Anatomic consideration of pedicle screw placement in the thoracic spine, comparison between Roy - Camille technique and Funnel technique

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Abstract

Purpose : To assess the conventional Roy – Camille technique and to determine whether pedicle screw placement aided by Funnel technique could decrease the incidence of pedicle violations or lessen the time taken for the procedure.

Materials & Methods : Ten cadaveric thoracic spines from T_1 to T_{12} were used for pedicle screw placements. Two techniques of insertion were used. The Roy–Camille technique (used in 120 screws placements on randomized selected either left or right side for each case) and the Funnel technique (used in same amount of pedicles and on the other side of spine for screw placements). After each screw placement, the time taken from the procedure was recorded and all specimen were evaluated visually to determine violations of the pedicles.

Result : The screw placements with the Roy–Camille technique had a higher percentage of pedicle violation (47%) than the Funnel technique (25%). But the average time taken for the pedicular screw placements with Funnel technique was significantly longer than the Roy–Camille technique. (241.9 vs.137.4 sec)

Conclusion : The Roy–Camille technique was confirmed to associate with a high incidence of pedicle violation, whereas screw placement with Funnel technique significantly reduced the incidence. Anyway, the later technique took significantly longer time for each screw placement. Pedicular screw fixation in thoracic spine remain a technical challenge and harmful so should not be used routinely. Screw placement with the Funnel technique is recommended if pedicle screw fixation is strongly indicated in the thoracic spine.

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บทคัดย่อ **การวิเคราะห์เปรียบเทียบผลของการใส่สกรูผ่าน pedicle ของกระดูกสันหลัง thoracic ระหว่างวิธีของ Roy-Camille และวิธี Funnel**

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วัตถุประสงค์ : เพื่อวัดความเที่ยงตรงของการใส่สกรูผ่าน pedicle ของกระดูกสันหลัง thoracic โดยวิธีดั้งเดิมของ Roy–Camille และประเมินผลว่าการใช้วิธี Funnel สามารถลดอัตราการทะลุของสกรูได้หรือไม่ พร้อมทั้งเปรียบเทียบเวลาที่ใช้ในการใส่สกรูทั้ง 2 วิธี

วัสดุและวิธีการ : ผู้ศึกษาได้ทำการใส่สกรูผ่าน pedicle ของกระดูกสันหลัง thoracic ที่ระดับ T 1 –12 ในศพสดจำนวน 10 ราย โดยใช้วิธีของ Roy –Camille และวิธี Funnel เท่าๆ กัน ทั้งข้างซ้ายและข้างขวา แล้วทำการจับเวลาของการใส่สกรูทุกครั้ง พร้อมทั้งตรวจสอบการทะลุของสกรูที่ใส่ทุกตัว

ผลการวิจัย : วิธีการใส่สกรูแบบ Roy–Camille มีอัตราการทะลุ (47%) ซึ่งสูงกว่าวิธี Funnel (25%) อย่างมีนัยสำคัญทางสถิติ แต่พบว่าระยะเวลาที่ใช้ในการใส่สั้นกว่า (137 วินาที และ 242 วินาที ตามลำดับ)

สรุป: การใส่สกรูผ่าน pedicle ของกระดูกสันหลัง thoracic โดยวิธีของ Roy–Camille มีอุบัติการณ์การทะลุของสกรูสูงมาก ในขณะที่วิธี Funnel สามารถลดอุบัติการณ์ดังกล่าวได้เป็นอย่างดี ถึงแม้ว่าจะต้องใช้เวลาในการใส่นานกว่า อย่างไรก็ตาม การใส่สกรูในบริเวณดังกล่าวต้องใช้ทักษะอย่างสูง และเมื่อสกรูทะลุออกนอก pedicle อาจก่อให้เกิดอันตรายต่อเส้นประสาทและไขสันหลังใกล้เคียงซึ่งเป็นภาวะแทรกซ้อนที่รุนแรง ดังนั้น การรักษาผู้ป่วยที่มีโรคกระดูกสันหลังบริเวณ thoracic ซึ่งจำเป็นต้องใช้ pedicle screw ในการรักษา การเลือกใช้วิธี Funnel จะให้ความปลอดภัยมากกว่า

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Introduction

Pedicle screws have revolutionized the surgical treatment for many spinal disorders.[3] The fixation has become widely used for stabilizations of unstable lumbar or lumbosacral spine. However, It has been used infrequently in thoracic spines because of their unique anatomy and the potentially devastating injury to adjacent neural structure[6,7,8]. Anyway, there are some articles in the literature about its applications such as : Roy–Camille[2] who used it to repair thoracic fractures or Suk[28] who used it in the treatment of thoracic idiopathic scoliosis.

There are many screw placement techniques suggested which can be divided into 3 groups include :

1. Screw placement based on posterior bony landmark merely (eg. Roy–Camille technique)[2,4,5,6],

2. Screw placement aided by partial laminectomy to directly visualize some part of outer pedicle walls. (eg. Open lamina technique)[6]

3. Screw placement by first remove inner

cancellous core to feel and visualize inner cortical wall of pedicle before screw placement (Funnel technique) which was cited by Gaines[3] to be safer and less technically difficult. However, there was no article evaluate about their comparative accuracy. Therefore, we designed this study to assess the Roy–Camille technique and determine whether Funnel technique could decrease the incidence of pedicle violations and compared the location, degree of pedicle penetration and the time taken between these 2 techniques

Materials and methods

Ten fresh cadavers (seven male, three female) with an age range of twenty seven to sixty one years (mean age thirty nine years) were included. With the cadaver prone, we made a posterior midline incision from C_7 to L_1 and all soft tissue were striped off the posterior bony surface from spinous process to transverse process. Two techniques of transpedicular screw placement were used equally: the Roy–Camille technique and the Funnel technique (alternately randomized side) for pedicle screw placements from T_1 – T_{12}. All the procedures were performed by one surgeon (C.U.) who was unexperienced in thoracic pedicle screw placement, using the 5 mm diameter screw of Isolar spinal system, Acromed company, USA.

The Roy–Camille technique used bony landmark for screw entry point which was the intersection between midline of facet joint and transverse process (figure 1). The screw direction was perpendicular to posterior plane of vertebrae. Finally, screw with proper length were placed into thoracic pedicles after drilling with 3.5 mm bit and tapping

The Funnel technique's detail (figure 2) was first removed 1 cm diameter section of cortical bone on top of the pedicle posteriorly to visualize

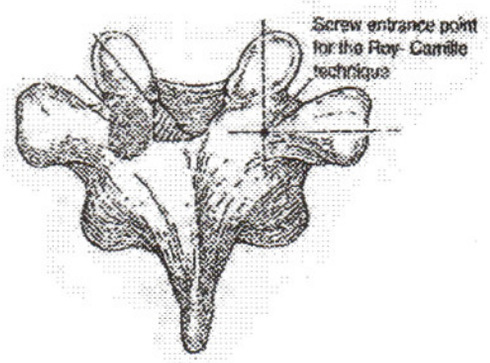


Figure 1. Illustration showing entry point for screw insertion in the Roy–Camille technique.

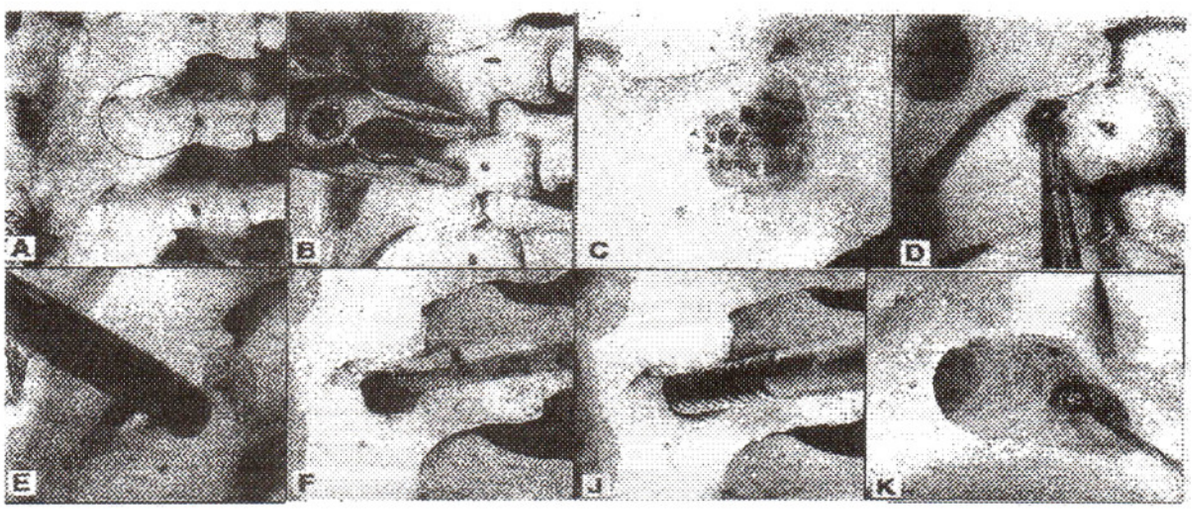


Figure 2. Photographs illustrating the Funnel technique.

the cancellous core within it, then using curette to remove the cancellous bone inside until the inner cortical wall of the pedicle could be felt and visualized and go deeper toward the isthmus. (in funnel like fashion). Then we used the 2 mm diameter probe to pass through the isthmus into the vertebral body and subsequently enlarged the path with 5 mm diameter probe. Finally thread were cut with the same size tap.

For outcome measurement in determining pedicle violation. We performed total laminectomy, facetectomy and adjacent soft tissue were removed to visualize all aspects of pedicle wall and it nearby neural structure directly. We classified pedicle's wall violation by degree of screw penetration that divided into 3 grades (figure 3) included:

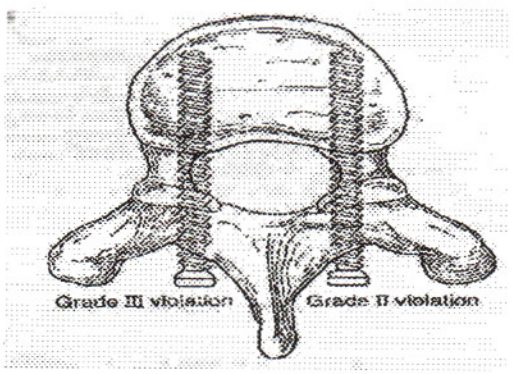


Figure 3. Illustration showing the Grade II (right) and Grade III (left) screw violations of the pedicle.

Grade I : minimum penetration of pedicle wall seen

Grade II : screw penetration of the pedicle wall with less than half of its diameter

Grade III: screw penetration more than half of its diameter

Finally, we recorded the time taken for each screw placement to compare between 2 techniques.

Result

Total of 240 screw placements were performed throughout T_1–T_{12} level of the ten cadavers. The Roy–Camille technique had a statistical significant higher percentage of pedicle violation (46.7%) than did that with the Funnel technique (25%). (paired, two tail student t–test, $p<0.05$). The total perforation rate was 35.8%.

In detail, the location of violations are shown on table 1. The largest percentage of violation site for Roy–Camille technique was in the lateral wall (19.2%) followed by the medial wall (15.8%). Unlike in Funnel technique, we found the medial wall were penetrated most frequently (12.5%) followed by the lateral wall (10.8%), but we could see that the least common violated wall was similarly superior wall for both technique (3.3% vs 0%).

For overall resultsb of location of pedicle violation (graph 1). The most common site of penetration was lateral wall (41.8% of total violation), followed by medial wall (39.5%), inferior wall (13.9%) and least common site was superior wall (4.7%).

While consider for severity of pedicle wall violations (shown on table 2), we found that grade III violations was accounted as the largest percentage for both techniques, which were 25.8% for Roy–Camille and 14.2% for Funnel technique. While focus on overall result of degree of violation, we found grade III violation was accounted for 55.8% of total violation, followed by grade II violation (32.6%) and grade I (11.6%) (graph 2.)

Finally, We found that the Funnel technique took longer time than Roy–Camille technique (mean 241.9 sec vs 137.4 sec) that was statistically significant (paired student t–test, $p<0.05$)

Table 1. Direction of pedicle wall violations : No (%)

direction / technique	Superior wall	Inferior wall	medial wall	lateral wall	total
Roy Camille (n=120)	4 (3.3%)	10 (8.3%)	19 (15.8%)	23 (19.2%)	56 (46.7%)
Funnel (n=120)	0 (0%)	2 (1.6%)	15 (12.5%)	13 (10.8%)	30 (25%)
Total (n=240)	4 (1.6%)	12 (5%)	34 (14.2%)	36 (15%)	86 (35.8%)

Graph 1. Overall results of location of pedicle violations (2. Techniques)

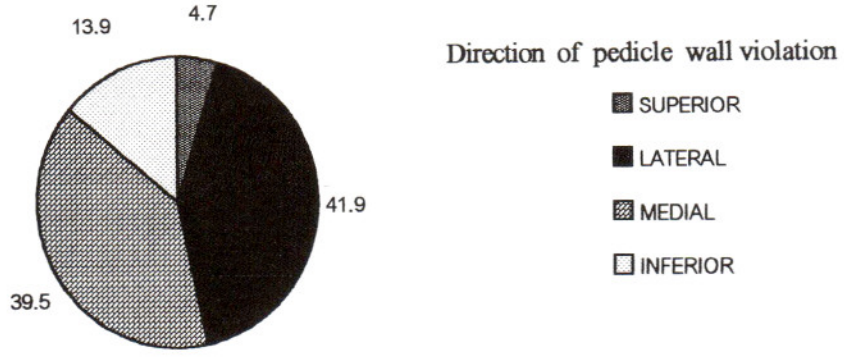
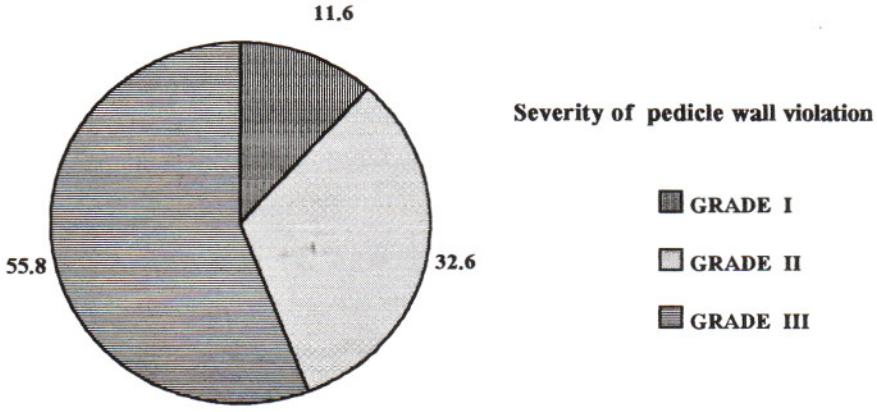


Table 2. Severity of pedicle wall violations : No (%)

severity / technique	grade I violation	grade II violation	grade III violation	total
Roy Camille (n=120)	6 (5%)	19 (15.8%)	31 (25.8%)	56 (46.7%)
Funnel (n=120)	4 (3.3%)	9 (7.5%)	17 (14.2%)	30 (25%)
Total (n=240)	10 (4.1%)	28 (11.7%)	48 (20%)	86 (35.8%)

Graph 2. Overall results of degree of pedicle violations (2. Techniques)



of violation of the lateral (19.2%) and medial wall (15.8%) than those placed with Funnel technique. Anatomically, the pedicle anteromedial inclination in the transverse plane varies from cephalad to caudal. In general, this angle decrease gradually from T_1 to T_{12} [6,9,12,15]. In the lower thoracic levels, screw placement with a straigthforward direction may safe. However, in the middle and upper thoracic level, this technique would have a higher incidence of penetration of the lateral wall due to the medial inclination. To avoid these complication and the potential adjacent neural structures injury, several screw orientations have been proposed. Roy–Camille et al recommended that a screw should be directed perpendicular to posterior plane of the facet[2]. Magerl favored a medial angle of 10–20 degree to the sagittal plane[6]. Louis advocated that the direction of a screw be 15–20 degree medially in the upper thoracic and straight ahead in the middle and lower thoracic spine[6]. The variations of the screw angle mentioned may be attributed to the different pedicle axis projection based on the data of Ebraheim et al[9], that the transverse angle of the pedicle axis was found to be 30–40 degree at T_1–T_2, 20–25 degree at T_3–T_{11} and 10 degree at T_{12}. Anatomic features of the thoracic pedicle and the result from previous and current studies suggested that the screw insertion technique using fixed entrance point and orientation described by Roy– Camille are not reliable for pedicle screw insertion in all thoracic levels and would be associated with higher incidence of penetration of the thoracic pedicle[5,6]

When compared with the Roy–Camille technique, the incidence of pedicle wall penetration in current study, in which we used the Funnel technique with direct visualization and feeling of the inner cortical wall, was significantly decrease to 25%, including 12.5% medial wall violation, 10.8% in lateral violation and 1.6% in inferior violation. For both technique, we could notice that the least common violated wall was similarly the superior wall. Also, severity of pedicle wall violations could be reduced with Funnel technique. The incidence of grade III and grade II violations in Roy–Camille were nearly twice were significantly reduced when screws were placed by using the Funnel technique, it was noted that the incidence of pedicle wall violations was still high. With the main violations seen either on the medial or lateral walls. This result may be because of the previously described smaller mediolateral diameter[7,15,16,24,27] The incidence of pedicle violation in this study were higher than that using open lamina technique[6] (25% VS 15.9%). This may be due to our unexperience in thoracic pedicle screw placement and restriction to only 5 mm diameter screw for every thoracic level that might be too large for the pedicle of middle thoracic vertebral zone (T_5–T_8). Finally, eventhough the incidence of pedicle wall violation in Funnel technique was less but the time taken for each insertion is significanty more than that for Roy–Camille technique, this drawback may cause more intraoperative blood loss and longer operative time in the real situations

In summary, based on experimental screw placement in thoracic pedicle, the Roy–Camille technique was associated with a high incidence of pedicle wall violation[4,5,6], whereas screw placement with Funnel technique significantly reduced the incidence of pedicle violation. However, pedicle screw fixation in thoracic spine remains a technical challenge and should not be routinely used. Screw placement with the Funnel technique is recommended if pedicle screw

fixation is strongly indicated in thoracic spine.

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