Computerized Tomographic Measurements of Morphometric Parameters of the C2 for the Feasibility of Laminar Screw Fixation in Korean Population

Young-June Kim, M.D., Woo Tack Rhee, M.D., Sang-Bok Lee, M.D., Seung-Hoon You, M.D., Sang-Youl Lee, M.D.
Department of Neurosurgery Gangneung Asan Hospital, College of Medicine, University of Ulsan, Gangneung, Korea

INTRODUCTION

Eighteen to twenty-three percent of C2 pars/pedicle is not safe to accept 3.5-mm diametered screw because of high-riding vertebral artery. In such cases, crossing laminar screw fixation can provide excellent mechanical strength comparable to transarticular or pedicle/pars screw fixation with minimal risk of vertebral artery injury. In addition, the placement of a laminar screw is relatively straightforward because anatomic structures of interest are exposed without fluoroscopic guidance. For this reason, the approach became popular among spine surgeons in Korea. However, the new technique is not always suitable for the patients as well as pars/pedicle screw fixation. According to a cadaveric study in a western country, at least one side of axial laminae would not be able to accommodate a 3.5-mm diametered screw with a 1 mm margin of bone around it at the thinnest portion in 37% of the specimens. The C2 laminar size of Asian may differ from non-Asian's. Therefore, it is important to know the C2 profile in Korean population for surgeon to plan a surgical approach.

MATERIALS AND METHODS

Patient selection and 3-D reconstruction of the cervical computed tomographies

All scans were obtained for the purpose of diagnosing...
the presence or absence of cervical spine disease at a clinic or emergency room of our hospital from January to April, 2008. We reviewed all the medical records and radiologists’ documents. CT scans of patients with systemic pathology known to effect bone morphology including rheumatoid disease, chronic renal failure, infection, trauma, and tumor were excluded. Finally, 102 patients aged from 20 to 81 were included in current study.

3-D cervical CT reconstruction was performed on a CT unit equipped with a 16-detector array (LightSpeed ultra-16, GE healthcare, TN, U.S.A) using the software (Advantage window 4.2, GE healthcare, TN, U.S.A).

**Measurements of morphometric parameters**

Linear measurements were taken using an electronic caliper accurate to 0.1 mm, and angular measurements were taken using a goniometer accurate to 0.1 degree.

The CT unit has been evaluated for the accuracy every third month by Korean institute for accreditation of medical image (Seoul, Korea).

To compare with results from western people, measurements followed previously reported methodology and included the laminar thickness, slope angle, spino-laminar angle and maximal screw length.$^{14,17}$.

Laminar thickness measurement was made at the thinnest portion of the lamina bilaterally on axial view (Fig. 1A). The slope angle of the screw starting point was determined on dorsal view (Fig. 1B). The measurement of spino-laminar angle was made on axial view bilaterally (Fig. 1C). Spino-laminar angle implies the lateral angulation of the screw trajectory. Maximal screw length was determined from the screw entry point to the foramen transversarium on axial view (Fig. 1D). Two observers measured individually for the whole panel of 102 3-D CT images, and the average values were adopted. Analysis was performed for the application of a 3.5-mm diametered screw.

**Statistical analysis**

Statistical analysis of parametric data was performed using Student’s $t$ test with $p$ value $< 0.05$ considered significant.

**RESULTS**

One-hundred-and-two CT reconstructions of sixty male and forty-two female patients were investigated in the study. Measurement values including the means and standard deviations are shown in Table 1. The age ranged from 20 to 81 and the mean was 48.4. There was no statistically significant age-related difference between male and female patients ($p = 0.565$).

The mean laminar thickness was 5.7 mm. Seventy-nine of 204 lamina (38.7%) could not accommodate a 3.5-mm diametered screw, assuming the need for a 1 mm margin on each side in ventro-dorsal dimension. The numbers of patients with bilateral laminae thicker than 5.5 mm were 35 of male patient (58.3%) and 16 of female patient (38.1%).
patients (38.1%). Fourteen of male patients (23.3%) and 9 of female patients (21.4%) had only one side lamina thicker than 5.5 mm. 11 of male patients (18.3%) and 17 of female patients (40.5%) could not be a candidate for 3.5-mm diametered laminar screw fixation bilaterally.

The laminar surface had an average slope of 32.9 degrees off the sagittal plane. The spino-laminar angle implying lateral angulation of the screw trajectory averaged 43.2 degrees (43.6 in males and 42.7 in females). The mean maximal screw length was 33.3 mm (34.3 mm in male and 31.9 mm in female) with wide range from 22.7 mm to 41.1 mm. None of the patients had maximal screw length shorter than 22 mm. The maximal screw length was significantly different between male and female patients ($p < 0.01$).

**DISCUSSION**

The major limitation of the transarticular screw technique that has been widely adopted for the atlantoaxial fixation is the potential risk of vertebral artery injury estimated up to 2.6-4.1%$^{14,16}$. The crossing laminar screw fixation can avoid the catastrophic complication$^{19}$. The technique is possible because the C2 has greatest laminar dimension to accept 3.5-mm diametered screws in the cervical spine$^{14,17}$. Then, atlantoaxial complex has unique anatomy and the axis has significant variations in the laminar profile$^{14,17}$. In addition to anatomical variations, Asians have smaller profiles in morphometric parameters of the C2$^{18}$. However, the clinical applicability of laminar screw fixation technique in Korean adult population is not known. The purpose of the study was to provide a set of quantitative data on anatomical parameters of the C2 in Korean population.

In our measurements, only the maximal screw length of four parameters showed statistically significant gender-related differences with $p$ value $< 0.05$. Regarding the laminar thickness, the most important parameter, male patients had greater thickness, however, the $p$ value (0.067) did not clearly demonstrate a statistically significant difference between males and females. Then, it is not likely that the difference is clinically important because the difference is not sufficient to state that male patients are safe for the laminar screw fixation. There were 25 male patients (35%) with at least one of the laminae unsuitable for 3.5-mm diametered screw. This emphasizes the necessity of individual analysis using the 3-D CT reconstruction before placing screws.

In addition, our investigation demonstrated that at least one side of the laminae would not be able to accommodate a 3.5-mm diametered screw with 1 mm bony tolerance at the thinnest portion of the lamina in 50% of the patients. The result was higher than 37% in western population$^{19}$. To our knowledge, there is only one Asian study from Japan recently published study results on the feasibility for the laminar screw fixation$^{16}$. According to the study, insertion of screws with diameter of 4 mm was possible in 50% of the males and only 24% of the females. Nakanishi and colleagues$^{19}$ performed the study with a different method and evaluated only one side of laminae. We once analyzed our data for the unilateral application of a 4-mm diametered screw although the direct comparison with their study was not proper. Sixty-two percent of males and 38% of females could accommodate 4 mm screw in at least one side of the laminae.

On the other hand, at least one side of the laminae would not be able to accommodate 4 mm screws in 47% of western patients included in Wang’s$^{19}$ investigation. Our data showed 72% of Korean patients had at least one side of the laminae unsuitable for 4-mm diametered screw. The comparisons have limitations of different methods and different sizes of study. Nevertheless, the results suggest that Korean patients should be carefully assessed for the C2 laminar screw fixation because of the narrow laminar profile.

The laminar slope of Korean population was bigger than that of western people. Assuming it would be ideal if the slope is orthogonal to the screw trajectory, careful drilling of entry site to reduce the slope angle is more required to Korean population. It is because less steepness of the screw starting point would result in inferiorly directed screw as placement of a screw is orthogonal to the entry surface on the bone. It is also ideal, if the laminar screw is placed in the thickest mid-level, equidistant from the superior and inferior margins, to achieve intraosseous placement$^{17}$. Modification of the screw trajectory or identification of screw tip placed intraosseously through a cortical window would be required in some occasions$^{13}$.

Finally, there was no patient with maximal screw length shorter than 22 mm. Therefore, insertion of the screw at the junction of the contralateral spino-laminar junction will permit placement of at least 22 mm screw in virtually all patients without entering the foramen transversarium.

**CONCLUSION**

Koreans have smaller profiles for the axis than western people. Half of patients had too thin lamina to accommodate 3.5-mm diametered screw, at least unilaterally on the axis. Careful preoperative assessment using the 3-D CT recon-
struction is mandatory for the safe purchase of the laminar screw in Korean population.

References