Morphological character of cervical spine for anterior transpedicular screw fixation

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Abstract

Background: Anterior cervical interbody grafts/cages combined with a plate were frequently used in multilevel discectomies/corpectomies. In order to avoid additional posterior stabilization in patients who undergo anterior reconstructive surgery, an anterior cervical transpedicular screw fixation, which offers higher stability is desirable. We investigated in this study the anatomical (morphologic) characters for cervical anterior transpedicular screw fixation.

Materials and Methods: Left pedicle parameters were measured on computed tomography (CT) images based on 36 cervical spine CT scans from healthy subjects. The parameters included outer pedicle width (Distance from lateral to medial pedicle surface in the coronal plane), outer pedicle height (OPH) (Distance from upper to lower pedicle surface in the sagittal plane), maximal pedicle axis length (MPAL), distance transverse insertion point (DIP), distance of the insertion point to the upper end plate (DIUP), pedicle sagittal transverse angle (PSTA) and pedicle transverse angle (PTA) at C3 to C7.

Results: The values of outer pedicle width and MPAL in males were larger than in females from C3 to C7. The OPH in males was larger than in females at C3 to C6, but there was no difference at C7. The DIP and PTA were significantly greater in males than in females at C3, but there was no difference in the angle at C4-7. The PSTA was not statistically different between genders at C3, 4, 7, but this value in males was larger than females at C5, 6. The DIUP was significantly greater in males at C3, 4, 6, 7 but was non significant at C5.

Conclusions: The placement of cervical anterior transpedicular screws should be individualized for each patient and based on a detailed preoperative planning.

Key words: Cervical anterior pedicle screw, corpectomy, pedicle parameter

Introduction

Anterior procedures are increasingly recognized as advantageous for multilevel cervical decompression in a compromised anterior spinal cord, having the ability for anterior release, durable reconstruction of physiological alignment and instrumented fusion through a less complicated approach compared to the posterior approach surgery.[1-3] With anterior procedures, decompression of the neurologic structures can be accomplished by means of segmental disectomy or corpectomy. However, in many cases, multilevel anterior disectomy or corpectomy and reconstruction is required. In such cases, the biomechanical stability of the anterior screw and plate system is limited.The fusion and complication rates at the anterior cervical spine have been shown to have a direct correlation with the mechanical stability of fixation. There are numerous reports of failure of instrumentation, especially in the weakened osteoporotic, neoplastic or infectious spine.[4,5] In such cases, a supplemental posterior stabilization is often required.[6,7] Such surgeries are known to have more complications.[8] To avoid the additional posterior surgery in such cases, without compromising the biomechanical stability of the cervical anterior screw-plate constructs, some authors introduced the concept of anterior transpedicular screw fixation and fusion.[9,10] Yukawa *et al.*[11] first reported the clinical results of anterior transpedicular screw fixation. Successful placement of anterior transpedicular screws in the cervical spine requires accurate identification of the screw axis depending on a sufficient three-dimensional understanding of the anatomical morphology of the pedicle. As a result of the anatomical features of the cervical pedicle and its

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intimately close relationship to critical neural and vascular structures, navigation of this structure poses serious risks and is not widely used.

Unfortunately little data exists on the anatomical morphologic character for cervical anterior transpedicular screw fixation. The aim of the present study, was to investigate anatomical morphologic trends with respect to linear and angular parameters associated with anterior transpedicular screw fixation in the cervical spine.

Materials and Methods

Thirty six healthy subjects were studied. Morphological parameters for cervical anterior transpedicular screw fixation were measured using a helical computed tomography (CT) scan and reconstruction at the Radiology Imaging Department of our University Hospital. Informed consent was taken from all subjects and the Institute Ethics Committee approved the study protocol. There were 18 males and 18 females, ranging in age from 22 years to 75 years (43.80 ± 8.02). Subjects with evidence of infectious, neoplastic, traumatic or congenital spine anomalies and significant degenerative changes were excluded from the study. Cervical CT scans were performed with a General Electric Light Speed Helical CT Scanner (Siemens©, Germany). Axial CT images were obtained using 1.0 mm thickness slice cuts. Sagittal, oblique sagittal and coronal bony window reconstruction images of the cervical pedicles from C3 to C7 were obtained using 0.75 mm thickness slices. The following left pedicle parameters were determined as diagrammatically shown in Figure 1, using the measuring tools of the Centricity Web Imaging software.

Pedicle transverse angle

Angle formed between transverse pedicle axis and mid-sagittal line.

Pedicle sagittal transverse angle

Angle formed between plane of anterior vertebral body wall at mid-sagittal line and pedicle axis, distance between the distance of the insertion point to the upper end plate (DIUP) in the sagittal plane.

Distance transverse insertion point

Distance between the transverse intersection point and mid-sagittal line at the anterior vertebral body wall. (outer pedicle width [OPW], a distance medial border of transverse foramen to the medial border of pedicle).

Outer pedicle height

Distance upper to lower pedicle surface in the sagittal plane, maximal pedicle axis length (MPAL), distance from the posterior cortex of the lateral mass to the anterior wall of the vertebral body along the pedicle axis. Linear parameters were measured in millimeters 1/10 mm. Angular parameters were measured to the 1/10th of a degree. The measurements were performed independently by three radiologists.

Statistical analysis

Descriptive statistics including mean values, standard deviations and ranges were used to summarize data. The Independent *t* test was performed to analyze the difference of the parameters for cervical anterior transpedicular screws fixation between females and males $P < 0.05$ was considered statistically significant. All analyses were done with SPSS 13.0 software.

Results

Thirty six cervical spines comprising 180 vertebrae from C3 to C7 were evaluated. The mean and standard deviations of linear and angular parameters were calculated at each level. There were 36 OPW (25 in females and 11 in males), less

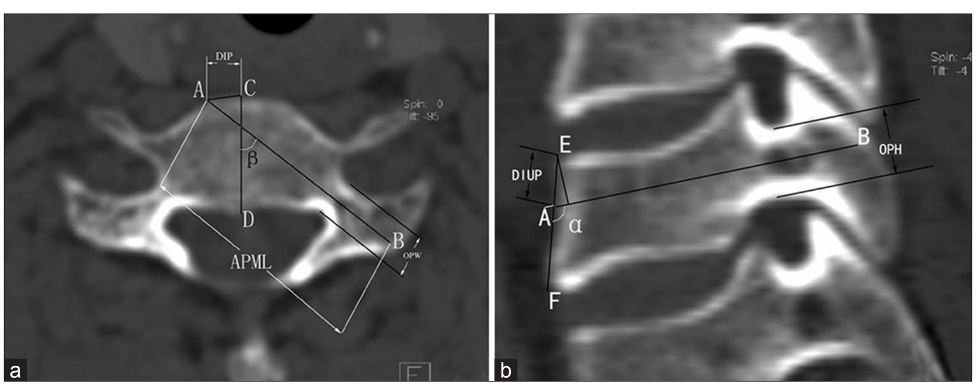

Figure 1: The measurement of anatomical morphologic parameters for cervical anterior transpedicular screw fixation. (a) Maximal pedicle axial length (the distance between A and B point), pedicle transverse angle (β, Angle formed between pedicle axis and mid-sagittal line, distance transverse insertion point (the distance between point A and C) and outer pedicle width (distance medial border of transverse foramen and medial border of pedicle). (b) Out pedicle height (distance upper to lower pedicle surface in the sagittal plane), distance of the insertion point to the upper end plate (distance between point A and E) and pedicle sagittal transverse angle (α, angle formed between plane of anterior vertebral body wall at mid-sagittal line and pedicle axis)

than 4.0 mm and only four OPH in females less than 4.0 mm. Only four DIUP less than 2.0 mm were observed in females.

Outer pedicle height

The overall average OPH ranged from 5.8 ± 0.9 mm to 7.3 ± 1.4 mm in C3-7. The largest OPH was found at C7 in both males (7.6 ± 1.7 mm) and females (7.1 ± 1.6 mm). The smallest average of OPH was found at C5 in females and males (5.4 ± 0.7 mm and 6.3 ± 0.9 mm). The average OPH was significantly greater in males than in females at C3-6, but there was no difference at C7 [Figure 2a].

Outer pedicle width

The overall average OPW ranged from 4.3 ± 1.0 to 6.0 ± 1.3 mm in C3-7. The maximal value of OPW was 8.7 mm at C7. The smallest mean PW was found at C3 in both males (4.7 ± 1.2 mm) and females (3.9 ± 0.5 mm); the largest mean OPW was at C7 in both males (5.8 ± 1.5 mm) and females (5.5 ± 0.5 mm). The average of OPW was significantly greater in males than in females at all levels [Figure 2b].

Distance of the insertion point to the upper end plate

The overall mean DIUP in C3-7 ranged from 4.0 ± 0.8 to 4.4 ± 1.2 mm. The maximal mean value of DIUP was found at C7 and C3 in females (4.6 ± 0.8 mm) and males (4.8 ± 1.4 mm). The minimal mean value was observed at C6 and C4 in females (3.9 ± 0.8 mm) and males (3.8 ± 1.0 mm). The average of DIUP was significantly greater in males than in females in C3, 4, 6,

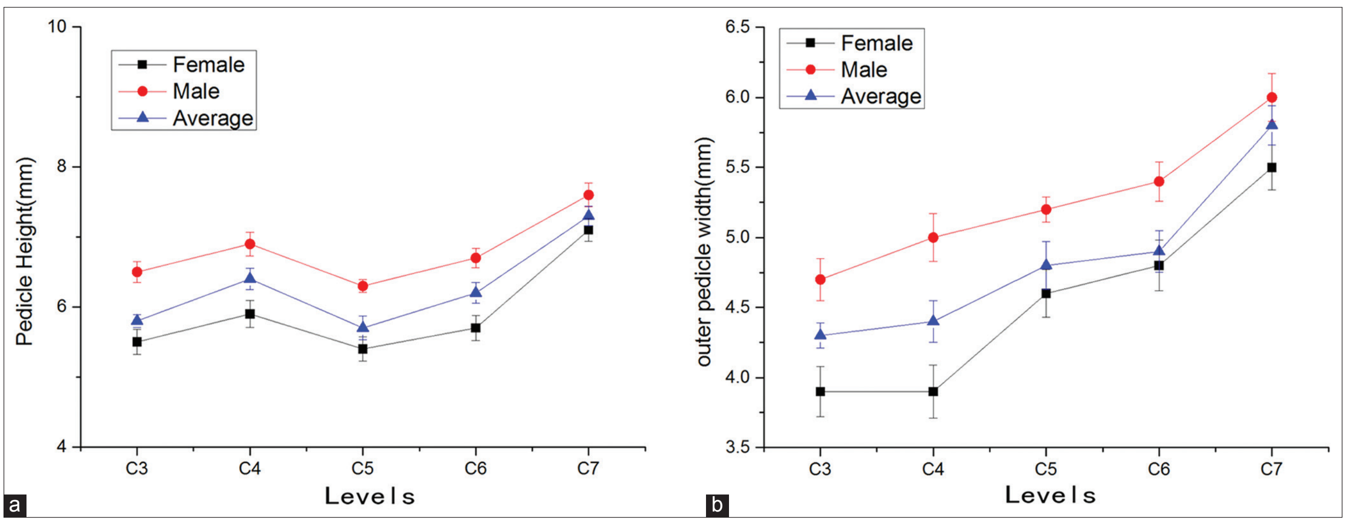

Figure 2: (a) Average of out pedicle height was greater significantly in males than in females at C3-6 (P<0.05), but there was no difference at C7 (P>0.05); (b) The average of outer pedicle width was greater significantly in males than in females at all levels P<0.05

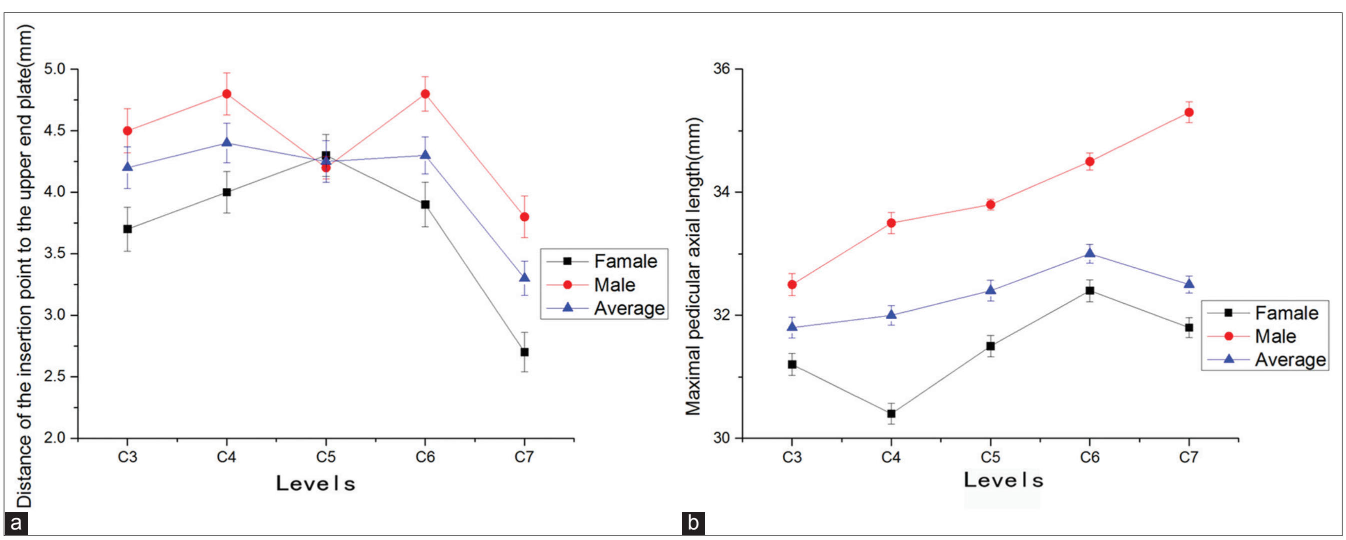

Figure 3: (a) Average of distance of the insertion point to the upper end plate was significantly greater in males than in females in C3, 4, 6, 7 levels, but it was no significant difference between females and males at C5. (b) The average of maximal pedicle axis length was greater in males than in females at all levels, and this difference were statistically significant at all levels (P < 0.05)

7 levels, but there was no significant difference between females and males at C5 [Figure 3a].

Mpal

The overall average MPAL ranged from 31.8 ± 2.0 mm to 33.3 ± 2.4 mm. The maximum mean MPAL in females and males was found at C6 (3 2.4 ± 1.8 mm) and C7 (34.7 ± 2.5 mm). The minimum mean value of MPAL was found at C4 in females (30.7 ± 1.4 mm) and C3 in males (32.5 ± 2.4 mm). The average MPAL was greater in males than in females at all levels and the difference was statistically significant at all levels ($P < 0.05$) [Figure 3b].

Distance transverse insertion point

The overall mean DIP in C3-7 ranged from 3.1 ± 0.8 mm to 4.5 ± 1.1 mm. The largest mean value of DIP was found at C5 in females (4.3 ± 1.3 mm) and C4 in males (4.9 ± 1.1 mm). The smallest value was at C 7 in both females (2.8 ± 1.9 mm) and males (2.8 ± 1.9 mm). The average of DIP was greater in males than in females at C3 ($P < 0.05$), but there was no statistically significant difference between females and males at C4-7 levels [Figure 4a].

Pedicle transverse angle

The overall mean PTA ranged from 44.4 ± 3.1° to 47.1 ± 4.1°. The smallest mean PTA was found at C6 in both males (44.9 ± 3.8°) and females (43.9 ± 4.8°). The largest mean PTA was observed at C3 in males (47.6 ± 2.1°) and at C5 in females (47.8 ± 4.0°).

The average PTA was significantly greater in males than in females at C3, but there was no statistical difference between females and males at C4-7 levels [Figure 4b].

Psta

The overall mean PSTA ranged from 99.2 ± 6.7° to 105.4 ± 6.0°. The smallest mean PSTA was found at C7 in both males (99.1 ± 5.8°) and females (99.3 ± 7.6°). The maximal mean value of PSTA was recorded at C6 in males (109.1 ± 5.4°) and at C4 in females (104.8 ± 6.2°). The mean value of PSTA showed no statistically significant differences at C3-4 and C7 level between genders, and was significantly greater in males than females at C5-6 [Figure 5].

Discussion

Transpedicular screw fixation provides greater strength to pull-out than does lateral mass screw fixation[12] or screw fixation into the vertebral body.[13] However, due to the close proximity of the spinal cord, nerve roots and vertebral arteries, transpedicular cervical screw fixation has been considered inherently more risky than cervical vertebral body fixation and is supposed to be technically more demanding.[14] Transpedicular fixation of the cervical spine is not widely performed because of its complex morphological structures. There are numerous reports of screw penetrating the pedicle due to the variation of cervical pedicle morphology.[15,16] It is, therefore very important to sufficiently understand the three dimensional pedicle morphology for pedicle screw fixation. Recently, several studies have been aimed at describing the anatomical morphologic characteristics of the cervical pedicle for posterior transpedicular screw fixation. Koller *et al.*[17] had reported that the morphologic character for cervical anterior transpedicular screw fixation was not different between left and right sides. We had previously investigated the morphologic characters and clinical results

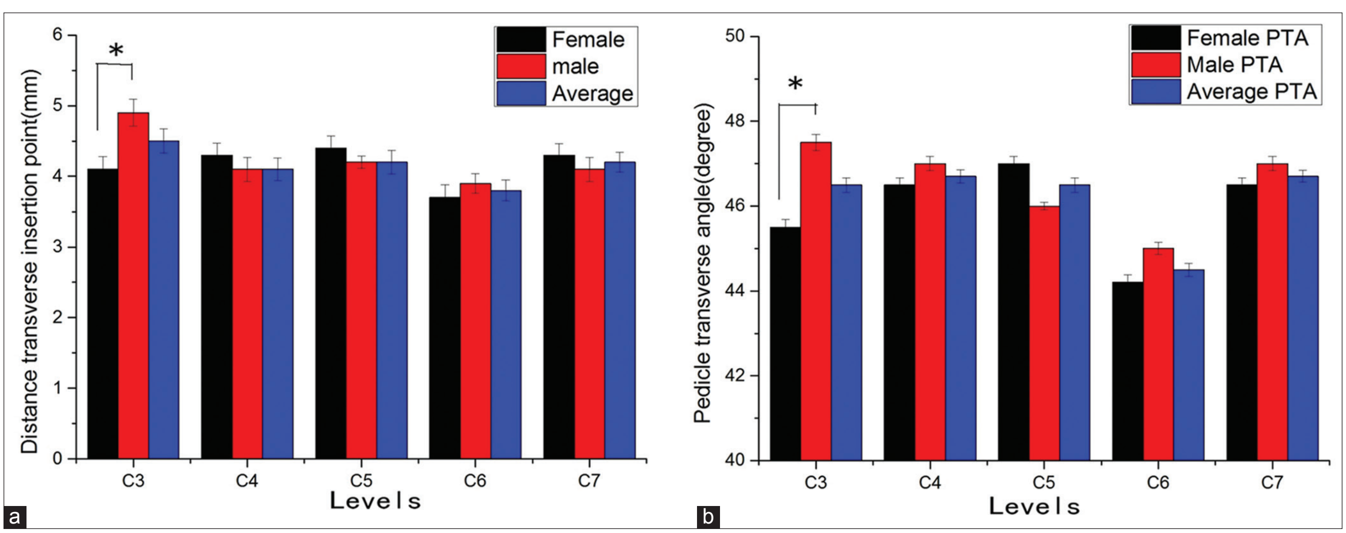

Figure 4: (a) Average of distance transverse insertion point was greater in males than in females at C3 (*P*<0.05), but there was no significant difference between females and males at C4-7 levels (*P*>0.05); (b) The average of pedicle transverse angle was significantly greater in males than in females at C3, but there were no statistically difference between females and males at C4-7 levels

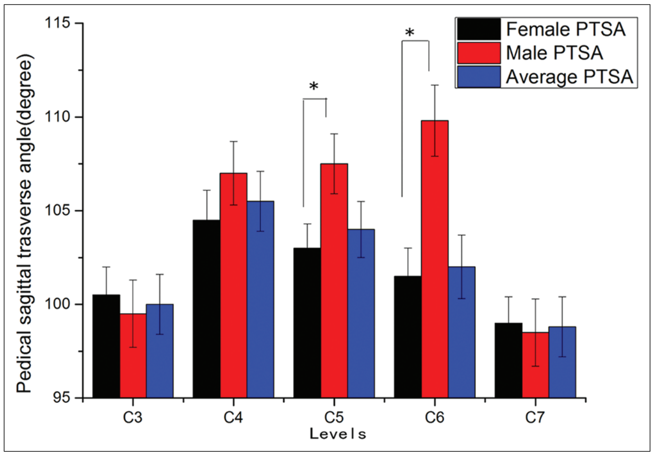

Figure 5: The mean value of pedicle sagittal transverse angle was no statistically significant differences at C3-4 and C7 level between gender and there was significant greater in males than n females at C5-6

for cervical anterior transpedicular screw fixation at C2.[18-20] Most right handed surgeons believed that the right side incision is more convenient and pedicle screws can only be implanted in the left pedicle. To measure the pedicle morphologic parameters, the helical CT scan is more accurate than artificial measure (means manual measure *in vitro*). *In vivo* measurements of the cervical pedicle using CT images are believed to provide more accurate linear and angular pedicular dimensions than similar measurements obtained manually in cadavers. In the present study, we used helical CT scan and reconstruction imaging to evaluate the *in vivo* cervical pedicle parameters. The measurements have been performed independently by three radiologists and the averages were analyzed.

In this study, the orientation of pedicles was described as PTA and PSTA and the insertion point was identified by the DIP and DIUP. The overall mean DIP and DIUP ranged from 3.1 ± 0.8 mm to 4.5 ± 1.1 mm and 4.0 ± 0.8 to 4.4 ± 1.2 mm, respectively. The overall mean PTA and PSTA ranged from 40.6 ± 3.1° to 47.1 ± 4.1° and 99.2 ± 6.7° to 105.4 ± 5.0° in this study.

As cervical posterior pedicle screw fixation, the OPW and OPH for anterior transpedicular fixation need to be larger than 4 mm to accept the smallest screw available today which has a diameter of 3.5 mm. In the present study, 180 cervical pedicles from 36 patients were measured. The overall average OPW and OPH were ranged from 4.3 ± 1.0 mm to 6.0 ± 1.3 mm and 5.8 ± 0.9 mm to 7.3 ± 1.4 mm in C3-7. There were 36 OPW (25 in females and 11 in males) was less than 4.0 mm, and only four OPH in females were less than 4.0 mm. Our results indicate that most pedicles are amenable to screw fixation. Furthermore, we found that the average of OPH and OPW were greater in males than in females at all levels ($P < 0.05$). The data suggests that when compared with the male population, a smaller percentage of female cervical pedicles will be able to accommodate the smallest cervical pedicle screw available today.

The DIUP was important for cervical anterior transpedicular screw fixation. DIUP should be sufficiently larger to accept the pedicle screws available today. However, there was no data of DIUP in present literature for the placement of anterior transpedicular screws in the cervical spine. We a hypothesized that the DIUP>2.0 mm is feasibile for placement of anterior transpedicular screws in the cervical spine. In our study, DIUP ranged from 4.0 ± 0.8 mm to 4.4 ± 1.2 mm, and only four DIUP were less than 2.0 mm (observed in females). Our data suggested that it was possible in most patients to do a cervical anterior transpedicular fixation.

In our study, the MPAL was larger than those reported in others studies, which investigated MPAL for cervical posterior transpedicular fixation.[4] The MPAL was lower in females than that in males at all levels and the difference was statistically significant ($P < 0.05$). The results were similar to those of Koller *et al.*[17] Our data indicated that the anterior transpedicular screw fixation in the cervical spine, results in more strength and can provide longer pathway than in cervical posterior transpedicular fixation. Thus longer pedicle screws can be used in males than in females for anterior transpedicular screw fixation in the cervical spine.

To conclude the results suggest that the placement of cervical anterior transpedicular screws should be individualized for each patient. The preoperative Helical CT scans and reconstructions for patients who would undergo cervical anterior transpedicular fixation should be thoroughly analyzed with attention to the pedicle size and its angulation.

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