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Injury Risk of Vertebral Artery during Screw Placement through Atlas Posterior Arch

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Abstract Screw placements into atlas lateral mass requires a detailed anatomy of the vertebral artery on the posterior arch of atlas (C1). This study was designed to determine the potential risk of injuring the vertebral artery during atlantoaxial fixation via the atlas posterior arch and assess the feasibility this site for screw insertion. Five parameters of the vertebral artery groove (VAG) were performed in thirty six adult dry atlas vertebrae of unknown sex using a Vernier sliding caliper. The distances, starting from the posterior midline, to the medial most edge of VAG on the inner and outer cortexes of posterior arch were 11.90 ± 2.97 mm and 17.58 ± 3.75 mm respectively, and to the lateral most edge of the VAG on the inner and outer cortexes were 16.30 ± 3.67 mm and 18.71 ± 3.64 mm respectively. The thickness of posterior arch at VAG was 3.99 ± 1.13 mm, with a total of 29 (80.6%) specimens were less than 5mm. In conclusion, the thickness of the lateral part of the posterior arch of atlas (C1) vertebra is not suitable for screw insertion in most cases and to avoid vertebral artery injury, the dissection should remain within 10 mm and 6mm lateral to the midline on the posterior and superior aspects respectively.

Keywords Vertebral artery injury, Atlas posterior arch, Screw fixation into C1 posterior arch, Vertebral artery groove

1. Introduction

The vertebral artery arises from a postero-superior position on the subclavian artery and the left side may arise from the arch of aorta (9%). Then it runs cephalad and posteriorly to enter the protective bony encasement of the vertebral column via the transverse foramen , usually at the level of the sixth cervical vertebra, but occasionally at a higher level[1]. It continues superiorly through the foramina of the fifth through the first cervical vertebra. At the superior border of the first cervical vertebra , the artery curves medially, crosses the posterior arch of the first cervical vertebra, and passes through the foramen magnum to enter the posterior cranial fossa[2]. The course of vertebral artery on C1 lamina complicates surgical procedures in this area[3]. The injury to the artery during surgery can lead to catastrophic intra-operative bleeding and compromise to the blood flow can lead to unpredictable neurological deficits, which will depend on the adequacy of blood flow from the contralateral vertebral artery[4]. Vertebral artery injury in posterior cervical surgery can occur with transarticular screw insertion and during lateral mass platting , as well as during exposure over the superior part of the posterior ring of atlas[5]. The increasing use of C1 (atlas) lateral mass screw placements for atlantoaxial fixation requires a detailed anatomy of the lateral mass and the relation of the entry zone to the vertebral artery[6]. This study was designed to determine the potential risk of injuring the vertebral artery during atlantoaxial fixation via the atlas posterior arch and assess the feasibility this site for screw insertion.

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2. Material and Methods

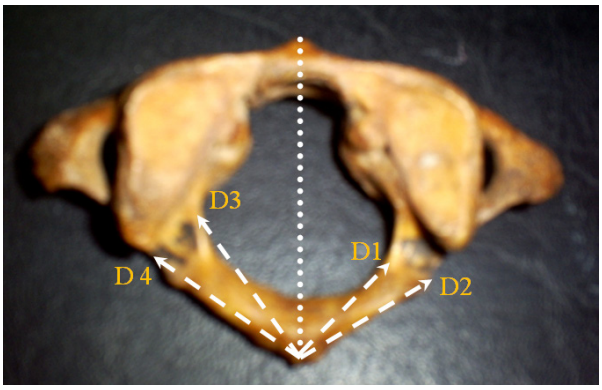

Figure 1. The linear parameters of VAG on the superior surface of the atlas vertebra, from the posterior midline. (D1) & (D2) extend to the medial most edge of the groove on inner and outer cortexes respectively. (D3) & (D4) extend to the lateral most edge of the groove on inner and outer cortexes respectively

The present study was carried out in Department of Anatomy, Faculty of Medicine, Zagazig University. Thirty six adult dry atlas vertebrae of unknown sex were used in this study. The selected vertebrae were grossly normal and did not show any acquired pathology or congenital abnormality.

The vertebral artery groove (VAG) was identified on the superior surface of the lateral part of the posterior arch of atlas vertebra in each specimen and five parameters were measured as previously described[7];[8];[9]. The following 4 linear parameters, starting from the posterior midline, were measured: (D1) and (D2) extended to the medial most edge of the VAG on the inner and outer cortexes respectively. (D3) and (D4) extended to the lateral most edge of the VAG on the inner and outer cortexes respectively (Figure 1).

The groove thickness (T) was taken as the height between the upper and lower surfaces of the lateral part of the posterior arch of atlas vertebra in its thinnest part (Figure 2).

Figure 2. The thickness (T) of the lateral part of the posterior arch of atlas vertebra at VAG (double-headed arrow)

The thickness of specimens were classified into 2 groups with a thickness either greater or less than 5mm to determine the capability of accepting screw insertion, as Lee et al[10] described that 5mm thickness should be available to safely pass a 3.5 mm screw without violating any of the cortical margin of the posterior arch. All measurements in this study were performed bilaterally (right and left) using a Vernier sliding caliper; accurate to 0.1mm. The range, mean and standard deviation of each parameter were calculated by the Microsoft office Excel computer program. A student-*t* test was used to compare each parameter on right and left sides to determine significant differences, if any ($P \leq 0.05$).

3. Results

The distances from posterior midline to the medial most edge of the VAG on the inner cortex (D1) was 11.90 ± 2.99 mm and on the outer cortex (D2) was 17.58 ± 3.75 mm. The distances from posterior midline to the lateral most edge of the VAG on the inner cortex (D3) was 16.30 ± 3.67 mm and on the outer cortex (D4) was 18.71 ± 3.64 mm. The higher values on the left side, based on *t- test*, were statistically non-significant ($P \geq 0.05$) (Table 1).

Table 1. The parameters (D1-D4) of the lateral part of arch of atlas at VAG (in mm) on the right (R) and left (L) sides and P value (NS: non-significant)

	Range	Mean ± SD	Mean (Bilateral)	t test (P value)
D1/R	5.96-18.25	11.44± 2.91	11.90± 2.99	0.189(NS)
D1/L	8.22-17.85	11.81± 3.08		
D2/R	10.26-23.60	17.08± 3.74	17.58 ± 3.75	0.261(NS)
D2/L	11.37-24.26	18.08± 3.74		
D3/R	9.65-22. 50	16.03 ± 3.68	16.30 ± 3.67	0.542(NS)
D3/L	10.29-22.89	16.56 ± 3.69		
D4/R	11.45-24.11	18.31 ± 3.70	18.71 ± 3.64	0.350(NS)
D4/L	12.37-25.21	19.12 ± 3.58		

The mean thickness (T) of the lateral part of the posterior arch of atlas vertebra at VAG was 3.99 ± 1.13 mm. The higher values on the left side, based on *t-test*, were statistically non-significant ($P \geq 0.05$) (Table 2).

Table 2. The thickness (T) of the lateral part of arch of atlas at VAG (in mm) on the right (R) and left (L) sides and P value (NS: non-significant)

	Range	Mean ± SD	Mean (Bilateral)	t test (P value)
T/R	1.88-6.86	3.92±1.12	3.99±1.13	0.568 (NS)
T/L	2.25-6.95	4.07±1.15		

A total of 29 (80.6%) specimens showed a lateral part of the posterior arch of atlas vertebra of less than 5mm in thickness (Table 3).

Table 3. Classification of the lateral part of posterior arch of atlas according to the thickness at VAG (in mm) on in the studied specimens. The capability of screw insertion was done according to Lee et al[10]

Group	Number	Percent	Screw insertion capability
<3 mm	8	22.2%	Less than 5mm 29 (80.6%)
3-3.5 mm	5	13.9%	
3.6 -4 mm	7	19.4%	
4.1-4.5 mm	5	13.9%	
4.6-5 mm	4	11.1%	
5.1-5.5	4	11.1%	Greater than 5mm 7 (19.4%)
> 5.6	3	8.3%	

4. Discussion

The surgical importance of vertebral artery on the posterior arch of atlas vertebra during posterior cranio-vertebral procedures is well-known. Cacciola et al[4] described that the artery makes a loop after its exit from foramen transversarium of C1, then occupies a vertebral artery groove over the surface of the posterior arch of atlas and in this location it is vulnerable to injury during a posterior midline approach. Ebraheim et al[7], to define a safe zone from the posterior midline to avoid injuring the vertebral artery, described a mean distance of 10.4 ± 1.7 mm (males) and 8.9 ± 0.8 mm (females); with a minimum of 8 mm for both genders, from the posterior midline to the medial most edge of VAG on the inner cortex, and described a mean distance of 19.2 ± 3.2 mm (males) and 16.5 ± 1.0 (females) ; with a minimum of 12 mm for both genders, from the posterior midline to the medial most edge of VAG on the outer cortex. The previous authors suggested, according to their findings, that dissection on the posterior aspect of the posterior ring should remain within 12 mm lateral to the midline, and that dissection on the superior aspect of the posterior ring should remain within 8 mm of the midline. The current study, in contrast to Ebraheim et al[7], revealed lower values for distances from the midline to the medial-most edge of the vertebral artery groove on the inner and outer cortex respectively; 11.90 ± 2.97 mm, with a minimum of 5.96 mm and 17.58 ± 3.75 mm, with a minimum of 9.65 mm (Table 1). Accordingly it is suggested, to avoid

injury of vertebral artery, that safe dissection of the posterior aspect of the posterior arch should remain within about 10 mm lateral to the midline and should remain within about 6 mm of the midline on the superior aspect. However, higher values for distances from the midline to the medial-most edge of the vertebral artery groove on the outer cortex were reported ; 15.03 ± 1.22 mm[3] , approximately 16 mm[8] and an average of 18.2 mm[4].

Concerning the thickness of the lateral part of the posterior arch at position of VAG , Tan et al[11] regarded it as other vertebral pedicle through which the screw fixation could be achieved and described a thickness of 4.58±0.65 mm (left side) and 4.72 ± 0.68 mm (right side) at the thinnest part of the groove with only 8% (4 out of 50) were less than 4mm. On the other hand, Ma et al[12] described a mean a thickness of 3.88±0.52 mm on the medial one-third portion of the posterior arch under VAG and 4.25 mm±0.51 mm on its lateral one-third portion of the arch. The same authors reported that the lateral one-third portion of the posterior arch under VAG would be ideal for screws to minimize the risk of injury to the vertebral artery in the groove. In the current study, a mean thickness of 3.99±1.13 mm of the lateral part of posterior arch at the groove was revealed which is slightly greater than the findings of Lee et al[10] , but less than the findings of Ebraheim et al[7]; Ma et al[12]; and Tan et al[11] with the latter authors showing the largest thickness (Table 4 & figure 3).

Table 4. Comparison between VAG thickness in current and previous studies (in mm)

Study	Current study	Ebraheim et al[7]	Tan et al [11]	Ma et al [12]	Lee et al[10]
VAG thickness	3.99	4.1	4.58	4.25	3.95

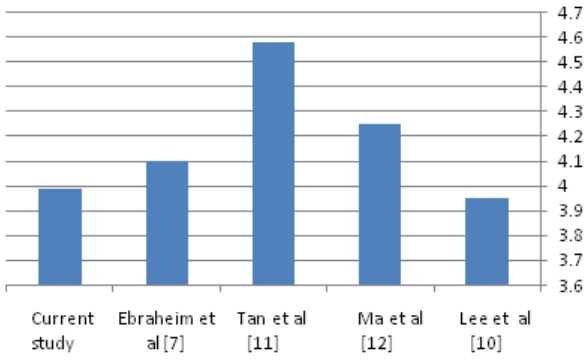

Figure 3. Histogram of the thickness of the lateral part of the posterior arch of atlas vertebra at VAG in current study compared to previous studies

According to Lee et al[10] , a minimum thickness of 5 mm to safely pass a 3.5 mm screw via the posterior lateral arch of atlas, without violating any of the cortical margins. The previous authors found that 13.7% (194 out of 709) of atlas specimens were greater than 5 mm. In the present study, 7 (19.4%) of specimens were greater than 5mm (Table 3). indicating that the screw placement via the posterior arch described by Tan et al[11] would be unfeasible and carries a great risk of injuring the vertebral artery.

5. Conclusions

The bone thickness of the lateral part of the posterior arch of atlas (C1) vertebra is not suitable for screw insertion in most cases and to avoid vertebral artery injury, the dissection should remain within 10 mm and 6mm lateral to the midline on the posterior and superior aspects respectively.

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