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REVIEW

Cervical spinal cord injury: comparative study on the optimal surgical approach based on the level of injury

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ABSTRACT

Anterior and posterior surgical approaches are used for immobilization of the unstable features of the cervical spine. The choice for optimal approach is still under discussion. Each procedure has advantages and disadvantages and the surgeon must be aware to make the right decision to assure patient's safety.
Intraoperative evaluation of reduction is essential to ensure satisfactory postoperative outcomes. However, immediate postoperative neurologic improvement is rare for patients with preoperative neurologic deficit and thus postoperative rehabilitation for improvement of motor and neurologic dysfunctions is imperative. Literature data report minor or severe intraoperative and postoperative complications for cervical spine surgery. The purpose of this mini review is to provide literature data on cervical spinal cord injuries and assess optimal surgical treatment based on cervical injury level. Moreover, the rate of postoperative complications and recovery time will be discussed.

KEY WORDS: Cervical spine injuries, Fusion, Instrumentation, Spinal cord injury, Rehabilitation

Introduction

The Cervical Spine consists of seven vertebrae (C1-C7) and supports the weight of the head (approximately 14 pounds). The first and second vertebrae, the "atlas" and "axis", do not have a disc between them, but are tightly bound together by a ligamentous complex [2]. The C1 (atlas) 'ring' rotates around the odontoid or 'peg' of C2 (axis), allowing for almost 50% of total cervical rotation. The spinal canal is housed within the cervical vertebrae and is widest between the C1 and C3 levels (A-P diameter 16-30 mm) and narrows as it progresses caudally (14-23mm). When the neck is fully extended, this canal can narrow an additional 2-3mm.

Traumatic spinal cord injuries (SCI) cause high morbidity and mortality worldwide. Common mechanisms include vehicular crashes, followed by falls, violence and sports and/or other recreational activities. Up to 80% of patients with SCI suffer multisystem trauma and require special considerations due to the risk of secondary cord injury from hypoperfusion and hypoxemia. Upon stabilization,

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Figure 1. *Cervical Spine Injuries. Dislocated Facets with posterior lateral mass screws and rods (A1 & A2). Burst fracture of C5 and anterior plating with screws (B1& B2).*

decisions for surgical decompression and/or spinal column stabilization remain especially challenging for polytrauma patients. In these situations, the management of the patient must be careful, and the surgeon must decide the perfect timing and approach of decompression for acute spinal cord injury [4].

Injury to the cervical spine is highly related to SCI (whether complete or incomplete). Two major issues must be addressed once the patient sustains an SCI: (i) the neurologic dysfunction due to persisting compression of neuronal structures and (ii) the residual instability that impairs early mobilization and rehabilitation. Primary treatment mandates decompression of the nervous structures either conservatively through traction, or surgically [3].Even if adequate decompression is achieved by closed means, operation may still be indicated to achieve segmental stability and allow patient's early mobilization [1].

Depending on the level of injury, different complications may emerge. Injuries from C1 to C4 may cause tetraplegia or quadriplegia, leading to trunk and upper and lower limb paralysis, impaired breathing and bladder and bowel disorders [4]. Such patients require continuous assistance for daily activities, such as eating, dressing, bathing, and getting in or out of bed. On the other hand, patients

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with injuries at the level of C5, preserve diaphragm function as well as some shoulder and elbow movement (mainly flexion) [5]. These patients will probably require assistance with most daily activities, but once in a power wheelchair, they can move from one place to another independently. Injuries at the level of C6 affect wrist extension and patient typically present with trunk, legs and hand paralysis. They will most probably be able to move in and out of wheelchair and bed with assistive equipment and drive an adapted vehicle. These patients demonstrated limited bowel or bladder control [7]. Injuries at C7 may maintain elbow and some finger extension. They can perform most daily living activities; however, they require assistance with more difficult tasks as well as for bowel or bladder control. Finally, injuries at C8 allow some hand movement and grasp. Patients can perform most daily living activities but will need assistance with more elective tasks as well as for bowel or bladder control [9].

The main goals of surgical treatment following SCI are: (i) achieve decompression of neuronal structures and (ii) provide segmental stability to the cervical spine. Surgery can be performed either through anterior approaches by means of plating and screws or through posterior approaches by means of lateral mass screws and plates or rods [6].

There is limited literature data to provide reliable guidelines on the choice of optimal surgical approach and instrumentation for the treatment of SCI according to the level of the cervical lesion [10, 15]. Even though both approaches may provide adequate stability, each one displays certain advantages and disadvantages that should be considered for assessing an optimal preoperative planning.

A thorough literature search was conducted in Pub Med, Web of Science, Cochrane, SCOPUS and EMBASE databases on anterior and posterior decompression for the treatment of cervical fractures with SCI [13]. Examined parameters included operative time, intraoperative blood loss, postoperative tactile score, postoperative motor score, postoperative vertebral height, hospitalization time, neurological function recovery, treatment efficiency, postoperative complications. References of included articles were reviewed to find additional studies [11]. Inclusion criteria comprised: (i) age between 18-65 years old, (ii) traumatic SCI of the Cervical Spine (C1-C7), (iii) traumatic SCI of the Cervical Spine associated with preexisting degenerative changes, (iv) absence of comorbidities, (v) anterior decompression-stabilization, (vi) posterior decompression-stabilization and (vii) combined approaches [17]. Exclusion criteria comprised: (i) animal studies, (ii) systematic reviews, (iii) SCIs receiving conservative treatment (iv) cervical trauma associated with Thoracic spine injuries and (v) cervical trauma associated with infection or tumor (Figure 1).

All patients were submitted to thorough preoperative assessment [16,18]. Applied procedures included anterior, posterior or a combination of these two approaches [19]. Neurologic recovery in most of the articles was evaluated with ASIA score and Barthel scale [20]. Most often complications comprised infection, dysphagia and neurologic recrudescence and postoperative kyphotic angulation.

Discussion

The treatment of an unstable cervical spine is still under discussion. Darrel et al support that decision for optimal procedure is mainly based on the "personality" of the cervical trauma. The term "personality" includes all the unique characteristics of a lesion: (i) the level of the neurologic compression, (ii) the type of fracture, (iii) the presence of irreducible dislocated facets, (iv) ligamentous instability and (v) the presence of disc herniation [3].

Based on Abitbol's findings, anterior approaches require less muscle splitting, providing easier approach to the cervical spine. Thus, reconstruction of the anterior column may be performed under direct visualization. On the other hand, posterior approaches may ensure anatomic reduction and increased stability of the facet joints due to higher biomechanical strength [13]. Surgical stabilization of the cervical spine has developed remarkably over the last 40 years since Robinson and Smith first depicted their approach and procedure for an anterior discectomy and fusion [12]. Since then, anterior plates with fixed angle unicortical screws, replaced older bicortical screw plate systems providing con-

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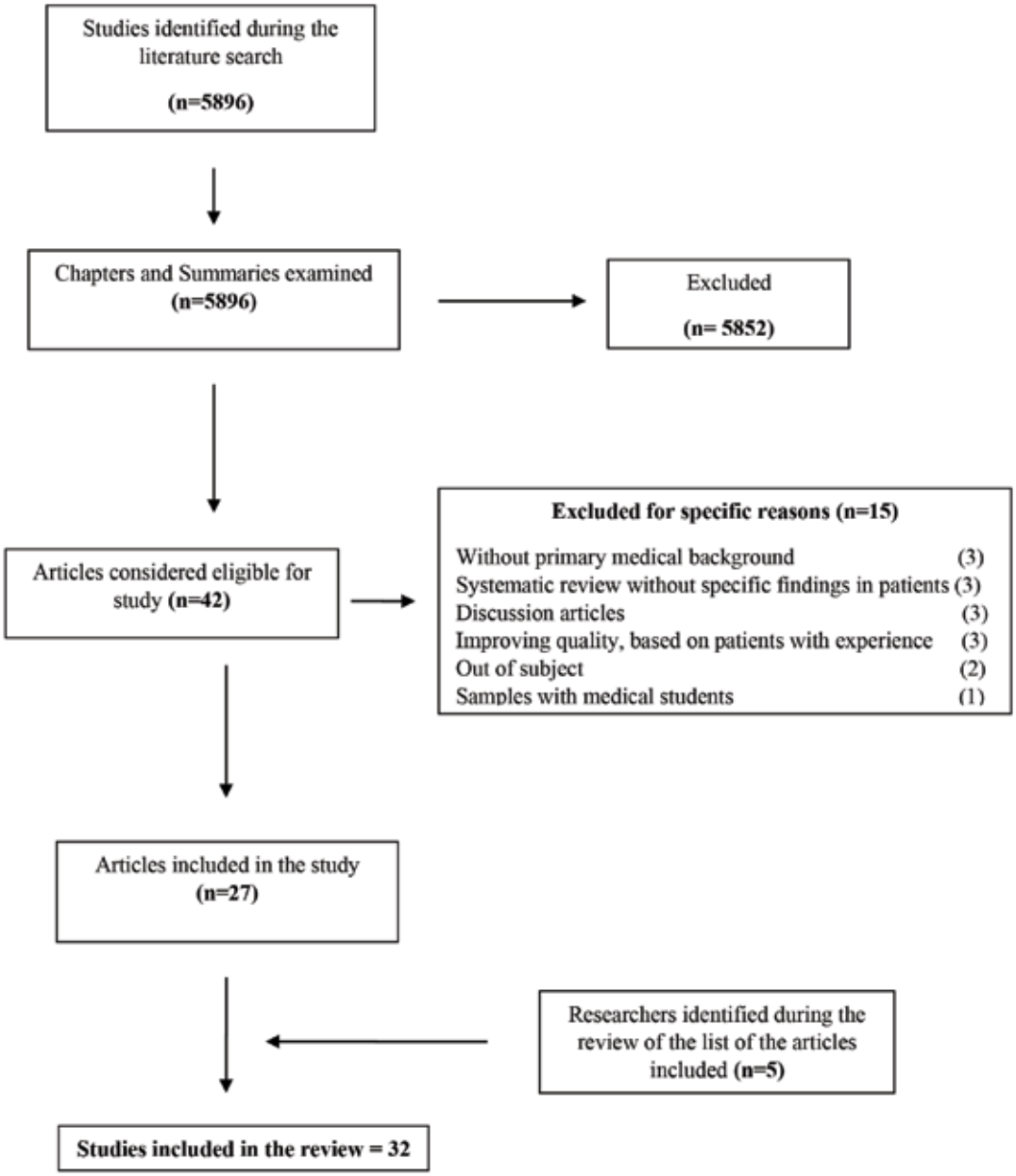

Figure 2. *Flowchart.*

venience in practice, adequate stability and reliable results [13-16]. They bring back normal or supernormal stiffness in flexion, extension, rotation and axial loading. More recently, posterior cervical fixation with lateral mass screws and plates or rods has been developed for the treatment of cervical spinal cord injuries [17]. *Ex vivo* studies, report increased stiffness in flexion, extension, and rotation as contrasted with anterior plates [13, 15].

Cao et al suggest that surgical treatment for cervical spine lesions aims to: (i) decompress spinal cord, (ii) reconstruct vertebral canal morphology, (iii) restore vertebral canal volume, (iv) restore physiological cervical angulation, and (v) manage intervertebral bony fusion [34].Surgeons must choose optimal approach based on the type of injury and the level in the cervical spine (Table 1).

Based on biomechanical studies related to stabil-

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TABLE 1. **The Surgical Approach to Cervical Spine Injuries**

Approaches / Level of injury	Anterior	Posterior	Combination
Upper Cervical Spine	• Type II odontoid fractures	• Type II/III odontoid fractures • Atlantoaxial instability • Atlantoaxial rotatory displacement • Type II/III Jefferson unstable fractures	None
Subaxial Cervical Spine	• Compression and Burst fractures • Unilateral or Bilateral Facet subluxation or Perched Facets • Unilateral or Bilateral Facet Fracture Dislocation/ Subluxation (when there is no anterior vertebral disruption)	• Unilateral or Bilateral Facet subluxation or Perched Facets (when MRI shows disc and posterior ligament disruption without herniation) • Unilateral or Bilateral Facet Fracture Dislocation/ Subluxation	• Unilateral or Bilateral Facet Fracture Dislocation/ Subluxation • Vertebral Burst Fracture or Dislocation (Teardrop Fracture)

ity following traumatic injury, Dennis divided the vertebral column into 3 vertical parallel columns. The anterior column comprises the anterior longitudinal ligament and the anterior half of the vertebral body. The middle column comprises the posterior half of the vertebral body and the posterior longitudinal ligament [35]. Finally, the posterior column comprises the pedicles, the facet joints and the supraspinous ligaments. Instability occurs when injuries affect 2 contiguous columns (i.e. anterior and middle or middle and posterior column). Obviously a 3-column injury is considered unstable [34]. There are many different types of spinal fractures: compression, burst, flexion-distraction, and fracture-dislocation [33]. Analyzing the three-column concept, a flexion-distraction fracture usually damages the posterior and the middle column while flexion-dislocation fractures usually involve all three columns [36].

Although there are guidelines for the cervical fractures and dislocations, Marcel et al suggest that the specific treatment of a cervical fracture and/or dislocation ultimately depends on a number of factors: (i) type and location, (ii) severity and amount of displacement, (iii) presence of spinal cord/nerve compression, (iv) presence of neurologic dysfunction or spinal cord injury, and (v) patient's age, medical condition and associated injuries [33].

Sethy et al reported that disc protrusion or vertebral body fragments displaced into the spinal canal require an anterior approach [37].On the other hand, Liu et al suggested that injury to the cervical spine associated with an irreducible facet dislocation mandates a posterior procedure [22]. Li et al claim that anterior approach is associated with fast recovery and improved neurologic outcomes [34]. Hatta et al state that posterior approaches provide higher postoperative stability [18], while Wang et al insist on the combination of both approaches to achieve optimal results [15].

Anterior Approaches

For burst fractures with compression of the spinal cord in subaxial area (C3-C7), an anterior approach and fusion is preferred. The only case that an anterior approach is recommended at the upper cervical spine is for the type II odontoid fractures. According to Theodotou et al, a surgeon prefers the anterior approach mostly in the subaxial cervical spine for: (i) compression fractures with 11 degrees of angulation or 25% loss of vertebral body height, (ii) unstable burst fractures with cord compression, (iii) unstable tear-drop fractures with cord compression, (iv) minimal injury to posterior elements, (v) facet

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dislocations reduced through closed methods with a MRI showing cervical disc herniation with significant compression on the spinal cord, and (vi) unilateral facet dislocations with failed closed reduction and disc herniation with significant compression on the spinal cord [35].

Patients suffering from multilevel degenerative cervical disease mainly demonstrate anterior spinal cord compression due to the formation of osteophytes and ligamentous hyperplasia associated with disc herniation. More rarely, posterior compression, due to the hypertrophy of the ligamentum flavum, can be encountered. These patients develop 'pincers'symptoms, due to anterior cord compression and should be treated through an anterior approach. Additionally, Diangelo et al support that anterior approach is also favorable for patients with ossified anterior longitudinal ligament [28]. Although anterior procedures are often applied for cervical spinal cord injury, several studies report that postoperative complications are more likely to happen with anterior approaches [21, 24-26].

Posterior Approaches

According to Anderson et al, a posterior approach is preferred for facet dislocations and injuries of the posterior ligamentous system. For unilateral dislocations, optimal approach could be either posterior or anterior; however closed reduction via cranial traction should be performed prior to surgery. On the other hand, for bilateral dislocations, a posterior approach is recommended for the effective treatment of residual instability [16].David et al support that in the upper cervical spine, the posterior approach is recommended for: (i) type II/III odontoid fractures, (ii) atlantoaxial instability, (iii) atlantoaxial rotatory displacement, and (iv) type II/III Jefferson unstable fractures. In the subaxial cervical spine, posterior approaches are indicated when: (i) there is significant injury to posterior elements, (ii) reduction, either closed or through anterior approach, is not feasible, and (iii) there is no anterior spinal cord compression (no disc herniation) [4]. Based on Liu et al, posterior approaches, including laminectomy and spinal fusion, have been applied to posteriorly decompress spinal cord, in the absence of anterior compression. Since posteriorly, the space of spinal canal is narrow, lesions of the cervical spine may induce compression at the tethering point of the nerve root. The latter has been recommended as main reason for segmental motor paresis (C5 nerve root palsy), influencing long-term postoperative outcomes. However, physiological curvature of the cervical spine cannot be restored using only a posterior approach. Loss of physiological curvature and emerging kyphosis prior to the operation are relative contraindications to the posterior approach [22].

Combination of Anterior and Posterior Approaches

Wang et al suggest that a combination of anterior and posterior procedure is performed, when injuries are highly unstable, and lesions affect both anterior and posterior columns. The "360 degrees" procedure is also indicated for Chance-like fractures [10]. Axiang et al insist on the combination of anterior and posterior approach for patients with subaxial cervical spinal cord injuries that cannot be reduced through closed or open anterior techniques, in the presence of disc herniation requiring decompression [9].

Pui et al reported that despite the numerous benefits of cervical surgery for treating SCI, several complications are likely to arise. For anterior approaches, the prolonged and forceful retractions should be avoided to prevent injury to the esophagus, recurrent laryngeal nerve and carotid arteries. For posterior approaches, protective foraminotomy minimizes the risk of postoperative C5 nerve root palsy. Preservation of posterior muscles and their attachments is essential to avoid postoperative neck pain and kyphosis [1].

Careful preoperative assessment of the bony and vascular structures should be performed, especially when internal fixation is chosen. Despite surgical approach, spinal cord monitoring should be mandatory in all cases of cervical spine surgery. Hee et al stated that with thorough preoperative assessment and intraoperative monitoring, cervical spine surgery demonstrates acceptable complication rates [23].

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In the study of Sasso et al, the authors analyzed several parameters that could influence recovery following cervical spine surgery. ***(i) Age***: the younger patients are more likely to demonstrate a fast recovery; however, it is quite rare for younger people to require neck surgery**.** *(ii)* ***Overall health***: preexisting comorbidities or unhealthy lifestyle demonstrate a negative influence on recovery time; the healthier the patient at the time of SCI, the shorter the recovery. Parameters such as smoking, obesity and drinking impact negatively on wound healing. (iii) ***Lifestyle:*** those who lead an active life and engage in regular healthy physical activity tend to recover quickly. Those who have very demanding, physical jobs, however, tend to recover much more slowly. If the patient is highly active, it will usually take longer to get back to that level of activity as well [24].

The most important goal is to realize the idea of independent mobilization for both complete and incomplete quadriplegic patients during the chronic period. Ambulation can be social, domestic and aimed at exercise. Individuals with a spinal cord injury, depending on the level and type of lesion, may have many complex needs and face wide-ranging, long-term restrictions in their ability to live independently, drive or use public transport, return to work or education, participate in leisure and social activities. Vaccaro et al stated that to ensure successful long-term management, coordinated community rehabilitation services and long-term support is required to know the long-term and on-going needs of individuals with a spinal cord injury [26].

Conflict of Interest

The authors declared no conflicts of interest.

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