Morphometric Identification of Entry Points Of Pedicle Screw Fixation in C1 Vertebra

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ABSTRACT

Introduction: There is great concern during surgery in the CV junction region of fear of injury to the closely related neurovascular structures. Surgery in the region includes decompression, reduction of subluxation and stabilization by internal fixation. Internal fixation is commonly done by placement of screws and rods which gives an immediate and long term rigid and strong fixation. The dissection in the region, is well realised to be difficult and associated with neurovascular issues, particularly when finding the entry point for screw fixation in atlas.

Methods: A prospective study was conducted for anatomic study of C1 osteology to locate the C1 screw entry point and where data was used in patients requiring C1 screw fixation. In this study, morphometric data were obtained from the C1 screw insertion entry points on the posterior arch of C1, in reference to the screw entry point of C2 in 3D CT images of normal persons, sawdust models, and cadavers. Using this information, entry points for pedicle screw fixation were located in C1 posterior arch in 18 patients needing C1-C2 fixation.

Results: It was found that the entry point of screw in the posterior arch of the C1 vertebra was 4 mm ±3 mm lateral to the vertical line drawn from the pedicle screw entry point at the C2 vertebra. Additionally, the entry points was 22 ± 3 mm from the posterior tubercle of posterior arch. Also, to identify the pedicle screw insertion points, similar measurements were obtained from CT scans of 18 patients requiring C1-C2 fixation.

Conclusion: By using morphometric analysis, the entry point for pedicle screw fixation of C1 can be easily located on the posterior arch of atlas, thereby reducing the need for extensive dissection and the potential for injury to the neurovascular structures.

Keywords: CV Junction; C1 Vertebra; Entry Points Morphometric Method; Pedicle Screws.

INTRODUCTION

The CV junction can become deformed and unstable due to pathologies such as trauma, degeneration, congenital anomalies, neoplasms, and infections, that compress the spinal cord, roots, or blood vessels. This requires decompression, reduction, re-alignment and fixation.[1,2] Fixation of C1 lateral mass and C2 Transpedicular screws with connection using rods, provides adequate immediate and long term rigid immobilization.[1,3,4] However, due to the proximity of vertebral artery, extensive and large venous plexus, nerve roots, dura and spinal cord, dissection and surgeries in this area, especially around the lateral mass of atlas vertebra (Figure 1), is found to have high risk of neurovascular injuries. For stability of thoracic and lumber spine, pedicle screw fixation has become a routine and a straight forward procedure as the entry points are localised morphometrically. Using the similar concept, the author believes that using the consistent bony reference points of the C1 vertebra, it is also possible to localise the entry points of the pedicle screw fixation in the spine.

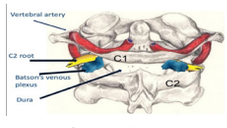
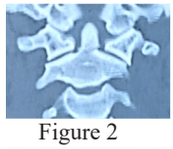


Figure 1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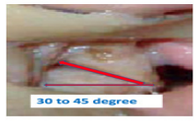

Figure 3

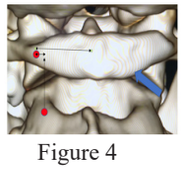
Figure 4

The objective of this study is to find these reference points and the measurement to locate the entry points without extensive and risky soft tissue dissection.

METHOD

This is an anatomic prospetive study of C1 osteology to locate the C1 screw entry point in patients requiring C1 screw fixation. This study was conducted in Nepal Medical College from August 2015 to July 2019. The data were received from normal 3D CT scans of upper cervical spine and analysed. The thickest and bulkiest part of C1 vertebra is the centre of lateral mass through which the fixation screws are passed to achieve a strong stability. Localising this point during surgery morphometrically as the entry point of the pedicle screw is the objective of this study. According to the most commonly performed C1 screw fixation technique[1] , the central point of the lateral mass is located at the junction of the facet joint and the posterior arch of the atlas, in between the medial and lateral margins of the facet joint. However, this entails a great deal of dissection of soft tissues with a high risk of injury to the spinal cord, dura, nerves, Batson's plexus, and vertebral artery.

This study tends to morphometrically localise the entry point of C1 screws, with minimal soft tissue dissection. The midpoint of the posterior arch of C1 and the entry point of the C2 pedicle screw are used as the reference points for localising the entry points of C1. The midpoint of the lateral mass of C1 (the screw entry point of C1) is not vertically straight above the centre of the lateral mass of C2 (screw entry point of C2), but is slightly lateral due to the angled facet C1- C2 joints (Figure 2 and 3). Similarly, there is almost a constant distance between the midline of the posterior arch of the atlas and the screw entry point of C1. Based on the aforementioned observation, using 3D CT images of healthy persons, C1 screw insertion points were located on the posterior arch of atlas and its morphometric relation to the posterior tubercle of the posterior arch of the atlas and the screw entry point of the C2 vertebra were obtained. These compelling morphometric results were further extrapolated and used in 18 patients who needed C1 screw fixation to locate the screw entry point. The positions of the screw were confirmed by the intraoperative and postoperative imaging.

Operative steps

All the 18 patients had 3D CT scans prior to surgery. The midpoints of the lateral mass of C1 was identified in reference to the posterior tubercle of C1 and screw entry point of C2. Under general anaesthesia, patients were kept in prone position with a cervical traction with 3 Kg weight. Through a midline incision laminae, the dorsal arch of C1 was exposed up to 2.5cm laterally. Similarly, dissection was continued in C2 and C3 spines, exposing up to the lateral margin of the lateral masses. The entry site of C2 pedicle screw was identified at the junction of midpoint of lateral mass and facet joint.

From the C2 entry point, a vertical line was drawn up. The C1 pedicle screw entry point was marked lateral to the vertical line on the posterior arch of C1, based on measurements taken from the 3D CT scan. Similarly, using the data obtained from the CT scan, the position of the entry point was reconfirmed from the posterior tubercle of the posterior arch. On the designated entry site, holes were made in the posterior arch of the atlas, avoiding the sulcus arteriosus and its contents. Intraoperative fluoroscope was used to confirm the accuracy of entry points. Under the direction of a fluoroscope, titanium poly-axial screws of the necessary length were placed and their positions were reconfirmed by postoperative imaging. Operative time and blood loss was compared to that with technique of Goel and Harms[1,2].

RESULTS

Measurements were made on the end-on posterior view of 3-Dimensional CT scan of 50 normal persons. The entry point of C1 lateral mass, i.e centre of C1 lateral mass, was 6±3mm lateral to the vertical line drawn up and above the entry point of C2 (Figure 4). On measuring the angle, it was 35±7 (Figure 4) degrees from the midline. The distance between the posterior tubercle of posterior arch of C1 to the entry point of C1 was 22 ±3mm (Figure 5). The values were analysed and the mean was calculated. It was found that the entry point of C1 lateral mass was 5 ± 3mm lateral to the vertical line drawn up and above the entry point of C2 (Figure 6). On measuring the angle, it was 35±7 (Figure 5) degrees from the midline. The distance between the posterior tubercle of posterior arch of atlas to the C1 lateral mass screw entry point was 22 ± 3mm (Figure 6).

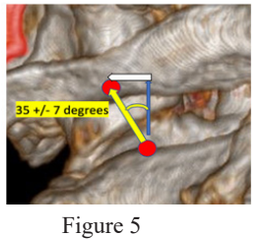

Figure 5

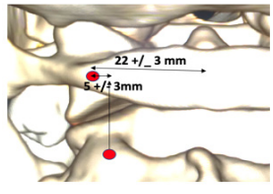

Figure 6

Total of 18 patients needing C1- C2 fixation were taken. Their ages ranged from 18 to 65 years (average age of 28 years). Of the 18 patients, 12 had trauma and six had congenital malformations. The details of the pathology is given in the table below:

Table 1: Pathology details

Cause	Grading	Total No.
Trauma	Type II odontoid fracture	8
	Type III odontoid fracture	1
	Traumatic atlanto axial subluxation	3
Congenital malformation	Basilar invagination	5
	Atlanto-axial subluxation	1

The operating surgeon was the same in all 18 patients and the results were compared with his own experience when Goel and Harms technique was used. In the 18 patients who needed C1-C2 fixation, the measurements obtained from their CT scan of individual patients were extrapolated intraoperatively to find the entry points of pedicle screws in C1 vertebrae. The entry points were reconfirmed by intraoperative fluoroscope (Figure 6). Since there was no need to dissect extensively in the region of C1-C2 facet joint, the time taken to identify the entry point and beginning of screw insertion was in average 18 minutes from skin incision, compared to 56 minutes when Goel and Harms technique were used. The blood loss was less than 25ml 25ml and the stress level of the operating surgeon was so less that the surgeon could perform the rest of surgery more efficiently.

Table 2: Temporal pattern of frequency of cases referred for cytogenetic analysis.

Subject	Case	Control (by Goel and Harns) method
Time taken to identify the entry points in Atlas	Average of 18 minutes	Average of 56 minutes
Blood loss	Average of less than 25 ml	Average of 220 ml

There were no cases of vertebral artery injury, fresh neurological deficit, CSF leak or other complications related to the identification of the entry points. The entry points were verified by postoperative CT scan and confirmed that the entry points and the screws were found to be in the planned area in the lateral masses of C1 vertebrae.

DISCUSSION

Craniovertebral junction is the region in the upper cervical spine that includes base of the skull including foramen magnum, C1 and C2 vertebrae along with all the muscles and neurovascular structures in the region5. It carries the responsibility of supporting the head, protecting the spinal cord and roots, preserving stability, and permitting 50% of the head's rotational mobility and 10% to 12% of the neck's flexion and extension[6,7,8,9,10].

Numerous research have been carried out to examine the specific anatomy and biomechanics of CV Junction[11.] Compared to other cervical vertebrae, the atlas (C1) has distinct anatomical characteristics.[2,12,13,14,15] It has no body or spinous process. The spinal cord is exposed between the C1 and C2 laminae, the vertebral artery curves around from both sides, and there is a massive venous plexus above and over the C1-C2 junction.[13] The region is prone for congenital variations in almost 2.8% of population.[16] About 10 to 20% percent of all spine disorders are related to the CV junction and include neoplasia, inflammation, infection, congenital anomalies and trauma.[17] The area is extremely vulnerable to instability and deformity that could compress and impair the neurovascular system. Intervention in this region is labelled as sensitive, complex and difficult due to the unique bony anatomy, closely related important neurovascular structure, unique biomechanics and substantially lower fusion rates.

The treatment could be either conservative or surgical. Majority of these diseases necessitate surgery in the form of neuronal decompression, deformity correction and stabilization in the form of internal fixation.[12,14,18,19] On attempting to find the best way to address instability and preserving the motion as much as possible, surgery of the region has undergone great revolution in the last five decades. Short-segment but very rigid fixation are preferred over the long fixations. Initially, spinous process and laminae of C1 and C2 were tied with wires or clamps.[20,21,22] However this method did not provide a rigid fixation especially for axial rotation and lateral bending motion.[23,24,25]

In 1990s, techniques of C1- C2 fixation using screws with plates or rods were introduced. Magerl in 1987[26,27] and Grob D in 1991[28] described C1-C2 trans-articular fixation The biomechanical properties suggest that this technique provides stability similar to trans-articular screws.[25,29-34] The most important anchor for internal fixation with C1 vertebra is the lateral mass, which is a very strong and bulky bone. Thus entry point of the screw fixation in C1 is the centre point of the lateral mass. On posterior approach, this centre point is marked as the junction of the medial border of the under surface of the lamina of C1 and the back of the lateral mass.[1,33] With this method, the entry point is 18 to 20 mm lateral to the midline (posterior tubercle) and 2 mm superior to the inferior border of posterior arch, 8.8 mm lateral to the vertebral artery and 5.8 mm from medial edge of the lateral mass[12].

With Goel's or Harms technique, reaching the entry point requires meticulous dissection and retraction of the vertebral artery, venous plexuses, cervical root, dura and spinal cord which are at risk of getting injured causing torrential bleed[35], CSF leak and neurological deficit, and may even cause death. Even a minor injury of the plexus can cause torrential bleed with blood loss up to 1,000 mL[35], extends operative time, cause great tension and exertion to the surgeon and at times even compels the surgeons to change their per-operative planning[1,36]. Thus the dissection in the area is fraught with fear among surgeons and the learning curve for surgery is long.

To avoid such complications, different techniques have developed. A notching technique, where a notch is made in the inferior edge of posterior arch, exposing the entry point at the junction of posterior arch and the lateral mass. This technique reduces injury and bleeding from Batson's venous plexus, nerve root and the dura36. Some anatomist believe that Atlas does not have a pedicle, as the lateral mass becomes confluent with the lamina at its origin. Some have referred to the base of the lamina as the pedicle[37]. Additionally, there is less irritation to the C2 nerve root and reduced injury of venous plexus. However, this method places the vertebral artery at a greater risk on the cephalad portion of the arch. [12,14] Therefore, width of the posterior arch at the region of entry point has to be more than 4 mm in order to avoid injury to vertebral artery during screw insertion[12] For more than half a century, the entry points for the pedicle screws in thoracic and lumber spine, are identified morphometrically with reference to the bony markings, avoiding extensive dissection and laminectomies. Author feels that morphometric methods could similarly be applied to cervical spine, to identifying the entry points of pedicle screws in C1 vertebrae and thus minimising soft tissue dissection and the associated complications.

In this study, relation of C1 entry point was marked in reference to the screw entry point of C2, in 50 normal patients using Multidetector computed tomography MDCT scan. MDCT gives better pictures assessment of the region and the best modality to assess the CVJ44. After confirming the entry points by imaging, the morphometrics obtained were used during surgery to locate the entry points for pedicle screws placement in the patients. The location of entry points were confirmed intraoperative by fluoroscope and postoperatively by CT scan. The author found that using these measurements, the entry point for pedicle screw insertion could be located accurately in C1, with minimum dissection and minimum risk of injury to the neurovascular structures. The technique suggested by the author might be the answer to those who find the surgery in the region difficult and risky. The limitation of the technique is that the C1-C2 subluxation or rotation must be corrected as the C1 entry point is located in the relation of the entry point of C2. This could be achieved preoperatively or intraoperatively by cervical traction. In future, similar morphometric methods and data could be used to perform the screw fixation with minimal invasive or computer guided image guidance techniques

CONCLUSION

Dissection on the lateral aspect of atlas vertebrae is needed to find the entry point for pedicle screw insertion during C1 and C2 fusion surgery. The surrounding neurovascular structures make the procedure difficult, along with high risk of neurovascular injury causing profuse bleeding and neurological deficit. However, all this complexity and complications could be minimised by localising the entry point morphometrically, making the procedure accessible by all spine surgeons.

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