atlas and axis instabilities. Current posterior fixation techniques at the upper cervical spine might include C1 lateral mass screws as well as stabilization techniques through the posterior arch of C1. Regarding the biomechanical characteristics of C1-C2 instrumentation techniques, recent investigation proved that C1 lateral mass screws in conjunction with C2 pedicle screws achieved a similar stability compared with Magrel C1-C2 transarticular screw fixation technique.<sup>12,20</sup> Use of transpedicular screws has been reported for treating spinal trauma, extensive laminectomies, and destruction of bony elements by neoplasm. Although pedicle screw has been found to provide superior fixation with the least likelihood of hardware loosening in comparison with other surgical techniques, controversy exists regarding its potential risks.<sup>21</sup> The rate of recognized vertebral artery injury was identified as 2% in the report by Gupta and Goel,<sup>3</sup> 4.1% in the study by Wright and Laurysen,<sup>22</sup> and 8% in the study by Madawi et al.<sup>5</sup> However, the actual incidence of vertebral artery injury may be higher than those reported because of the low survey response and the possibility of unrecognized vertebral artery injury. The actual risk of neurological deficit was only 0.2% per patient because the contralateral uninjured vertebral artery circulation was adequate and no ischemia was observed.<sup>6</sup> Gupta and Goel<sup>3</sup> reported that they encountered bleeding probably through a vertebral artery laceration in 2 of 106 cases in which plate and screw technique was applied, and bleeding was stopped after the tightening of screw in these cases.

Unicortical and bicortical lateral mass screws are inserted into the atlas directly underneath the base of the superior arch. Even though the bicortical C1 lateral mass screws have a higher pull out strength than unicortical lateral mass screws, one has to consider the potential risk of an injury of the hypoglossal nerve or the internal carotid artery from bicortical screws.<sup>23,24</sup> Screws inserted through the posterior arch of C1 into the lateral mass have a longer trajectory compared with lateral mass screws. Because of this, the so-called pedicle screws inserted through the posterior arch of C1 has a superior biomechanical stability than lateral mass screws.<sup>17</sup> In addition to the larger pull out strength screws placed through the posterior arch into C1, a main argument for preferring this instrumentation technique is to avoid an excessive venous bleeding from the venous plexus around the C2 root during the classical subarcuate procedure in the placement of lateral mass screws.

According to our study, the mean distance between both transverse processes of atlas was  $71.98 \pm 4.6$  mm with a range from 64.28 to 81.10 mm. The mean distance between the outermost edges of the transverse foramina was  $58.18 \pm 4.26$  mm with a range from 51.80 to 65.87 mm; the mean distance between the innermost edges of the transverse foramina was 45.38 mm with a range from 39.78 to 50.95 mm. Lang<sup>25</sup> reported that the mean distance between the transverse processes was 78.2 mm; the mean distance between the outermost edges of the transverse foramina was 64 mm; and the mean distance between the innermost edges of the transverse foramina was 52.3 mm. The transverse foramen through which the vertebral artery

**Table 1** Showing different anatomical parameters measured

Sr. No	Description of parameter
A	Distance between both tips of transverse process
B	Distance between both lateral most edge of transverse foramen, Tf-Tf
C	Distance between medial edge of transverse foramen, Tf-Tf
D	Distance from midline to medial most edge of vertebral artery groove outer cortex (right)
E	Distance from midline to medial most edge of vertebral artery groove outer cortex (Left)
F	Distance from midline to medial most edge of vertebral artery groove on inner cortex (right)
G	Distance from midline to medial most edge of vertebral artery groove on inner cortex (left)
H	Max transverse diameter of vertebral canal
I	AP dimension of vertebral canal, maximum
J	AP dimension of vertebral canal, minimum
K	superior articular facet length, left
L	superior articular facet breadth, left
M	superior articular facet length, right
N	superior articular facet width, right
O	Inferior articular facet length, left
P	Inferior articular facet breadth, left
Q	Inferior articular facet length, right
R	Inferior articular facet breadth, right
S	Thickness of vertebral artery groove, right
T	Thickness of vertebral artery groove, left
U	Foramen transversarium anterior posterior diameter, right
V	Foramen transversarium transverse diameter, right
W	Foramen transversarium anterior posterior diameter, left
X	Foramen transversarium transverse diameter, left

passes lies lateral to the transverse process of C1. Immediately behind the superior articular facet is a transverse groove for the vertebral artery. The articular process usually overhangs this groove anteriorly. There is often a bony bridge over the course of vertebral artery.<sup>25</sup> Ebraheim et al<sup>13</sup> suggested that dissection of soft tissue attachments on the posterior arch of C1 was limited to 8 to 12 mm. Anatomically, the bony groove on the superior surface of the posterior arch of C1 represents the exact location of the vertebral artery. Damage to the vertebral artery can be avoided, if exposure of the posterior arch of C1 remains medial to the groove.<sup>13</sup> In our study, we found the thickness of the vertebral artery groove on C1 to be  $03.79 \pm 1.08$  mm with a range of 01.70 to 07.58 on right side and  $04.05 \pm 00.86$  mm with a range of 02.70 to 06.92 mm on left side. This thickness is satisfactory for applying some fixation techniques such as clamp and hook plating, and anatomical wiring. It implies the role of adequate study of microanatomy by fine computed tomographic cuts to choose the size of the screw or plan the type of fixation which needs to be chosen from case to case. Thickness of the vertebral artery groove on the atlas was found by Ebraheim et al to be 3 to 5 mm.<sup>13</sup> Sengul and

Kadioglu<sup>19</sup> revealed that the range from the sagittal midline to the inner most edge of the vertebral artery was 11 mm for left side with a minimum of 9 mm for both the sides and suggested that the dissection on the posterior arch of the C1 should be limited to 10 mm to prevent injury to the vertebral artery during dissection through the posterior approach. According to our study, the range from the sagittal midline to the innermost edge of the vertebral artery groove is found to be from 07.8 to 20.00 mm with a mean of  $10.73 \pm 2.92$  mm on the right side and from 06.00 to 17.8 mm with a mean of  $09.72 \pm 2.56$  mm on the left side. From our study, we can say that dissection on the posterior arch of C1 can be extended to 12 mm from the midline through the posterior approach.

The shape of the superior facet of the atlas was generally ovoid. Miller and Ramage et al<sup>4</sup> stated that a kidney-shaped facet of C1 was not frequent and they were not symmetric as mirror images on both sides. Gupta and Goel<sup>3</sup> found kidney-shaped superior facets in 24% of facets and they were not mirror symmetric. Sengul and Kadioglu<sup>19</sup> found 72% of superior facets to be of oval-shaped; only 28% were kidney-shaped and none of the facets were exactly similar to each other, in their study. In our study, 74% are oval in shape and



**Table 2** Showing the result of measured parameters

Sr. No	Description of parameter	Mean (mm) $\pm$ SD	Range (mm)
A	Distance between both tips of transverse process	71.98 $\pm$ 4.6	64.28–81.1
B	Distance between both lateral most edge of transverse foramen, Tf–Tf	58.18 $\pm$ 4.26	51.80–65.87
C	Distance between medial edge of transverse foramen, Tf–Tf	45.38 $\pm$ 3.25	39.78–50.95
D	Distance from midline to medial most edge of vertebral artery groove outer cortex (right)	24.85 $\pm$ 2.78	20.20–32.8
E	Distance from midline to medial most edge of vertebral artery groove outer cortex (left)	24.39 $\pm$ 2.06	20.9–29.00
F	Distance from midline to medial most edge of vertebral artery groove on inner cortex (right)	10.73 $\pm$ 2.92	07.8–20.00
G	Distance from midline to medial most edge of vertebral artery groove on inner cortex (left)	09.72 $\pm$ 2.56	06.00–17.80
H	Max transverse diameter of vertebral canal	27.31 $\pm$ 2.74	22.70–34.46
I	AP dimension of vertebral canal, maximum	29.44 $\pm$ 2.54	23.11–35.32
J	AP dimension of vertebral canal, Minimum	28.58 $\pm$ 2.27	24.60–33.73
K	superior articular facet length (left)	21.84 $\pm$ 2.11	16.68–25.49
L	superior articular facet breadth (left)	12.19 $\pm$ 1.58	09.55–15.51
M	superior articular facet length (right)	22.13 $\pm$ 2.26	16.99–25.80
N	superior articular facet width (right)	11.82 $\pm$ 1.79	09.52–18.11
O	Inferior articular facet length (left)	16.67 $\pm$ 1.84	12.62–20.36
P	Inferior articular facet breadth (left)	16.39 $\pm$ 1.93	13.14–20.06
Q	Inferior articular facet length (right)	16.24 $\pm$ 1.44	13.67–21.16
R	Inferior articular facet breadth (right)	15.84 $\pm$ 1.83	12.69–19.95
S	Thickness of vertebral artery groove (right)	03.79 $\pm$ 1.08	01.70–07.58
T	Thickness of vertebral artery groove (left)	04.05 $\pm$ 0.86	02.70–06.92
U	Foramen transversarium anterior posterior diameter (right)	07.40 $\pm$ 1.13	05.49–09.45
V	Foramen transversarium transverse diameter (right)	05.91 $\pm$ 1.03	04.29–08.60
W	Foramen transversarium anterior posterior diameter (left)	06.97 $\pm$ 0.98	05.00–08.99
X	Foramen transversarium transverse diameter (left)	05.53 $\pm$ 0.72	04.13–07.02

26% are kidney-shaped. These also are not mirror symmetric. This is in accordance with the previous study. Doherty and Heggeness<sup>26</sup> studied the vertebral canal and the arches of 88 dried human C1 vertebrae. They found that the canal diameter ranged from 32 mm in transverse trajectory, and 29 mm in AP trajectory. In the study by Lang,<sup>25</sup> these dimensions were 30.2 and 34.5 mm, respectively. In the study presented here, the transverse diameter of vertebral canal of C1 had a mean of 27.31  $\pm$  2.74 mm with a range of 22.70 to 34.46 mm; and the maximum AP dimension of the vertebral canal had a mean of 29.44  $\pm$  2.54 mm with a range of 23.11 to 35.32 mm.

## Conclusion

We found that the transverse diameter of vertebral canal of C1 had a mean of 27.31  $\pm$  2.74 mm with a range of 22.70 to

34.46 mm; and the maximum AP dimension of the vertebral canal had a mean of 29.44  $\pm$  2.54 mm with a range of 23.11 to 35.32 mm. The thickness of the vertebral artery groove on C1 is 03.79  $\pm$  1.08 mm with a range of 01.70 to 07.58 mm on the right side and 04.05  $\pm$  0.86 mm with a range of 02.70 to 06.92 mm on the left side. The range from sagittal midline to the innermost edge of the vertebral artery groove is found to be 07.8 to 20.00 mm with a mean of 10.73  $\pm$  2.92 mm on the right side and 06.00 to 17.8 mm with a mean of 09.72  $\pm$  2.56 mm on the left side. Overall, 74% of superior articular facets are oval in shape and 26% in kidney shape. None of them are exactly similar to each other. On the basis of these findings, we concluded that this thickness is satisfactory for applying some fixation techniques such as clamp and hook plating, and anatomical wiring and the dissection on the posterior arch of C1 can be extended to 12 mm from the midline through the posterior approach.

## References

- 1 Apfelbaum RI. Anterior screw fixation of odontoid fractures. In: Rengachary SS and Wilkins RH, eds. *Neurosurgical Operative Atlas*. Vol 4. Illinois, IL: AANS; 1995:19–28
- 2 Dickman CA, Hurlbert RJ. Cannulated screws for odontoid and atlantoaxial transarticular screw fixation. In: Rengachary SS and Wilkins RH, eds. *Neurosurgical Operative Atlas*. Vol 7. Illinois, IL: AANS; 1998:29–41
- 3 Gupta S, Goel A. Quantitative anatomy of the lateral masses of the atlas and axis vertebrae. *Neurol India* 2000;48(2):120–125
- 4 Miller RJ, Ramage JD. Absence of symmetry in superior articular facets on the first cervical vertebra in humans: implications for diagnosis and treatment. *J Manipulative Physiol Ther* 1994;17(9):624–626
- 5 Madawi AA, Casey AT, Solanki GA, Tuite G, Veres R, Crockard HA. Radiological and anatomical evaluation of the atlantoaxial transarticular screw fixation technique. *J Neurosurg* 1997;86(6):961–968
- 6 Mandel IM, Kambach BJ, Petersilge CA, Johnstone B, Yoo JU. Morphologic considerations of C2 isthmus dimensions for the placement of transarticular screws. *Spine* 2000;25(12):1542–1547
- 7 Goel A, Desai KI, Muzumdar DP. Atlantoaxial fixation using plate and screw method: a report of 160 treated patients. *Neurosurgery* 2002;51(6):1351–1356, discussion 1356–1357
- 8 Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. *Spine* 2001;26(22):2467–2471
- 9 Levine AM, Edwards CC. Fractures of the atlas. *J Bone Joint Surg Am* 1991;73(5):680–691
- 10 Oda I, Abumi K, Sell LC, Haggerty CJ, Cunningham BW, McAfee PC. Biomechanical evaluation of five different occipito-atlanto-axial fixation techniques. *Spine* 1999;24(22):2377–2382
- 11 Resnick DK, Lapsiwala S, Trost GR. Anatomic suitability of the C1-C2 complex for pedicle screw fixation. *Spine* 2002;27(14):1494–1498
- 12 Richter M, Schmidt R, Claes L, Puhl W, Wilke HJ. Posterior atlantoaxial fixation: biomechanical in vitro comparison of six different techniques. *Spine* 2002;27(16):1724–1732
- 13 Ebraheim NA, Xu R, Ahmad M, Heck B. The quantitative anatomy of the vertebral artery groove of the atlas and its relation to the posterior atlantoaxial approach. *Spine* 1998;23(3):320–323
- 14 Hong X, Dong Y, Yunbing C, Qingshui Y, Shizheng Z, Jingfa L. Posterior screw placement on the lateral mass of atlas: an anatomic study. *Spine* 2004;29(5):500–503
- 15 Li L, Wang H, Cui S. Application of atlas pedicle screw system fixation and fusion for treatment of upper cervical disease [in Chinese]. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi* 2007;21(5):461–464
- 16 Ma XY, Yin QS, Wu ZH, Xia H, Liu JF, Zhong SZ. Anatomic considerations for the pedicle screw placement in the first cervical vertebra. *Spine* 2005;30(13):1519–1523
- 17 Ma XY, Yin QS, Wu ZH, et al. C1 pedicle screws versus C1 lateral mass screws: comparisons of pullout strengths and biomechanical stabilities. *Spine* 2009;34(4):371–377
- 18 Tan M, Wang H, Wang Y, et al. Morphometric evaluation of screw fixation in atlas via posterior arch and lateral mass. *Spine* 2003;28(9):888–895
- 19 Sengul G, Kadioglu HH. Morphometric anatomy of the Atlas and Axis vertebrae. *Turk Neurosurg* 2006;16(2):69–76
- 20 Melcher RP, Puttlitz CM, Kleinstueck FS, Lotz JC, Harms J, Bradford DS. Biomechanical testing of posterior atlantoaxial fixation techniques. *Spine* 2002;27(22):2435–2440
- 21 Panjabi MM, Shin EK, Chen NC, Wang JL. Internal morphology of human cervical pedicles. *Spine* 2000;25(10):1197–1205
- 22 Wright NM, Laurusen C; American Association of Neurological Surgeons/Congress of Neurological Surgeons. Vertebral artery injury in C1-2 transarticular screw fixation: results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves. *J Neurosurg* 1998;88(4):634–640
- 23 Currier BL, Maus TP, Eck JC, Larson DR, Yaszemski MJ. Relationship of the internal carotid artery to the anterior aspect of the C1 vertebra: implications for C1-C2 transarticular and C1 lateral mass fixation. *Spine* 2008;33(6):635–639
- 24 Eck JC, Walker MP, Currier BL, Chen Q, Yaszemski MJ, An KN. Biomechanical comparison of unicortical versus bicortical C1 lateral mass screw fixation. *J Spinal Disord Tech* 2007;20(7):505–508
- 25 Lang J, ed. *Skull Base and Related Structures*. Stuttgart: Schattauer; 1995:292
- 26 Doherty BJ, Heggeness MH. The quantitative anatomy of the atlas. *Spine* 1994;19(22):2497–2500