Original Article

An institutional study on accuracy of freehand cervical C1 C2 screws placement by knock and drill technique in craniovertebral anomalous bony anatomy: An evaluation of more than 600 screws based on SGPGI screw accuracy criteria

ABSTRACT

Purpose: To assess the accuracy of freehand cervical C1 C2 screws placement by knock and drill (K and D) technique in craniovertebral anomalous bony anatomy.

Materials and Methods: From January 2017 to December 2022, 682 consecutive C1 C2 screws in 215 patients with craniovertebral junction (CVJ) anomalies were enrolled. All patients underwent posterior fixation with K and D technique without any fluoroscopic guidance. The patient's demographic details, clinical details, radiological details, major intraoperative events, and postoperative complications were noted. The screws malposition grades and direction on CT images in the axial and sagittal plane were defined as new per proposed "SGPGI accuracy criteria." All patients had a clinical evaluation at 3-month follow-up.

Results: Total 682 C1, C2 screws were placed in 215 patients for CVJ anomalies using K and D technique. The accuracy of screws placement by freehand technique was 84.46% (576/682). So with technique explained the rate of malplacement in simple (16.35%) and complex (15.19%) groups were almost comparable and comparison difference was not significant (*P* = 0.7005).

Conclusion: The freehand technique, as described, is effective in cases of anomalous bony anatomy, and it is mandatory in complex CVJ anomalies. The accuracy of screw placement and VA injury is comparable with major studies. This technique is supposedly cost-effective and less hazardous to both health-care workers and patients.

Keywords: Atlantoaxial dislocation, knock and drill technique, SGPGI accuracy criteria, simple and complex craniovertebral junction anomalies

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INTRODUCTION

The surgical treatment in cases of craniovertebral junction (CVJ) anomaly requires occipitocervical or C1 (Atlas)-C2 (Axis) fixation along with neural decompression. Despite the biomechanical superiority, the placement of

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C1-C2 screws inherits considerable risks of injuries to adjacent vital structures such as neuroaxis and vertebral artery. To avoid these serious complications, there have been several attempts to improve the accuracy of cervical screw insertion using modern gadgets such as intraoperative C-arm, O-arm, and navigation systems. Numerous reports have been published regarding the fluoroscopic-guided (with or without neuronavigation) screw placement and its malposition rates.[1-8] These modalities have been associated with high operating cost, increased operative time and radiation exposure to both the patient and health-care personnel. This radiation exposure is not without risk, especially for surgeons who perform numerous surgeries over the course of his/her career (Including radiation exposure from C-arm in surgery and Digital substraction angiography (DSA) procedures). To overcome these challenges, freehand screw placement techniques for subaxial, dorsal, and lumbar regions have been amply described in literature, however, a very few reports are available for CVJ region.[4,9-11] The description of the anatomical landmarks and other surgical nuances of free hand technique for CVJ are barely mentioned in the literature, and none for the anomalous CVJ conditions where the anatomical landmarks are variable. We, at our place (SGPGIMS, Lucknow, India) have been exercising the free hand nonfluoroscopic technique (Knock and Drill [K and D]) for the past 10 years, popularized by the Department of Neurosurgery, SGPGIMS. The aim of this study is to evaluate the accuracy of C1-C2 screws placement with K and D (freehand) technique based on intraoperative articular mass delineation correlated with preoperative three-dimensional (3D) computed tomography (CT) anatomy in CVJ anomalies.

MATERIALS AND METHODS

Patient data

From January 2017 to December 2022, consecutive 682 C1 C2 screws in 215 patients of CVJ anomalies were enrolled. The patients of traumatic CVJ and purely sub-axial instrumentation were excluded (owing to their normal anatomical landmarks). The patient's demographic details, clinical details, radiological details, major intraoperative events and postoperative complications were noted. The preoperative dynamic CT with CT angiography of CVJ region with 3D reconstruction was done for the assessment of CVJ anatomy and courses of vertebral arteries as per departmental protocol. All patients underwent posterior fixation with K and D technique without any fluoroscopic guidance. On the basis of anatomical characteristics, we divided the patients into two groups, a simple and complex CVJ anomaly. Simple CVJ anomaly included mobile or fixed atlantoaxial dislocation with symmetrical C1-C2 joints with normal course of vertebral arteries. Irreducible AAD with at least two criteria, as mentioned below were considered complex CVJ anomaly; the criteria were basilar invagination (with or without platybasia), articular mass hypoplasia (C1 lateral mass [LM], C2 pars and pedicle), asymmetrical C1-C2 joints with rotational component, anomalous vertebral artery course (institutional criteria).[12]

Operative technique

Position and exposure

The patient was placed prone with the head end of the operating table elevated by 30° under traction of about 7%–10% of body weight. A midline skin incision was made from inion to C-5 spinous process. The posterior arch of atlas (assimilated or nonassimilated) with C2 laminae on both sides along with occipital squama were exposed with sharp subperiosteal dissection. The sharp dissection is followed on the medial border securing the neuraxis along with the dura mater avoiding and securing the venous bleeding leads to junction of pedicle with pars. Further, walking superiorly on the C2 pars will lead to the C1–C2 joint space [Figure 1]. The C1/C2 joint space is formed by the end plate of Superior border of the C2 articular facet and inferior border of C1 LM [Figure 1]. The posterior arch of C-1 (separate or occipitalized) is followed to the LM where it joins the later with a small pedicle. This point forms the entry point for C1 LM screw placement. The LM is further exposed medial, lateral and if required superior as well and with this exposure we have all the border of C1 LM well delineated for the instrumentation. The orientation of LM in the sagittal plane is guided by the C1 end plate as well as it helps in deciding the screw length, the axial angulation is defined by following the medial border. The C2 pedicle width and its orientation are also delineated with sharp dissection by following the medial border of the lamina. C2 pars/pedicle screws are placed

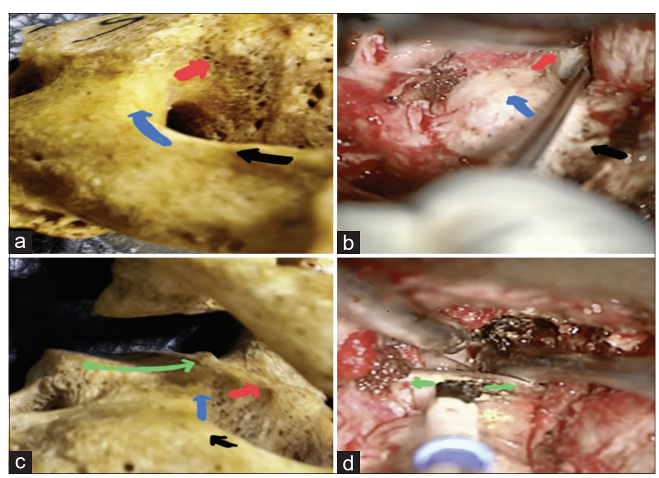

Figure 1: (a and b) Dissection plane from laminae (black arrow) to pars (blue arrow) to C2 pedicle (red arrow) exposed C1-C2 facet joint. (c and d) Showing C1 C2 joint with exposed facets with foramina transversarium (lateral end of green arrow)

depending on the exposure and available best entry point for purchase using the K and D technique without fluoroscopy, avoiding injury to adjacent neurovascular structures. The length of the screw is determined with drill bit tapping or from preoperative 3D CT.

C-2 Pars scoring

Orientation with entry point, bulk for purchase and direction is determined intraoperatively with exposure explained above.

C2 Pedicle scoring

Pedicle is seen and felt for direction, orientation, and purchase with entry point determined.

The knock and drill technique

The concept of K and D technique is nothing but simultaneous utilization of drill bit for drilling as well as sound probe to ensure safe and accurate bone drilling. The drilling is done with a drill bit of 1.1 or 1.2 mm diameter (22–25 mm long tip) and the drill bit is tapped after every few mm of drilling as a sound probe in all the direction to ensure the intactness of the articular mass. The give way confirms the breach in the articular mass while in C1 LM this can ensure bicortical purchase. The rest of the steps are common such as Awl, manual drill, and then putting the screw of appropriate length. The use of a very thin drill bit offers the advantage of less bone loss during drilling and thus several attempts of drilling are possible without compromising the safety.

Screw's accuracy evaluation

The accuracy of novel technique was assessed in both simple and complex CVJ anomaly groups with postoperative CT to evaluate accuracy within a week of postoperative day in all the patients. All patients had clinical evaluation at 3-month follow-up. We reviewed and evaluated C1 Transpedicular, C1 LM, C2 pars, and C2 pedicle screws on postoperative imaging (CT scan) of all these patients. The breach criteria were defined as >50% of the screw lying outside of the pedicle/LM in either medial-lateral or superior-inferior direction (malposition grade 2, 3). The medial and lateral direction of malposition was seen on the axial CT scan, whereas superior and inferior malposition was seen on the sagittal CT scan. The screws malposition grades and direction on CT images in the axial and sagittal plane were defined as new per proposed "SGPGI accuracy criteria (SAC)" for CVJ region screws enumerated below.

- Grade 0 (G-0): Correct placement.
- Grade 1 (G-1): Malposition by less than half screw diameter.
- Grade 2 (G-2): Malposition by more than half screw diameter but less than or equal to the screw diameter.
- Grade 3 (G-3): Malposition by more than the screw diameter.

This study was permitted by our Institutional Ethical Committee (IEC code no: 201308MCH67]).

RESULTS

Demography and clinical symptoms

Out of 215 patients, 142 were male and 73 were female. The mean age of presentation was 27.44 years with SD 15.046. The mean duration of illness was 3.203 years with SD of 3.6904. The major presenting symptoms were spastic quadriparesis, restricted neck movements, sensory symptoms with least being LCN involvement, autonomic involvement in the descending order.

Radiological details

On radiological evaluation there were 56.3% occipitalized C1 arch, 35.8% C2-3 fusion, 46.5% platybasia, and 29.8% syrinx. There were 9.8% syndromic association, 4.2% inflammatory association. The common diagnosis were AAD with BI 57.7% (124/215), Os odontoideum with AAD 14.9% (32/215), AAD 11.6% (25/215), ACM with BI 7.4% (16/215), ACM with AAD with BI 4.7% (10/215), and ACM with AAD 3.7% (8/215) in descending order. Anomalous vertebral artery was present in 28/215 (13.0%) cases. Codominant vertebral artery was present in 51/215 (23.7%), right dominant in 102/215 (47.4%), and left dominant in 62/215 (28.8%) patients.

Procedural details

The most common procedure performed was C1-C2 (58.6%) fixation followed by O-C2-C3 (19.1%), O-C2-C4 (16.7%), O-C2 (4.2%), C1-C3 (0.9%), and O-C2-C3-C4 (0.5%) fixations in descending order. Transoral odontoidectomy was done in 7.0% (15/215) patients. Foramen magnum decompression was done in 31.6% (68/215) patients. Vertebral artery mobilization was done in 5/221 patients for proper joint remodeling and screws placement.

Postoperative computed tomography details

A total of 682 C1, C2 screws were placed in 215 patients for CVJ anomalies using K and D technique. The accuracy of screws placement by freehand technique was 84.46% (576/682). Overall malposition rate was 15.54% (106/682) and out of them the majority belonged to Grade-1 in 12.61% (86/682) followed by Grade-2 in 2.20% (15/682) and Grade-3 in 0.73% (5/682) [Table 1]. As to the direction of screw malposition, 34.90% (37/106) of the malpositioned screws were placed medially, 30.19% (32/106) inferiorly, 26.42% (28/106) laterally and 8.49% (9/106) superiorly [Table 2].

Table 1: Distribution of all screws according to SGPGI accuracy criteria

	Frequency (%) (all screws)
Grade 0	576 (84.46)
Grade 1	86 (12.61)
Grade 2	15 (2.20)
Grade 3	5 (0.73)
Total	682 (100)
Overall malposition (grade 1+2+3)	106/682 (15.54)

Table 2: Direction of malposition of screws in simple, complex craniovertebral junction anomaly group

	Frequency (%)		
	Simple CVJ group	Complex CVJ group	Overall
Superior	1 (2.94)	8 (11.11)	9 (8.49)
Inferior	9 (26.47)	23 (31.94)	32 (30.19)
Lateral	13 (38.24)	15 (20.83)	28 (26.42)
Medial	11 (32.35)	26 (36.11)	37 (34.91)
Total	34	72	106

CVJ - Craniovertebral junction

Out of 215 patients, malposition was present in 99 patients. A total of 254 screws were placed in C1 and 428 screws were placed in C2. 219/254 (86.22%) C1 screws and 357/428 (83.41%) C2 screws were placed without any bony breach. 35/254 (13.78%) of C1 and 71/428 (16.59%) of C2 screws (total 106) were found in a malplaced position, according to SAC. The malposition rates of C1 screws (13.78%) and C2 screws (16.59%) were not significant in comparison ($P = 0.328$).

Fifty-eight (27%) patients were in the simple CVJ anomaly group whereas 157 (73%) patients were in the complex CVJ anomaly group forming majority. In simple group total 208 C1, C2 screws were placed with 174 (83.65%) in grade 0 (correct placement). Total 34 (16.35%) were malplaced, with 29 (14.50%) in Grade-1, 3 (1.50%) in Grade-2, and 1 (0.50%) in Grade-3 [Table 3]. As per direction of malplacement in simple CVJ group 9/34 (26.47%) in inferior direction, 13/34 (38.24%) in lateral direction, 11/34 (32.35%) in the medial direction and 1/34 (2.94%) were in superior direction were found malplaced [Table 2]. In complex CVJ group total 474 C1, C2 screws were placed with 402 (84.81%) in grade 0 (correct placement).Total 72 (15.19%) screws were found malplaced with 57 (12.02%) in Grade 1, 11 (2.32%) in Grade 2 and 4 (0.84%) in Grade 3 [Table 4]. According to direction of malplacement in complex CVJ group 26/72 (36.11%) in medial direction, 23/72 (31.94%) in inferior direction, 15/72 (20.83%) in lateral direction and 8/72 (11.11%) in superior direction were found malplaced [Table 2]. So with technique explained the rate of malplacement in simple (16.35%) and complex (15.19%) groups were almost comparable, and the comparison difference was not significant (*P* value-0.7005). In simple CVJ anomaly group, the most common direction of malposition was lateral 13/34 (38.24%) followed by 11/34 (32.35%) medial whereas in complex CVJ anomaly the most common direction of malposition was 26/72 (36.11%) in medial followed by 23/72 (31.94%) in an inferior direction. However, the superior malposition remains the least common in both groups.

Table 3: Postoperative complications in simple versus complex craniovertebral junction anomaly patients

Postoperative complications	Frequency (%)		*P*
	Simple CVJ anomaly patients	Complex CVJ anomaly patients	
Power deterioration	4 (6.90)	11 (7.01)	0.978 (NS)
Respiratory complication	2 (3.45)	6 (3.82)	-
Wound complications	4 (6.90)	10 (6.37)	-
Total patients	58	157	-

NS - Not significant; CVJ - Craniovertebral junction

Table 4: Simple and complex craniovertebral junction group outcome (all c1c2 screws)

	Frequency (%)		*P*
	Simple CVJ group	Complex CVJ group	
Grade 0	174 (83.65)	402 (84.81)	
Grade 1	29 (13.94)	57 (12.02)	
Grade 2	4 (1.92)	11 (2.32)	
Grade 3	1 (0.48)	4 (0.84)	
Overall malposition (grade 1+2+3)	34/208 (16.35)	72/474 (15.19)	0.7005 (NS)

NS - Not significant; CVJ - Craniovertebral junction

Complications

The major complications encountered intraoperatively were cerebrospinal fluid leak in 10.7% (23/215), vertebral artery injury in 1.4% (3/215) and anaphylaxis in 1/221 patients. The most common postoperative complications were power deterioration (6.98%), wound infections (5.6%), respiratory infections (2.79%) with one patient having vision loss. 31/215 patients needed postoperative ventilatory support but eventually weaned off from ventilator. 30/215 patients were discharged with tracheostomy tube *in situ* in stable conditions. Out of 215 patients, malposition was present in 99 patients with 116 patients had all correct placement of C1 C2 screws. Complications in malpositioned screw patients were power deterioration in 11/99 (11.11%) patients, respiratory complications in 5/99 (5.05%) patients, wound related complications in 6/99 (6.06%) patients. Complications in correct screw placed patients were power deterioration in 4/116 (3.45%) patients, respiratory complications in 3/116 (2.59%) patients, wound related complications in 8/116 (6.90%) patients [Table 5]. Instrument failure at 3 month assessment in malpositioned screw patients group was 5.05% (5/99 patients) compared to

1.72% (2/116 patients) in correct screws patients group with difference being nonsignificant ($P = 0.171$).Vascular injury involving vertebral artery injury occurred in 3/215 (3.03%) patients all in malplaced screws patient group with complex CVJ anomalies. The difference between power deterioration rate between malplaced and correct screws patient group was significant ($P = 0.0284$) with more rate in malplaced screws patient group. 58 (27%) patients were in the simple CVJ anomaly group whereas 157 (73%) patients were in the complex CVJ anomaly group. Complications in simple CVJ anomaly patients were power deterioration in 4/58 (6.90%) patients, respiratory complications in 2/58 (3.45%) patients, wound related complications in 4/58 (6.90%) patients. Complications in complex CVJ anomaly patients were power deterioration in 11/157 (7.01%) patients, respiratory complications in 6/157 (3.82%) patients, wound related complications in 10/157 (6.37%) patients [Table 3].The power deterioration rate in simple and complex CVJ anomaly group were not significant ($P = 0.978$).

Outcome

The outcome was assessed with preoperative and postoperative nurick grading at 3 months follow up. In preoperative period most common nurick grading were grade 3 (35.8%) followed by grade 4 (34.0%), grade 5 (15.8%), grade 6 (6.5%), grade 2 (5.1%), grade 1 (2.3%), and grade 0 (0.5%) in descending order [Figure 2].In postoperative follow up at 3 months the common nurick grading were grade 3 (43.7%) followed by grade 4 (15.8%), grade 2 (14.9%), grade 6 (10.7%), grade 5 (9.3%), grade 1 (4.7%), grade 0 (0.9%) in descending order. According to nurick grading comparison preoperative and at 3 months' postoperative period 37.21% (80/215) patients had improvement, 55.35% (119/215) patients had same nurick grade as preoperative grade and 7.44% (16/215) had deterioration in nurick grading. The mean nurick grading preoperative and postoperative at 3 months were 3.74 and 3.40 respectively.

DISCUSSION

Shifting from the anatomical landmarks to tailored technique

There are various methods described for posterior fixation in CVJ pathologies. Among all the most popular methods is Goels–Harm technique.[11] This technique is usually performed under fluoroscopic guidance with or without neuronavigation. The adjuncts used for fixation offer a safe and accurate placement of screws. As per our study, authors have emphasized that good understanding of anatomical landmarks followed by exercising the same in anomalous anatomy with complete exposure and palpation of the articular mass of interest is the key to place safe and accurate screws with acceptable rate of complications described in literature.[5,9,10,12-14] In our series, the authors have emphasized the following points to understand the detailed anatomy and orientation of C1 LM and C2 Pars or pedicle to purchase it safely. Normal craniometric points cannot be easily reproduced intraoperatively in CVJ

Table 5: Postoperative complications in correct versus malplaced screws patients

Malposition-related complication	Frequency (%)		*P*
	Malplaced screws patients	Correct screws patients	
Power deterioration	11/99 (11.11)	4/116 (3.45)	0.0284 (significant)
Vascular injury	3/99 (3.03)	0/116	-
Instrument failure at 3 months	5/99 (5.05)	2/116 (1.72)	0.171 (NS)

NS - Not significant

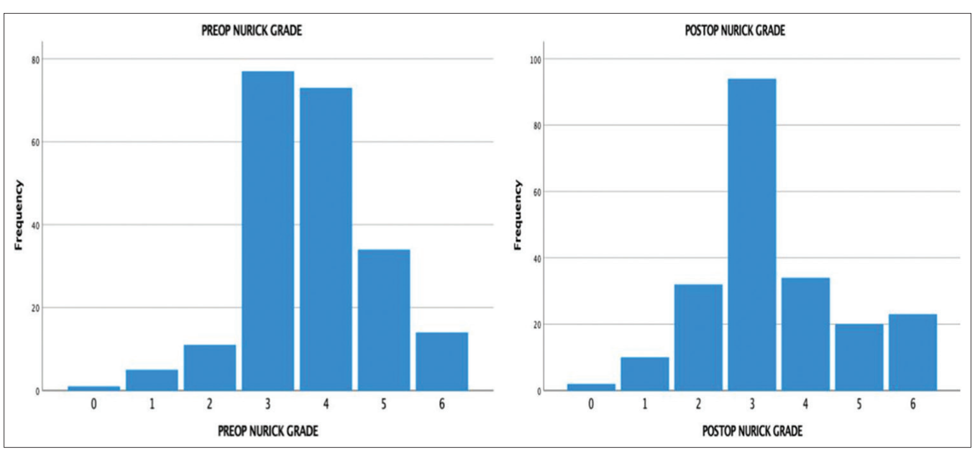

Figure 2: Distribution of patients according to Nurick gradings in preoperative and at 3 months' postoperative period

anomalies because of distorted anatomy of the region. These patients have multiple associated anomalies such as occipitalised C1 (posterior arch fused to occiput), anterior C1 tubercle fused with clivus, hypoplastic or short C1 LM, unilateral hypertrophied C1 LM, Joint rotation, C2-3 fusion, hypoplastic or thin C2 pars/pedicle, anomalous vertebral artery course (high riding vertebral artery, single dominant vertebral artery) etc.[15,16] In such patients with anatomic deviations malposition can lead to internal carotid artery, vertebral artery and neuroaxis injury. Identifying the entry point of screws and their trajectory based on craniometric points and fluoroscopic guidance can be difficult in these patients with CVJ anomaly. Adhering to the basic technique of visualisation of C1 LM and C2 pars/pedicle, defining the lateral, medial, superior and inferior limits with direct assessment of axial, coronal and sagittal orientation of C1 LM, C2 pars/pedicle after opening of the C1-C2 joint with or without vertebral artery mobilization are very much helpful in identifying the entry point, trajectory and straightforward screw placement. These techniques, however, rely almost exclusively on visual and tactile feedback from a pedicle probe to guide both the medial-lateral and cephalic-caudal trajectories. The important landmark to identify the entry point of C1 LM which is like a Cuboid mass is junction of C-1 LM with posterior arch representing C1 pedicle [Figure 3] and if you want to preserve C-2 nerve root you can directly drill through the pedicle, which is attached to the LM.[13,17] The chasing anterior tubercle in sagittal/Lateral plane by utilizing fluoroscopy during the surgery to score C-1 LM in cases of complex CVJ anomalies on several occasions is difficult as there is assimilation of anterior arch in most of the cases. In these situations, the surgeon should look for the end plate of C-1 facet which is normally concave. There should be drilling of facet edges to shave off the cartilage to make it flat. To define the orientation of LM follow the direction of the inferior end plate of C-1 LM. Further accuracy is enhanced by the exposure or palpation of the medial and lateral border of the LM. The height of the LM is anticipated by understanding the fact that about 50% of LM lies above the junction of the C1 pedicle to the LM. For defining entry point and trajectory of C2 screws the exposed medial border of pars medially and Vertebral artery (VA) with its foramen laterally gives enough information about the width and axial orientation of the pars [Figure 4]. While the pedicle of C2 can be easily defined and thus the entry point is selected under vision avoiding any possibility of VA injury or neuraxis injury, the exact medial-lateral angles and cephalad-caudal trajectories remain subject to surgeon preference. The exposed C1/C2 joint with exposed superior endplate of C2 gives further information about sagittal orientation of the pars [Figures 1 and 4]. With this information and by applying K and D technique, the accurate C1, C2 screw placement can be done.

Need of a stringent grading criterion for craniovertebral junction screw accuracy

Many criteria of screw malposition in different parts of the spine are defined accordingly.[2,9] However, literature is lacking a dedicated criterion that can measure the malposition of screws exclusively for CVJ region. The peculiar anatomy of CVJ region owes a need for stringent and specific criterion which can address the malposition of screws in all four directions (medial, lateral, superior, and inferior), unlike the other areas of the spine where only medial and lateral malposition were focused more.[2,9] The major complications which can arise after the malpositioning of screws are neuroaxis injury in the form of power deterioration, vertebral artery injury, hypoglossal canal injury and instrument failure. To address these issues authors have proposed a new "SAC" for CVJ region screws as described in the methodology section. In these criteria, G-0 is defined as a correctly positioned screw while malpositioning was graded from G-1 to G-3. This criterion is very robust as it is capable of reporting the breach in all four directions and minimal malposition (even less than half diameter of screw) by studying each screw on axial as well as sagittal cuts of CT scan. The criteria will not only help to pick the malposition of screws but also can predict the potential complications which can arise due to malposition subject to further validation by studies.

Is it really effective?

Overall malposition rate in our study was 15.54%, comparable to 14.8% malposition rate under fluoroscopy guidance in a study done for cervical pedicle screws placement by Hojo *et al*.[2] An interesting fact was noticed following screw insertion based on above-explained technique and observation is that the malposition rate is comparable or even less (15.19%) in the complex CVJ group than the simple CVJ group (16.35%). As per Hojo's study of screw placement under fluoroscopic guidance, the most common direction of malplacement was lateral (79.7%) followed by medial (19%) and superior (1.3%), respectively, with no screws placed inferiorly.[7] However, in contrast to the above study, in our study (K and D freehand technique), the most common direction of screw malposition (overall) was medially (34.91%) followed by inferiorly (30.19%), laterally (26.42%) and superiorly (8.49%), respectively.

On further study between simple and complex groups, the most common malposition direction in the simple CVJ group was lateral followed by medial, while it was medial followed by inferior in complex CVJ group, with superior remaining least common in both groups. The rate of accurate screw placement by K and D technique without use of fluoroscopic or neuronavigation guidance was comparable to the large studies published in

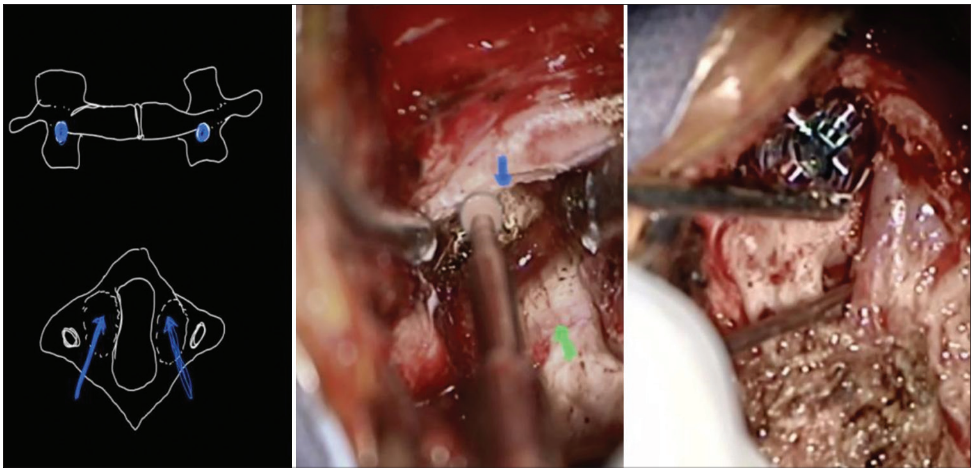

Figure 3: First image showing entry point (blue dot) for C1 LM screw and direction (blue arrow). Second image blue arrow showing the entry point for C1 LM screw placement. Drilling of the inferior facet of C1 is shown to see sagittal orientation with medial (suction tip) and lateral borders exposed to see axial orientation for direct screw placement. Green arrow showing C2 pars. Third image showing C1 LM screw placed

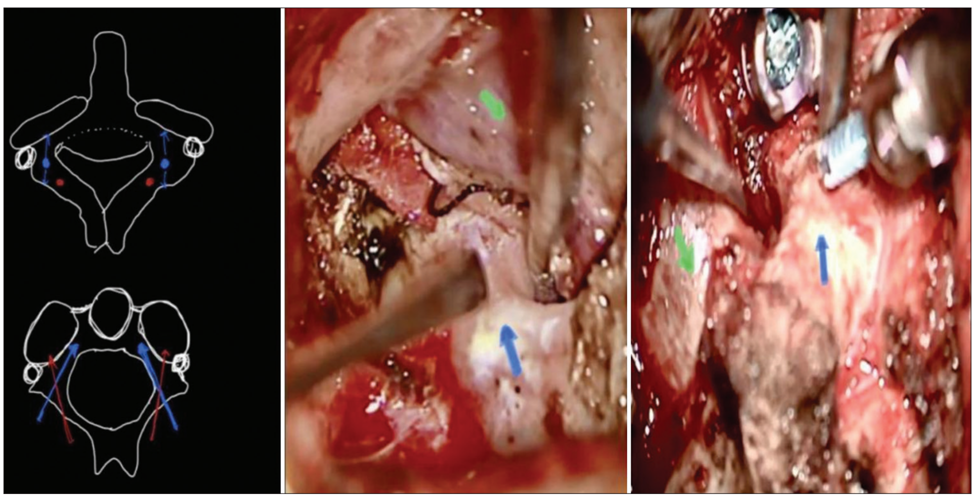

Figure 4: First image showing entry points for C2 pedicle screw (blue dot) and C2 pars screw (red dot) with direction for C2 pedicle screw (blue arrow) and C2 pars screw (red arrow). Second image showing medial border of C2 pedicle with the dissector tip and blue arrow showing the pedicle. Third image showing the entry point for C2 pedicle screw insertion

literature.[1,4,5,9,10,13,18] The power deterioration rate was found statistically significant in malplaced screws group than correct screws placed group, Interestingly, only 4 breached screws was found malplaced medially that is directed towards neuraxis out of 20 malpositioned screws in grade 2 and 3 in total. This observation suggests that power deterioration is multifactorial. Probably, the factor responsible was not only the malpositioned screws, but the inherent complexity and incomplete biomechanical addressal of deformity added to the deterioration in the power. Hence, the correct screws placement is paramount to avoid neurological deterioration as seen with malposition and correct group outcomes.

The most important point to be noted that ours is a unique study where the free hand technique was utilized in anomalous anatomy while the study quoted by Hojo *et al*. and others, the technique was used in mixed cases, and they have utilized fluoroscopy as well.[1,2,4-6,9,10,13,18]

Advantages versus disadvantages

This practice can significantly cut down the fluoroscopy hazards to both the patient and health-care personnel involved in the operating room. As no fluoroscopy or neuronavigation systems used, this automatically reduces the duration of the surgery, number of healthcare personnel involved, prolonged prone position-related complications, prolonged anesthesia-related complications and indirectly improving patient outcome and reducing the infection rate (instrument and operating room related).We have encountered intraoperative vertebral artery injury incidence 1.4% that is in 3 cases without any mortality and morbidities. Fortunately, all these patients were of co-dominant VA. We would like to emphasize the importance of the preoperative

3D CT Angio workup and being very careful in cases of anomalous vertebral artery course and/or single dominant VA cases. As the free hand technique described here is a nothing but classical microneurosurgical procedure under high magnification to directly visualize or mobilize the VA during dissection and instrumentation is practiced in our centre probably is the explanation for the acceptable VA injury rate. We recommend the dissection and exposure on the dominant side first as surgeons used to be relatively less tired and more careful. This approach is helping us in tailoring the procedure and exploring new domains like the oblique approach and VA mobilization.

Uniqueness

This study validates the open hand technique (K and D) for putting C1 LM screw and pars or pedicle screw as described first by Goel harms. This is the largest study validating the accuracy of the open hand technique and concludes that it is not only accurate but also a mandatory step to avoid the malposition in the complex CVJ anomalies attempted with fluoroscopy. The CVJ anomalies are common in poor socioeconomic status patients. The developing country where cost-effectiveness with 3D model, O-arm, and other navigational tools are of greater concern, this study defies use of all these modern gadgets along with the fluoroscope in cases of CVJ instrumentation where a bicortical robust purchase is required.

Cost effective

This practice is more cost-effective and time-saving considering the profile of the patients (poor socioeconomic status) and considering our national policies. The cost-cutting will remain a major advantage as these anomalies are more common in developing countries with non uniform insurance coverage.

Knock and drill technique: Alternative or necessity

Instrumentation in anomalous CVJ poses various challenges owing to its anomalous variables such as articular masses, various kinds of bony assimilation, tilt, rotation, and vascular anomalies. Following the normal craniometric points with fluoroscopic guided trajectories is not going to help much, in contrast, can deceive a surgeon and can lead to life-threatening conditions such as vertebral artery injury or myelopathy. The best possible option seems to be neuronavigation-guided screw placement to avoid the said mishappenings. However, literature is scarce, with few reports advocating O-arm navigation guided screw placement with best results of 90%–95% accuracy observed in single plane. We would like to highlight that the accuracy rate with free hand technique was 84.46% in our study, strictly observed in all the three planes justifying its accuracy at par or maybe better than navigation. The CVJ anomalies are a disease of poor socioeconomic status and seen in developing countries where the cost effectiveness and availability of these costly surgical equipment has been a great concern. Hence, considering other added advantages mentioned above we think the free hand (K and D) technique proposed by us for the CVJ anomalies is not an alternative rather it is a necessity.

New avenues

The new 3D model simulated surgical instrumentation technique is nothing but actually promoting the freehand technique and is easily reproduced with intraoperative exposure and planning as described in our technique.[19] A nice preoperative 3D reconstruction image interpretation of anatomy and vertebral artery course can cut down even the use of costly 3D Printing. This freehand technique also helps in better understanding of C1-C2 joint orientation in relation to the C2 ganglion and helps us to preserve it in most of our cases.

CONCLUSION

The freehand technique, as described, is effective in cases of anomalous bony anatomy, and it is mandatory in complex CVJ anomalies. The accuracy of screw placement and VA injury is comparable with major studies. This technique is supposedly cost-effective and less hazardous to both health-care workers and patients.

Limitation

A retrospective study was done at a high-volume center where cases were operated on by surgeons having exclusive exposure to CVJ surgeries for more than 5 years.

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Conflicts of interest

There are no conflicts of interest.

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