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Subaxial cervical spine ligamentous instability anterior versus posterior fixation: prospective nonrandomized study

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Abstract

Background: The goals of cervical internal fixation are to provide immediate stability to control an unstable segment and to improve bony union. Early cervical fixation methods preferred a posterior approach and consisted of simple wire and cancellous bone graft. Later, anterior, and posterior fixation became recent additions to surgeon's armamentarium.

Objectives: Comparing between anterior and posterior fixation in cervical subaxial ligamentous subluxation regarding the applicability, safety, and clinical efficacy in achieving stability and enhancing bony union. Also cost-related variables are studied.

Methods: This prospective clinical and radiographic analysis was performed on 40 patients with cervical subaxial ligamentous subluxation. Half of these patients were treated with anterior cervical fixation and interlocking screws with inter-body cage fusion. The other half was treated by posterior fixation with lateral mass fixation and inter-facet bone fusion.

Results: There were 27 male and 13 female patients with mean age 37.4 years. The level of cervical dislocation was C4–5 in four, C5–6 in 14, C6–7 in 20 and more than one level in two patients. Closed reduction was achieved in 33 patients while open reduction through the posterior approach was done in four cases and through anterior approach in other three cases. Statistically significant difference between the two groups was found for estimated blood loss and operating room time with better results in the anterior group. There were no perioperative deaths in both groups. Regarding surgery-related complications, there was injury to a cervical root during posterior fixation in two cases. There was no statistical difference between the two groups regarding the length of the hospital stay. The mean hospital stay was 7 days. Positioning of the plate and screws in all cases was satisfactory. All patients were followed up for at least 6 months. Mean follow-up period was 13 months. Vertebral body alignment (radiological stability) was achieved in all cases with anterior fixation while one case with posterior fixation showed delayed subluxation. Solid bony cage fusion was found in 85% with anterior fixation and solid bony fusion in 70% with lateral mass fixation.

Conclusions: Although some of the literature have indicated that posterior fixation in ligamentous cervical subaxial injury is more solid than anterior fixation, yet most of these studies were done on cadaver subjects so eliminating any bony fusion, long-term stability, and hardware failure. This study proved that anterior cervical fixation is not only safer and simple procedure than posterior fixation, but also it restores the cervical stability better than the posterior fixation.

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Keywords: Cervical subaxial subluxation, Ligamentous injury, Anterior fixation, Lateral mass fixation

Background

The goals of cervical internal fixation are to provide immediate stability to control an unstable segment, improve bony union, correct spinal deformity, and decrease the need for cumbersome bracing. Before the advent of spinal instrumentation, many of the cervical subluxation injuries were managed with traction, postural reduction, or external orthoses with frequent success. However, the morbidity and mortality associated with prolonged immobilization for 3 months, prompted surgeons to investigate the usefulness of internal fixation in the management of these injuries [1, 2]. Furthermore, ligamentous disruption is associated with an increased likelihood of failure of external immobilization (as Hało vest or Minerva cast) in the treatment of these injuries [3, 4].

Early cervical fixation methods prefer the posterior approach and consist of simple wiring and cancellous bone graft. Later, wire was combined with structural contoured rods. Recently screw–plate constructs have been used successfully in fixation of the cervical spine either through anterior or posterior approach. In cervical subaxial ligamentous subluxation, some authors recommended posterior cervical arthrodesis and stabilization with lateral mass plates as it is a biomechanical sound construct in multiple planes of motion [5, 6]. While several recent studies have shown that anterior cervical fixation offers equal biomechanical stability to posterior lateral mass fixation [2, 3, 7].

The surgeon must choose an appropriate approach on the basis of the mechanism of injury, the patho-anatomy of the lesion and his familiarity with the technique and device, keeping in mind the goals of internal fixation and fusion, which are reduction and maintenance of alignment, early rehabilitation and perhaps enhancement of fusion and avoidance of the need to use an external orthoses [8]. Also the surgeon should select the optimal type of implant on the basis of the advantages and potential risks of each type [6].

Aim of the work is to compare between anterior cervical fixation with cage fusion and posterior lateral mass fixation with bone fusion in the treatment of subaxial cervical ligamentous subluxation in terms of efficacy in maintaining stability and enhancing bony fusion, morbidity, and significant cost-related variables.

Methods

From January 2019, through January 2021, 40 patients presenting to El-minia university hospitals with ligamentous subaxial cervical dislocation (C3–C7) were chosen to participate this prospective study. Among all cases presenting with subaxial cervical spine, dislocation patients who fulfilled the following criteria were selected: (1) patients who had sustained significant ligamentous injury based on MRI assessment with minimal or no bone disruption; (2) no associated cervical disc herniation; (3) no spinal canal stenosis due to degenerative spondylosis at the level that may mandate posterior approach rather than anterior; (4) no associated connective tissue or bone disease (rheumatoid arthritis or marked osteoporosis). Those 40 patients were later subdivided into 2 equal groups: first group was treated by anterior cervical fixation and the second group treated with lateral mass fixation. Deciding which approach to use was based on the site of compression if present, otherwise random selection was used. In the first group cage bony fusion was used and in the second group inter-facet bony fusion was used.

All patients were subjected to full history, general and neurological examination. Plain radiographs computerized tomography scans and MR images of the cervical spine were obtained in all patients.

Following radiographic evaluation, all patients indicated for traction—according to radiological evaluation—were put on skull traction using Gardner–Wells tongs to achieve alignment of cervical spine while cervical hard collars were used in patients not indicated for traction. Patients who presented with complete or incomplete spinal cord injury (SCI) were treated using the standard high-dose methyl prednisolone protocol according to the policy of our department and guidelines outlined in the national acute spinal cord injury study [9]. After stabilization of the patient's general condition all patients underwent a surgical procedure in which reduction of the dislocation if still needed and stabilization of the spine were performed.

Patients with locked facets, preventing alignment of spine despite the standard measures used for closed reduction underwent surgery for open reduction and fixation either through anterior approach or posterior approach. All patients underwent surgery within 48 h of admission except if there were general contraindication of early surgery. Reduction of the locked facet through anterior approach was done through inter-body spreader causing more distraction and then upward angulation to return the facets into position. While in posterior approach, the technique for open reduction of the locked facet consisted of a partial or complete facetectomy. In cases with anterior cervical fixation right-sided approach was used in all cases. Transverse oblique neck skin

incision was used when single-level fixation was needed while longitudinal incision for two-level fixation.

The technique of screw insertion in posterior fixation was similar to that used by Tessitore et al., which has been shown to be the safest in avoiding danger to the nerve root, facet and vertebral artery [10]. Drilling is initiated at a point 1 mm medial to the medial portion of the lateral mass and proceeded along the course 15 cephalad and 20–30 lateral. This trajectory affords reasonable protection of the neurovascular structures while obtaining sound screw purchase in the articular masses.

In anterior cervical fixation, the plate of an appropriate length was selected such that the bone screw entry points were located approximately in the mid-portion of each vertebra. Fixation systems with interlocking screws were used with cage bony fusion where the cage was filled with bone from the osteophytes of the affected vertebrae. While in posterior fixation with lateral mass fixation bone from the spinous processes was used to achieve bony union after curettage of the facet surface. All cases were done under C-arm image control. A short neck collar was worn postoperatively for short period (2–3 weeks) for post-operative pain relief.

The follow-up period was at least 6 months in each case. Solid fusion status was considered to have been achieved when a homogeneous fusion mass could be visualized on lateral X-ray films. Clinical and radiological cervical stability had been defined when all the following three parameters were fulfilled: (1) there was no segmental motion on flexion extension films after at the 6-month follow-up visit; (2) there was no progressive deformity during the follow-up period; and (3) there were no new symptoms or signs of neurological deterioration.

Results

27 male and 13 female patients ranged in age from 19 to 60 years (mean 37.4 years). 22 of the patients were involved in road traffic accident and 18 patients were injured in a fall from height or during diving.

24 patients presented with myelopathy and radiculopathy; 8 of them were complete spinal cord injury. 11 patients had only radicular affection, and 5 patients were neurologically intact. The level of cervical dislocation was C4–5 in 4 patients, C5–6 in 14 patients, C6–7 in 20 patients and more than one level in two patients, one of them had cervicodorsal junction fracture (C7–T1 level) in addition to C6–C7 dislocation (Table 1).

Satisfactory reduction of misalignment through skeletal traction was achieved in all cases except seven. In these patients open reduction was done before fixation. Open reduction was done in 4 cases during posterior fixation and in the other three cases through anterior approach.

Table 1 Incidence of subaxial dislocation level

Level of this dislocation	Number of patients	Percentage (%)
Single level		
C4–5	4	10
C5–6	14	35
C6–7	20	50
Multiple levels	One patient each	5
C3–4, C4–5		
C5–6, C6–7		

Table 2 Average operative time

Operative step	Anterior approach		Posterior approach	
	Mean time	Range	Mean time	Range
Anaesthesia and positioning	15	10–25	28	15–35
Exposure	44	30–57	50	33–68
Instrumentation	14	10–31	29	23–44
Closure	8	5–13	21	15–45

No further difficulty was encountered during facet reduction through anterior vs posterior approach.

Average operative time for the posterior operation was 140 min (range 110–225 min), and the average intraoperative blood loss was 230 ml (range 80–760 ml).

On the other hand, in anterior fixation group the average operative time was 93 min (range 64–142 min) and average blood loss was 100 ml (range 50–240 ml) statistically significant differences between loss and operating room time (p value > 0.05). Comparison between the two approaches regarding the time mainly in four steps was done: (1) anaesthesia and positioning, (2) exposure: from skin incision till being ready for instrumentation, (3) instrumentation, (4) closure (Table 2).

Postoperative pain (neck pain in posterior group and throat pain in the anterior group) was more in posterior fixation group in comparison to the other group (18 patients in posterior vs 11 patients in anterior group).

There were no perioperative deaths. There were no surgery-related complications except in two cases there was evidence of new post-operative cervical root injury after posterior fixation. In these two patients post-operative X-ray and CT cervical spine failed to show misplacement of the screws. One of these two patients had C6–C7 fixation and the other had C4–C5 instrumentation, they were treated conservatively.

Regarding the length of the hospital stay there was no statistical difference between the two groups. The mean hospital stay was 7 days (range 3 to 9 days). Any hospital stay for just physical therapy was not included. The

ratio between the average cost of the posterior fixation systems and anterior systems was 1:1.6.

Clinical follow-up evaluation revealed no change in neurological status in 11 patients and improvement in 27 patients. In the 8 patients who presented with complete cord injury, there was no improvement in neurological status postoperatively, except for recovery of nerve root function at the level of injury in two cases. In two cases there was post-operative new nerve root affection (presented mainly by sensory dysesthesia) that was partially improved by medications. Both of them were approached posteriorly (Table 3).

Early post-operative X-ray cervical spine showed satisfactory position of the plates and screws in all cases. All patients were followed up for at least 6 months. Mean follow-up was 13 months. The vertebral body alignment was normal in all cases with anterior fixation while 1 case with posterior fixation showed delayed subluxation (3 months after surgery). In this case, multiple levels fixation (from C5 to C7) was done and delayed subluxation was due to pull out of the screws inserted in C7 lateral mass. This patient had another surgery with removal of the posterior instrumentation followed by anterior fixation. There was no hardware failure except in the previously mentioned case. In that case, loosening of one screw had occurred leading to delayed subluxation.

Solid cage fusion and bony union could be suspected at the latest follow-up X-ray (minimum follow-up was 6 months) in 17 patients with anterior cage fusion (85%) and in 14 cases with posterior fusion (70%). So, the ratio of pseudoarthrosis (no definite solid bony union in follow-up X-ray after at least 6 months) between anterior and posterior group was 1:2.

All cases with anterior fixation and follow-up X-ray failed to show solid cage bony union were clinically and radiologically stable. All these cases showed no radiological instability in dynamic plain X-ray cervical spine.

Moreover, there was no new neurological symptoms related to the improper cage fusion, while one case with posterior fixation and no definite solid bony union showed delayed instability (Table 4).

Table 3 Clinical outcome

Outcome	Number of patients	Percentage (%)
Improved	27	67.5
Stable	11	27.5
Deteriorated	2	5

Discussion

Many anterior or posterior techniques can be used for cervical spine stabilization. Several decisions are required for the successful planning of surgery. The surgeon must determine whether the neural elements need to be decompressed, whether the spinal architecture needs to be rebuilt and whether instrumentation is necessary. Moreover, it is necessary to consider the risks inherent in the various treatment methods available. The goals of cervical internal fixation are to provide immediate stability and to enhance the bony union. These goals should be achieved with a single approach whenever possible [11].

In ligamentous subaxial cervical subluxation there are two points making posterior approach in treating these cases more considered than anterior fixation. First, theoretically, it is appropriate to use the posterior approach to treat instability resulting from injuries to the ligamentous structure of the facet joints where either only the posterior column was disrupted (in facet subluxation) or the three columns were disrupted (in facet dislocation) [12]. So in facet dislocation the only structural maintaining some integrity maybe the anterior spinal ligamentous complex, so surgical intervention should not disrupt the intact structures and increase the instability and stress on a fixation construct [7, 13, 14]. However, recent studies stated that "the only absolute indication for the approach for stabilization (anterior vs posterior) is the site of compression".

Second point favouring posterior approach in treating subaxial cervical ligamentous subluxation is the feasibility of unlocking the locked facets in cases with failed closed reduction by traction [14]. However, many authors now showed successful reduction of the locked facets through the anterior approach also [2, 15].

In this series, closed reduction was achieved in most cases. There were 7 cases (17.5%) in which skeletal traction was not sufficient to achieve closed reduction of

Table 4 Achievement of stability and bony union in late follow-up

	Anterior fixation cases with cage fusion	Lateral mass plate in cases with bone effusion
Clinically and radiologically stable spine with solid bony union	17	14
Clinically and radiologically stable spine without solid bony union	3	5
Unstable spine	0	1
Total number	20	20

the cervical facet dislocation. Successful open reduction of the dislocated facets was achieved through the posterior approach (in four cases) or the anterior approach (in three cases). Many authors had an overall incidence of failure of closed reduction about 26% [14, 16–18]. Previously it was thought that failure of closed reduction in locked cervical facets mandate posterior approach to unlock the facets, but a recent series proved that ventral surgical reduction, and stabilization procedures provide the safe and effective alternative to the posterior approach even those cases [3, 4].

The differences between the two groups of patients regarding the estimated blood loss and the operating room time were statistically significant in favour with the anterior approach. It was found that the time of positioning in posterior approach was nearly double that in anterior approach with more risk of re-subluxation during turning the patients to the prone position. Zeidman and his co-workers reported that 60% of cervical spine operations were done anteriorly and 35% are done posteriorly, leaving some 5% to be some kind of a combination procedure [19]. This may point to the fact that the learning curve of anterior fixation is much faster than that of lateral mass fixation because the first approach is used more frequently with cervical disc pathology. Although there were no cases with infection in the primary wound site (neck incision), it is well-known that operative time is an important factor in controlling the incidence of intraoperative infection. This might explain the high infection rate reported in some series with posterior fixation (4–22.2%) [4].

In many series, operative complications related to the insertion of lateral mass plates and screws are mostly limited to injury to neurovascular structures [12]. The incidence of root injury during lateral mass fixation varied in the different series. It ranged from 0% in few series [13] to 25% risk per patient [20]. Graham et al. reported in 1996 on the use of 164 screws in 21 patients and found a 1.8% per-screw risk of radiculopathy that is translated to a 14% risk per patient for post-operative radiculopathy [12]. Even in comparing different methods for applying the screws in lateral mass fixation, it was found that there was always a high incidence of root injury. The overall percentage of nerve violation was significantly higher with Magerl and Anderson techniques than with the technique used in this series [21].

Root injury had been attributed either to direct root injury [18] or to "iatrogenic foraminal stenosis" secondary to a lag effect occurring at the formina as lateral masses were pulled toward the plate during screw purchase [2]. In this study, the neurovascular complications encountered were root injury into cases (10%) with posterior fixation while there were no complications after anterior fixation. As there was no misplacement of screws in the post-operative X-ray and CT cervical spine in these two patients; it was assumed that the radiculopathy that happened was secondary to this lag effect. Also one of these two patients had C6–C7 and it was reported that at C7 the lateral mass is small and the lateral mass screw in this site increase the risk of a C8 radiculopathy [20].

Lateral mass fixation required application of the screws in a predetermined entry point and if for the variability of the anatomy the two-hole plate was not fitting over these predetermined points one either will move the entry point with increasing risk of vascular injury or will use a 3-hole plate with extra level stabilization. It was proved that the inter-facet distances from the centre of the lateral mass to the next lateral mass from C3 to C7 vary between 9 and 16 mm (average 13 mm). This may lead to malposition of the screws with increased risk of neurovascular injury [10].

Reported complications for lateral mass fixation included lateral mass fractures in 6% to 7% [21] and vertebral artery injury with bicortical screws in about 6% [13, 22] while recently with interlocking screws this incidence became negligible [1].

On the other hand, in the group of patients with anterior fixation there was no neurovascular or any soft tissue injury. Lowery and his co-workers reported in their study in 1998 with 109 patients with anterior fixation no single case with injury to soft tissue structures of the neck including the oesophagus trachea and vessels. Moreover, they reported 35% hardware failure and despite this failure, no patient experienced trachea-esophageal erosion or neurovascular compromise [10].

Both group of patients showed good post-operative alignment and the hardware (either anterior or posterior) maintained this alignment in early postoperative period and after removal of the traction. Only one case (5% of patients with posterior fixation) showed delayed subluxation due to screw loosening. The incidence of this complication in similar series ranged from 1.1 to 11.4% [2]. This patient had multiple levels fixation (from C5–C7). Heller et al. found decreased pullout strength for lateral mass screws inserted at both of C2 and C7 levels [17]. Also the increased rate of screws pullout in these two cervical levels encourage neurosurgeons to use pedicular screws instead of lateral mass screws in these levels [21].

In this series, although solid bony union in the latest follow-up X-ray could not be suspected in 9 cases (3 patients with anterior fusion and 6 patients with lateral mass fixation), yet instability occurred only in one case. No cage fusion was encountered in 15% of the anterior fixation and 30% in lateral mass fixation. In similar series cage bony fusion with anterior fixation was confirmed in

95% after 12 months and 100% after 36 months [19]. So longer follow-up period may improve the incidence of solid cage fusion in this series. Also, in the literature it was found that determining the existence of a solid cage bony union following attempted fusion can be extremely difficult as routine radiography was notoriously inaccurate and the gold standard was surgical re-exploration [23].

The higher incidence of pseudarthrosis with lateral mass fixation may be secondary to the small surface area in which the bone chips were put (inter-facet). While in anterior fixation the contact surface area between the cage and the vertebrae were larger (inter-body) enhancing cage bony union. However, pseudarthrosis was not encountered in either anterior or lateral mass fixation in other series with longer follow-up periods [4].

In the literature, among all patients with subaxial cervical injuries treated operatively, it was found that anterior cervical fixation procedures were associated with less failure to maintain stability when compared with posterior cervical fusion (0 to 5% versus 3 to 14%, respectively) [1, 3, 13, 14, 16].

Yet some studies stated posterior fixation was better than anterior fixation in terms of the stability in ligamentous injury [4, 12]. Also other studies have suggested that anterior plate reconstruction for flexion injuries (resulting in concomitant posterior ligamentous disruption) should be supplemented with posterior instrumentation [5]. However most of the studies that recommended posterior instrumentation in ligamentous injury were in vitro studies that ignore the most important point in instrumentation which is bony union which is the main goal of these surgeries [11, 15, 18]. In contrast, clinical studies have shown the successful use of isolated anterior fixation in patients with traumatic posterior ligamentous disruption [6].

Although there was no kyphotic deformity in both anterior and posterior group, the literature revealed the good number of cases with ligamentous subluxation patients had spondylotic cervical spine with kyphotic deformity. It was proved that lateral mass plates and screws were frequently ineffective in the treatment of fixed or progressive kyphotic deformities and patients with such a condition were generally managed by an anterior approach using distraction to reduce the kyphus [19]. The incidence of kyphotic deformity of the anterior fixation was 0% in many series [13, 14, 16]. In contrast, the incidence was up to 4% of the posterior fusion with lateral mass plate fixation [2, 19].

Dissatisfaction from lateral mass fixation, especially at the cervicothoracic junction and presence for some opposing series to anterior fixation alone in cervical ligamentous subluxation, have led spine surgeons to use cervical pedicle screw fixation for reconstruction in some of these cases. Advantage of pedicular screws is the three-column fixation it achieves [16]. In two published studies involving a total of 52 patients with cervical pedicle screw fixation reported there was no complications involving the spinal cord, roots, or vertebral artery. This appears to be promising, however, because it is a newly developing technique and long-term follow-up has not been established, it is difficult to compare this method of fixation was that of lateral mass fixation [24, 25].

Conclusions

Although some of the literature have indicated that posterior fixation in ligamentous cervical subaxial injury is more solid than anterior fixation, yet most of these studies were done on cadaver subjects so eliminating any bony fusion, long-term stability, and hardware failure. As far as we know this study is the first clinical study that compared between anterior cervical fixation and lateral mass fixation in patients with ligamentous cervical subluxation. It proves that anterior cervical fixation is not only safer and simple procedure than posterior fixation, but also it restores the cervical instability and enhances bony cage fusion better than the posterior fixation.

Abbreviations

SCI: Spinal cord injury; ACDF: Anterior cervical disc fixation; MRI: Magnetic resonance imaging; CT: Computed tomography.

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Author contributions

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Availability of data and materials

Data are available at the Department of Surgery—Faculty of Medicine—Minia University.

Declarations

Ethics approval and consent to participate

An informed written consent was taken from each patient prior to the operation. This consent was done according to the guidelines of Faculty of Medicine Research Ethics Committee (FMREC), Minia University, El-Minia, Egypt. With MUFMIRB No. 341-2018.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflicts of interest.

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