Safety of thoracic pedicle screw application using the funnel technique in Asians: a cadaveric evaluation

Chris Yin Wei Chan · Mun Keong Kwan ·
Lim Beng Saw

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Abstract The objective of this cadaveric study is to determine the safety and outcome of thoracic pedicle screw placement in Asians using the funnel technique. Pedicle screws have superior biomechanical as well as clinical data when compared to other methods of instrumentation. However, misplacement in the thoracic spine can result in major neurological implications. There is great variability of the thoracic pedicle morphometry between the Western and the Asian population. The feasibility of thoracic pedicle screw insertion in Asians has not been fully elucidated yet. A pre-insertion radiograph was performed and surgeons were blinded to the morphometry of the thoracic pedicles. 240 pedicle screws were inserted in ten Asian cadavers from T1 to T12 using the funnel technique. 5.0 mm screws were used from T1 to T6 while 6.0 mm screws were used from T7 to T12. Perforations were detected by direct visualization via a wide laminectomy. The narrowest pedicles are found between T3 and T6. T5 pedicle width is smallest measuring 4.1 ± 1.3 mm. There were 24 (10.0%) Grade 1 perforations and only 1 (0.4%) Grade 2 perforation. Grade 2 or worse perforation is considered significant perforation which would threaten the neural structures. There were twice as many lateral and inferior perforations compared to medial perforations. 48.0% of the perforations occurred at T1, T2 and

T3 pedicles. Pedicle fracture occurred in 10.4% of pedicles. Intra-operatively, the absence of funnel was found in 24.5% of pedicles. In conclusion, thoracic pedicle screws using 5.0 mm at T1–T6 and 6.0 mm at T7–T12 can be inserted safely in Asian cadavers using the funnel technique despite having smaller thoracic pedicle morphometry.

Keywords Thoracic pedicle screws · Funnel technique · Asian cadavers

Introduction

Pedicle screws have superior biomechanical as well as clinical data when compared to other methods of instrumentation [1, 9, 11, 13]. Despite earlier concerns regarding the safety of thoracic pedicle screws insertion, introduction of newer techniques has lowered pedicle perforation rates [2, 15]. However, there is great variability when comparing the morphometric parameters of the thoracic pedicle in the Western population to those in the Asian population as proven in previous anatomical studies [12, 17, 18, 20, 25]. Therefore, the feasibility of thoracic pedicle screw insertion in Asians has not been fully elucidated yet. The aim of this cadaveric study is to evaluate the safety of thoracic pedicle screw placement in the Asian population utilizing the funnel technique.

Materials and methods

This is a cadaveric study involving ten fresh Asian cadavers. This study was carried out from December 2006 to September 2007. Approval by the medical ethics

C. Y. W. Chan (✉) · M. K. Kwan · L. B. Saw
Department of Orthopaedic Surgery,
Faculty of Medicine, University of Malaya,
Lembah Pantai, 50603 Kuala Lumpur, Malaysia
e-mail: chrnat01@yahoo.com

M. K. Kwan
e-mail: munkeong42@hotmail.com

L. B. Saw
e-mail: saw_lb@yahoo.com

committee of our institution was obtained. The cadavers were inspected after dissection and no spinal abnormalities were detected clinically. This was later confirmed by the pre-insertion radiograph which was reviewed by an independent surgeon and noted to be free from any abnormality.

A pre-insertion radiograph was taken with an enlargement reference scale to control for magnification error (Fig. 1). The enlargement reference scale is a radio opaque marker with a known diameter placed at the same depth as the posterior laminae at the time the pre-insertion radiograph was taken. The surgeons were blinded to the pre-insertion radiograph. The radiologic parameters which were measured included the pedicle width (PW) and the pedicle height (PH). PW and PH were then measured using a computer software program (DICOM works) at the outer diameter of the pedicles with the cadaver in a supine position.

Fig. 1 Pre-insertion radiograph with the presence of an enlargement reference scale

Pedicle screws were inserted using the funnel technique as first described in 2000 by Gaines [8]. A standard posterior approach to the thoracic spine was used. The posterior spinal musculature was elevated from the spine exposing the thoracic spine subperiosteally from the spinous processes to the transverse processes. The posterior projection of the pedicle entry point was estimated based on anatomical landmarks. For T1–T10, the entry point was located superior to the intersection between the midpoint of the base of the transverse process and the lateral border of the facet joint. For T11 and T12, the entry point was over the base of the transverse process. A 10 mm circle of cortical bone overlying the pedicle entry point was removed. Cancellous bone was removed with a curette to outline the boundaries of the funnel and to identify the isthmus of the pedicle (Fig. 2).

Once the funnel was visualized, the direction of the pedicle was probed, enlarged and the length of the screw was determined. The pedicle was then examined for perforation prior to insertion of the screw using a pedicle sound. After this, 5.0 mm multi-axial pedicle screws were inserted from T1 to T6 while 6.0 mm screws were inserted from T7 to T12. The thread depth was 0.85 mm and the core diameter was 3.3 mm for 5.0 mm screws. For the 6.0 mm screws, the thread depth was 1.15 mm and the core diameter was 3.7 mm. All pedicle screws were inserted by the authors who were experienced in insertion of thoracic pedicle screws. A wide laminectomy was then performed and the pedicle was inspected for medial, superior and inferior perforations as well as pedicle fracture (Fig. 3). The vertebrae were then skeletonized to examine for any lateral perforations. The outcome measures were pedicle perforation and/or pedicle fracture. Pedicle fracture was distinguished from pedicle perforation by identifying violation of the cortical wall by the screw threads in the event of pedicle perforation.

The following grading of screw perforation was used [16]:

Table 1 Demographic and anthropometric data for the ten cadavers

Cadaver no.	Age	Gender	Weight (kg)	Height (cm)
1	67	Male	74	170
2	34	Male	67	176
3	36	Male	51	164
4	50	Male	55	168
5	30	Male	50	155
6	29	Male	108	184
7	26	Female	46	152
8	27	Male	56	173
9	50	Female	43	160
10	30	Female	60	170

Fig. 2 Insertion of screw using the funnel technique: **a** the funnel after removal of cancellous bone, **b** removing the cancellous bone using the curette, **c** the funnel, **d** probing the isthmus of the pedicle through the funnel

Fig. 3 Direct visualization of medial, superior and inferior wall of the pedicle with illustration of a medial breach of the pedicle wall

Fig. 4 Average values for pedicle width from T1 to T12 in the cadavers

Fig. 5 Average values for pedicle height from T1 to T12 in the cadavers

- (a) Grade 0: no perforation;
- (b) Grade 1: only thread of screw outside pedicle;
- (c) Grade 2: core of screw outside pedicle;
- (d) Grade 3: screw completely outside pedicle.

Significant perforation was defined as Grade 2 or 3 perforation.

Results

Two hundred and forty thoracic pedicle screws were inserted in ten cadavers. The demographic and anthropometric data for the ten cadavers are shown in Table 1.

The trend of the average measurement of the PW and PH in our cadaveric specimens is shown in Figs. 4 and 5, respectively.

The narrowest average diameter of the thoracic pedicle occurred between T3 and T6. The narrowest pedicle was at T5 with a mean measurement of 4.1 ± 1.3 mm. Also, 62.5% of pedicles had PW values less than 5.0 mm from T1 to T6 whereas up to 64.2% of pedicles had width 6.0 mm or less when measured on the radiograph at T7–T12. Further, there was a consistent increase in the pedicle height measurements from T1 to T12.

There were 25 pedicle perforations (10.4%). However, out of these 25 perforations, there were 24 Grade 1 perforations and 1 Grade 2 perforation. Grade 1 perforation was considered once the grittiness of the screw thread was felt during examination of the pedicles. There were no Grade 3 perforations in all 240 screws inserted. This gave a significant perforation rate of 0.4% or 1 in 240 thoracic pedicle screws inserted. The Grade 2 perforation occurred at T6 and the screw perforated medially; however, the

Fig. 6 Significant medial perforation at T6 showing the presence of the core of the screw beyond the pedicle margin. However, there was no dural or nerve injury

Fig. 7 Frequency of pedicle perforation at various levels

dural sac was not breached in that case (Fig. 6). Lateral perforation occurred in 13 screws followed by 6 medial perforations and 6 inferior perforations. 48% of the perforations occurred at T1, T2 and T3. No perforations occurred at T11 and T12 levels (Fig. 7).

The pedicle fracture rate was 10.4%. In all 25 pedicle fractures, the fracture pattern consisted of vertical slits along the axis of the pedicle which opened up as the screws were tightened and closed back once the screws were removed. The cortical wall was not violated by the screw threads.

Intra-operatively, we also found that the funnel could not be found in 24.5% of thoracic pedicles. In such cases, the entrance into the pedicle was covered by a bony roof.

When this occurred, the pedicle screws were inserted after breaking the bony covering. The direction of the pedicle is guided by the conical shape of the funnel wall.

Discussion

Pedicle screw fixation has the advantage of purchase of all three spinal columns without encroaching into the spinal canal. This theoretical advantage has been translated to superior clinical results in fracture fixation as well as in deformity correction [6, 7, 10, 14, 24]. However, earlier studies demonstrated high perforation rates leading to questions regarding the safety of its use in the thoracic spine [4, 21].

The safety margin for this technique has been improved through the use of image-guided techniques [2, 15]. Nevertheless, these newer techniques require additional equipment as well as the use of fluoroscopy which increases the radiation exposure. We have chosen the funnel technique as it allows direct visualization of the entrance into the pedicle as well as its direction without the problems mentioned earlier. Two papers have been published evaluating the safety of this technique [22, 23]. In cadavers, the perforation rate of this technique has been reported to be 6% with a critical perforation rate of 0.4% [23]. This technique was then evaluated in the clinical setting and no major complications were noted [22]. However, both of these studies were carried out in the Western population.

Significant differences exist between the morphometric values of the thoracic pedicle in the Western and the Asian population [12, 17, 18, 20, 25]. This has been clearly shown in previous published anatomical studies. Asian thoracic pedicles were quoted to be on average 30% smaller than the pedicles in the Western community [18]. The effect of smaller pedicles on the safety profile of thoracic pedicle screw insertion has not been investigated in the cadaveric model.

The morphometric profile of the thoracic pedicles in our study is comparable to figures quoted in other Asian anatomical studies [5, 19]. We do not routinely perform computed tomography of thoracic pedicles prior to insertion of the pedicle screws. Therefore, plain radiographs were used to determine the dimensions of the pedicles.

The Grade 1 perforation rate in our study is higher compared to a similar study which was carried out in Caucasian cadavers [23]. This could be attributed to different morphometric characteristics of the thoracic pedicle which exist between the two study populations as well as the use of relatively larger screws. However, the rate of significant perforation is the same, which is a 0.4% or 1 in

240 screws. Even when significant perforation has occurred in one pedicle, the respective dural sac was not injured and the spinal cord was spared. This indicates that thoracic pedicle screws using 5.0 mm diameter screws for T1–T6 and 6.0 mm diameter screws for T7–T12 can be inserted safely using the funnel technique in Asians. With the use of smaller diameter screws, the perforation rate might even reduce further. The other reason why we have chosen a larger diameter screw for this study is to assess the feasibility of the Asian thoracic pedicle for percutaneous thoracic screw placement which will require the use of a larger diameter screw, due to its cannulated system. Although the funnel technique is not utilized in percutaneous insertion methods, the results of our study have suggested the feasibility of percutaneous technique in Asians.

Another finding which might be clinically important is the occurrence of pedicle fractures during pedicle screw insertion. More than 60% of the pedicles were smaller than the size of the screws inserted and the rate of pedicle fracture was only 10.4%. This illustrates the capability of the thoracic pedicle to expand during screw insertion. Although pedicle expansion can occur, exceeding the limit will lead to fracture of the pedicles [3]. This has resulted in a significant rate of pedicle fracture in this study. As the pedicle is the strongest point of purchase, fracture of the pedicle might lead to significant reduction in the stability of the construct.

The sample size in our study is not big enough to account for differences which occurs with anthropometric and demographics variation in the population. Postmortem changes in the cadavers may also have an influence on the outcome of this study.

Conclusion

In conclusion, thoracic pedicle screws using 5.0 mm diameter screws at T1–T6 and 6.0 mm diameter screws at T7–T12 can be inserted safely in Asian cadavers using the funnel technique, despite having smaller thoracic pedicle morphometry.

Conflict of interest statement None.

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