

FREE HAND DIRECT POSTERIOR SCREW INSERTION INTO AXIS BODY IN HIGH VERTEBRAL ARTERY GROOVE

# Free Hand Direct Posterior Screw Insertion into Axis Body in High Vertebral Artery Groove

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## Abstract

**Background Data:** Transpedicular screw is an important fixation technique of axis. It does not depend on intact posterior components like sublaminar wires or translaminar screws. Unlike transarticular screw, transpedicular screw provides segmental fixation so each screw is inserted independently. Moreover, it is biomechanically superior to other fixation methods. However, high arched vertebral artery groove (VAG), an anatomical variant may be present unilaterally up to 18 % of cases, presents a challenge that makes screw insertion hazardous due to risk of vertebral artery injury.

**Purpose:** The aim of this work is to assess the safety, feasibility and limitations of a new free-hand technique of direct posterior screw insertion into axis body in case of C2 high arched VAG.

**Study Design:** An anatomical-surgical study.

**Material and Methods:** The morphology of C2 VAG was studied in 30 dry axis vertebrae.

**Results:** High arched VAG was noted in (13.3%) of studied axis vertebrae (8 sides). In these 6 axis vertebrae with high arched VAG (2 bilateral and 4 unilateral), 8 screws were successfully inserted directly into the pedicle vertebral body interface with bicortical purchase. The entry point was 3-5 mm inferior to the superior facet of axis. The average screw angulation was  $40 \pm 3.7^\circ$  medially and  $5.6 \pm 3.5^\circ$  rostrally. The average screw length was  $25.9 \pm 3.3$  mm while the average bone purchase distance inside axis body was  $17.3 \pm 1.5$  mm.

**Conclusion:** The direct posterior screw insertion into axis body is a feasible technique in case of high arched VAG, but further investigations are needed to assess the technique biomechanically and clinically. (2015ESJ093)

**Keywords:** Axis Fixation, Direct body screw, High Arched Vertebral Artery Groove, transpedicular screws.

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## Introduction

Transpedicular screw fixation is an important segmental fixation technique of axis. It was first pioneered in 1964 by Leconte<sup>7</sup> and followed by Borne et al,<sup>2</sup> for treatment of traumatic spondylolisthesis (hangman's fracture) of axis. In 1994, Goel and Laheri<sup>4</sup> revolutionized atlantoaxial fixation by using atlas lateral mass screws and axis transpedicular screws connected via plate and screw construct.

Transpedicular screws do not depend on intact posterior vertebral components like sublaminar wires, cables, hooks or translaminar screws.<sup>18</sup> Unlike transarticular screws, transpedicular screws provide segmental fixation independent on atlas fixation.<sup>8</sup> Moreover, they are biomechanically superior to translaminar and transpars interarticularis screws.<sup>9</sup> However, high arched vertebral artery groove (VAG), an anatomical variant may be present unilaterally in approximately 18% of cases, presents a challenge that makes screw insertion hazardous due to risk of vertebral artery injury.<sup>1,13,16</sup> Alternatively, translaminar or transpars interarticularis screws were recommended in atlantoaxial fixation in case of high VAG.<sup>16,18</sup>

The objective of this study is to assess the variations of C2 VAG and describe a novel technique of direct posterior screw insertion into axis body in case of high arched VAG.

## Material and Methods

This study was conducted at Kasr Al-Aini Medical School, Cairo University, during the period from January 2014 to December 20014. The morphology of the pedicle and the intimately related VAG of 30 dry axis vertebrae (total 60 sides) were studied.

The 30 dry axis vertebrae of unknown age and sex obtained from Egyptian population were studied using Vernier caliper (sensitive to 0.1mm). They were assessed according to Wang et al,<sup>16</sup> method. The 2 parameters used for classification of VAG were the minimum

vertical distance from the apex of VAG to the upper facet joint surface (high if  $\leq 4.5\text{mm}$ , low if  $>4.5\text{mm}$ ) and the minimum horizontal distance from the entrance of VAG to the vertebral canal, which is the pedicle width (narrow if  $\leq 4.5\text{mm}$ , wide if  $>4.5\text{mm}$ ) (Figure 1). Thus, there are 4 types of VAG, type I wide and low, type II narrow and high, type III narrow and low and type IV wide and high.

### **Surgical Technique:**

A new free-hand technique of direct posterior screw insertion into axis body was described in 8 sides of axis vertebrae with high arched vertebral groove (Figure 2).

Unlike the conventional entry point for transpedicular screw which is located at the lateral aspect of the C-2 lateral mass, just caudal to the transition of the lateral mass into the C-2 pars (the star in Figure 3.A), the starting entry point of drilling for direct posterior body screw was located about 3mm below the superior facet of axis. The posterior and lateral aspects of the vertebral groove were de-roofed (Figure 3 B, C) and the vertebral artery groove was protected by a dissector (and in clinical scenario, the vertebral artery should be retracted laterally).

The drilling of the small sized pedicle continued antero-medially till the vertebral body was reached, thus the pedicle was the guide to the posterior surface of the axis vertebral body (Figure 4). The drill was directed 40-45° medially and 0-10° rostrally until the anterior cortex was perforated (bicortical purchase). After tapping, a 3.5 mm poly axial screw was inserted. It is noteworthy that additional screw length of approximately 8-10 mm remained superficial to the posterior cortex of the axis body to facilitate connection of the screw head to the rod (Figure 5).

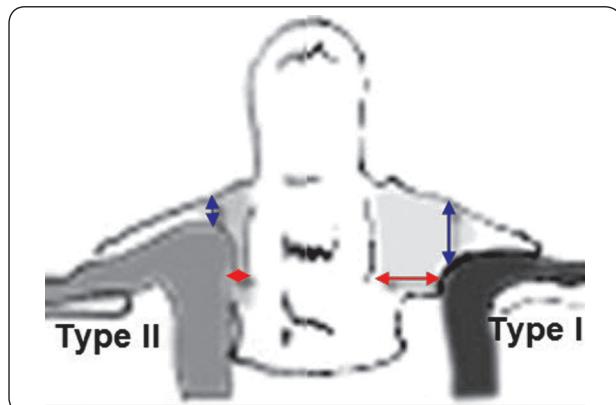
## Results

The VAG was classified into 4 subgroups (Table 1). Type II, (High arched VAG with narrow pedicle  $<4.5\text{mm}$ ) was noted in (13.3%) of

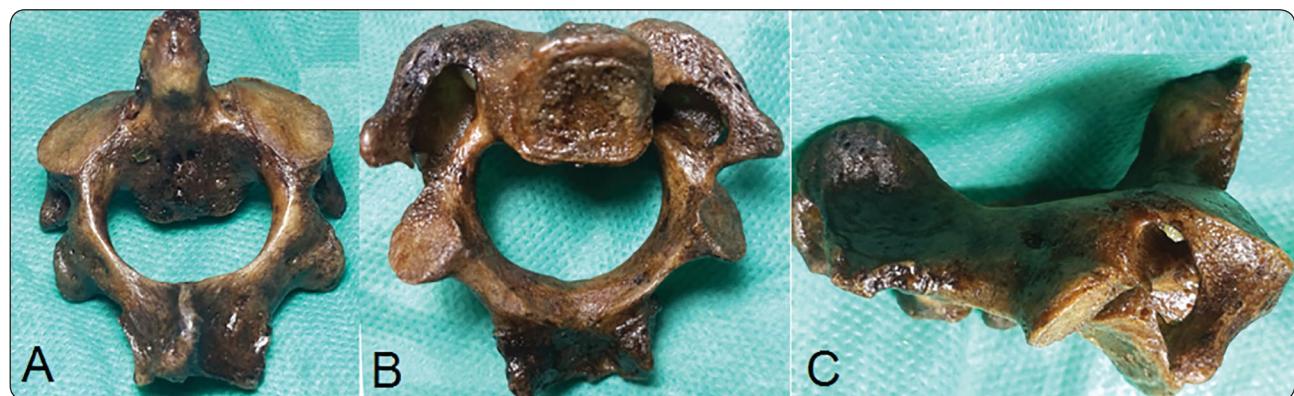
studied axis vertebrae. This type is of surgical importance because it is difficult for a 3.5mm screw to be placed safely in this small pedicle.

In these 6 axis vertebrae with high and narrow VAG (2 bilateral and 4 unilateral), 8 screws were successfully inserted directly into the pedicle vertebral body interface with bicortical purchase

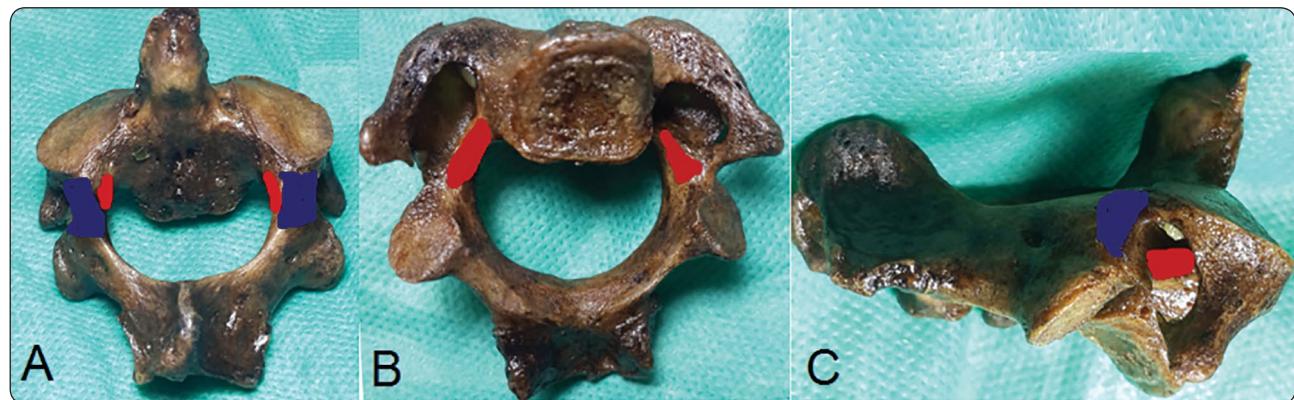
(figure 6). The average screw angulation was  $40\pm3.7^\circ$  (Range 34-45°) medially and  $5.6\pm3.5^\circ$  (Range 0-10°) rostrally. The average screw length was  $25.9\pm3.3$ mm (Range 21-30mm) while the average bone purchase distance inside axis body was  $17.3\pm1.5$ mm (Range 15-19mm) (Table 2).



**Figure 1.** The 2 parameters used for classification of VAG according to Wang et al, the vertical distance from the apex of VAG to the upper facet joint surface (the blue double head arrow) and the horizontal distance from the entrance of VAG to the vertebral canal, which is the pedicle width (the red double head arrow).



**Figure 2-I.** The axis vertebra with bilateral high vertebral artery groove type II (A) posterior view, (B) Inferior view, (C) Lateral view.



**Figure 2-II.** The same figure in 2-I with coloration of the pedicle with red color while the pars is colored with blue (A) posterior view, (B) Inferior view, (C) Lateral view.



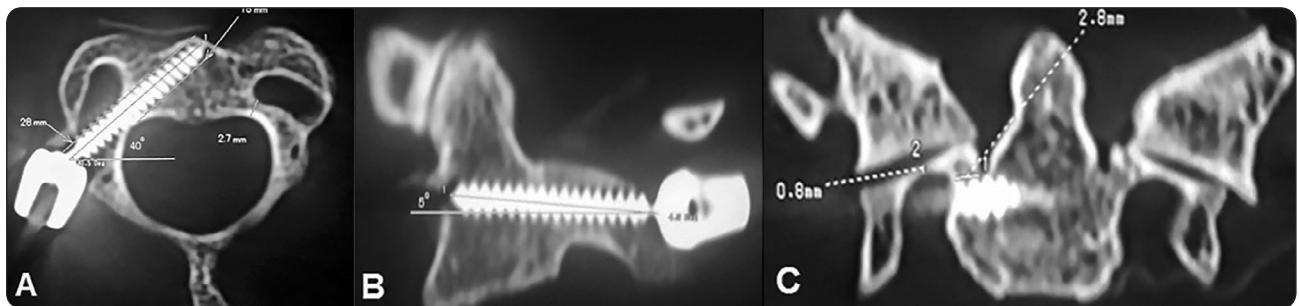
**Figure 3.** Unlike the conventional entry point for transpedicular screw (the star in fig A), the starting entry point lies higher about 3 mm below the superior facet of axis. The posterior and lateral aspects of the vertebral groove are deroofed (Fig B, C Rt side) and the vertebral artery is protected and retracted laterally (N.B: this is the same axis vertebra shown in figure 2).



**Figure 4.** A) Lateral view, B) superior view and C) inferior view of the trajectory of drilling. The drill is directed 40-45° medially and 0-10° rostrally until the anterior cortex is perforated (bicortical purchase).

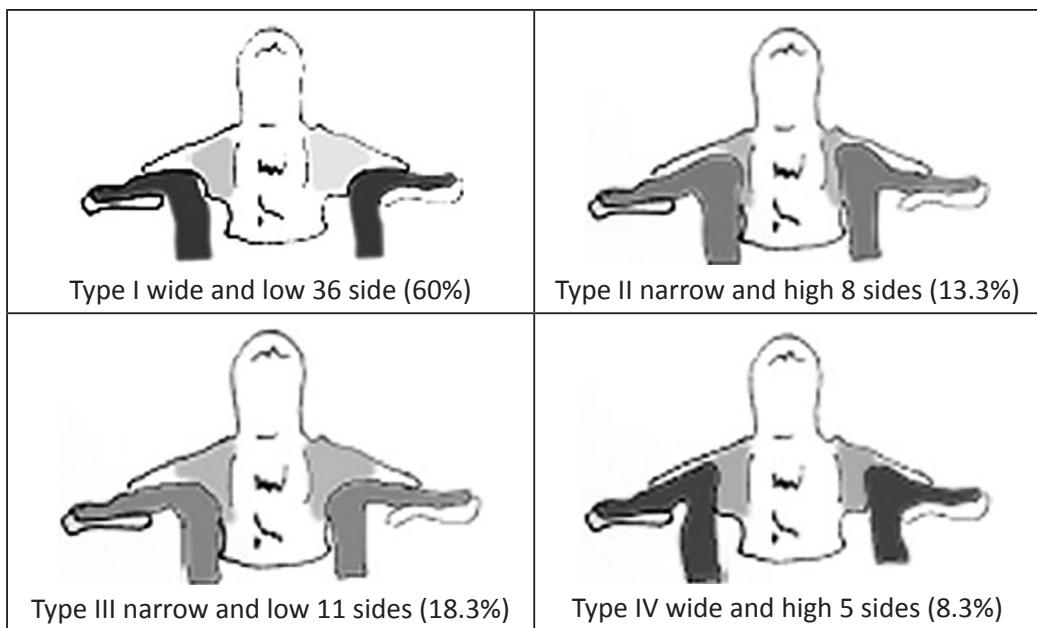


**Figure 5.** After screw insertion: A) superior view, B) Lateral view and C) inferior view After insertion of 3.5 mm poly axial screw.



**Figure 6.** CT scan after insertion of direct posterior axis body screw ( A) axial, B) sagittal and C) coronal views) of the same axis vertebra shown in (figures 2-5); A) shows Rt direct posterior axis body screw, the medial angulation was 40° and the screw length was 28mm with 18mm was inserted in the body; Note that the diameter of pedicle is 2.7mm only and the lamina thickness is 2.5mm. B) the rostral inclination is 5°, C) shows severe type II VAG with horizontal distance from the entrance of VAG to the vertebrae canal 2.8mm while the vertical distance from the apex of VAG to the upper facet joint surface was only 0.8mm.

**Table 1.** The classification of 120 vertebral artery groove according to the VAG height and pedicle width.



**Table 2.** The angulation, length and distance of bone purchase of 8 screws inserted via the new technique of direct posterior screw insertion into axis body in case of high arched VAG.

No.	Medio-lateral/°	Rostral/°	Length/mm	Bone Purchase/mm
1	41	10	27	17
2	36	3	22	16
3	41	4	26	16
4	34	0	21	15
5	40	5	28	18
6	45	7	30	19
7	44	9	29	19
8	39	8	24	18

## Discussion

Transpedicular screw fixation is the most biomechanically robust technique for axis fixation.<sup>9</sup> Transpedicular screws do not depend on intact posterior vertebral components like wiring techniques or translaminar screws. Therefore, C2 laminectomy can be done if necessary.<sup>4,5</sup> Unlike transarticular screws, transpedicular screws provide segmental fixation independent on atlas fixation. So, perfect anatomic alignment of the C1–C2 joint complex is not mandatory before instrumentation.<sup>4,5,18</sup>

High arched VAG, an anatomical variant may be present unilaterally in approximately in 18 % of cases presents a challenge that makes screw placement hazardous due to high risk of vertebral artery injury.<sup>16</sup> The reported breach rate of transpedicular screws vary from 5-29% and the majority occurring laterally towards VAG,<sup>11,12</sup> which may be due to the fact that the lateral wall of the C-2 pedicle is thinner than the medial wall and may be vulnerable to injury during the pedicle screw placement.<sup>3</sup> Sciubba et al,<sup>15</sup> reported a breach rate of 15% during transpedicular screw placement and most violations occurred laterally (80%), and superiorly (20%) without any medial breaches. Yeom et al,<sup>19</sup> reported VAG violations rates of (20%) after using postoperative fine-cut CT scans and CT angiography with multi planar and three dimensional reconstructions. They speculated that the real frequency of VAG violation may be underestimated due to inaccurate evaluation methods.

There is confusion regarding the terminology and the differentiation between the C2 pars interarticularis and the pedicle which arises from the anatomical confusion.<sup>10</sup> The C2 pars interarticularis (isthmus) is present between the superior and inferior articular processes covering the pedicle completely from posterior view, and the pedicle is the structure beneath the C-2 isthmus which connects the lateral mass–inferior articular process to the body of

the axis. So, the term trans pedicolo-isthmic screw fixation is more appropriate than transpedicular screw fixation because the screw passes through the pars before the pedicle to reach the vertebral body of axis.<sup>3,10</sup>

This novel technique of direct screw insertion into axis body in case of high VAG depends on drilling of the C-2 isthmus (pars interarticularis) to uncover the C-2 pedicle which is small in case of high VAG and not useful for screw placement. The posterior vertebral body is accessible via drilling of the pedicle which is the guide towards the posterior body surface.

Unlike the conventional entry point for transpedicular screw which is located at the lateral aspect of the C-2 lateral mass, just caudal to the transition of the lateral mass into the C-2 pars,<sup>15</sup> the starting entry point of drilling for direct posterior body screw was located at a higher point, about 3 mm below the superior facet of axis. This higher location coincides directly with the pedicle at the thinnest overlying pars.

The vertebral artery groove was deroofed and the vertebral artery was protected by a dissector (and in clinical scenario, the vertebral artery should be retracted laterally). Thus the screw was inserted directly into the posterior body via a free hand technique under vision not blindly like the conventional transpedicular technique.

Eight screws were successfully placed directly into the pedicle vertebral body interface with bicortical purchase to increase the screws insertional torque and pull out strength. The average screw angulation was  $40 \pm 3.7^\circ$  (Range 34-45°) medially, while the rostral angulation was  $5.6 \pm 3.5^\circ$  (Range 0-10°). It is noteworthy that any further rostral angulation will violate the superior facet. This trajectory is slightly different from the trajectory of the conventional transpedicular screws which is (25-40°) medially and (15-20°) rostrally because the entry point of the former is higher than the latter.<sup>2,4,5,15,18</sup>

The average bone purchase distance inside axis body was  $17.3 \pm 1.5$  mm (Range 15-19 mm)

which is comparable to the transpars screw length. Hoh et al,<sup>6</sup> reported that the maximum safe length of transpars screw not to violate VAG is 14mm after studying 100 thin slice CT scans. On the other hand, the reported maximum safe length of translaminar screw is longer, ranging from 21mm to 28mm.<sup>14,20</sup> However, the recent radiological and cadaveric studies reported that the thickness of C2 laminae was too small to accommodate safely a 3.5mm diameter screw in 15-21 % of laminae when their cutoff thickness was considered 5mm and 5.5mm respectively.<sup>16,17</sup>

*In summary*, high arched VAG is not uncommon (13.3% of studied VAG in the current study). In this situation, the currently available alternatives for axis fixation are translaminar or transpars screws. The novel technique of direct posterior screw insertion into axis body after minimal pars/pedicle drilling is a new alternative for segmental axis fixation in high VAG especially if associated with small lamina or previous laminectomy.

## Conclusion

The direct posterior screw insertion into axis body is a feasible technique in case of high arched VAG, but further investigations are needed to assess the technique biomechanically and clinically against more established techniques of axis fixation.

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## الملخص العربي

**التركيب المباشر للبراغي في فقرة المحور خلفيا في حالة ارتفاع أخدود الشريان الفقاري: دراسة تشريحية**

**البيانات الخلفية:** المسamar السويقة هو من أساليب التثبيت الهاامة للفقرة الثانية. أنها لا تعتمد على مكونات الخلفي سليمة مثل الأسلامك تحت الصفائح أو مسامير خلال الصفائح. على عكس المسamar خلال المفصل. يوفر المسamar السويقة ثبات القطعى حتى يتم إدخال كل المسamar بشكل مستقل. وعلاوة على ذلك، أنها متوفقة ميكانيكيا على طرق التثبيت الأخرى. ارتفاع تقوس الأخدود الشريان الفقري في العينات التشريحية الحالي من ناحيه واحدة تصل إلى ١٨٪ من الحالات، يمثل تحديا الذي يجعل إدراج المسamar خطر بسبب خطر الإصابة الشريان الفقري.

**الهدف:** يهدف هذا البحث لتقييم أسلوب جديد لتركيب البراغي في فقرة المحور خلفيا في حالة ارتفاع أخدود الشريان الفقاري (الموجودة طبيعيا في حوالي ١٨٪ من البشر).

**تصميم الدراسة:** دراسة تشريحية.

**الطريقة:** تم تركيب ٨ براغي في جسد ٦ فقرات محور جافة بنجاح بعد حفر العنيقة و يقع المدخل ٣-٥ مم أدنى من الوجه العلوي للمحور. كان متوسط زاوية دخول البراغي حوالي ٤٠° للداخل أفقيا و ٦٠° لأعلى رأسيا. بلغ متوسط الطول الكلي للبراغي ٢٠,٩ ملم حين كان متوسط المسافة داخل عظم جسم المحور حوالي ١٧,٣ ملم.

**الاستنتاج:** التركيب المباشر للبراغي في فقرة المحور خلفيا في حالة ارتفاع أخدود الشريان الفقاري تقنية مجدهية ولكن هناك حاجة لمزيد من التحقيقات لتقييم التقنية معمليا وسريريا.