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Injuries of the cervicothoracic junction with neurological signs: choice of spinal fusion and association with neurological and functional rehabilitation

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ABSTRACT

Injuries of the cervicothoracic junction (CTJ) are demanding with high rate of neurological complications. Due to its unique and diverse anatomical characteristics, the approach of CTJ for stabilization is challenging. The purpose of this study is to review the neurological and functional outcome of the spinal fusion in CTJ injuries with neurological signs. This is a simple literature review using the Pubmed internet database. Papers were searched with the use of the following keywords: ("cervicothoracic" OR "C7-T1") AND ("injury" OR "fracture" OR "dislocation" OR "spondylolisthesis") AND ("fusion" OR "fixation" OR "instrumentation"). The search retrieved a total of 199 papers (see flowchart). After screening of titles and abstracts, 158 articles were rejected. Of the 41 publications evaluated, 25 were rejected, leaving 16 studies for the present review. There were 3 prospective studies, 4 retrospective studies and 9 case reports. The evolution of surgical techniques and hardware has facilitated the approach and the instrumentation of the CTJ, allowing for low profile, rigid fixation. Complications of operations around the CTJ are frequent and the associated morbidity is significant. Appropriate training along with meticulous preoperative planning, surgical technique and postoperative care are essential for the prevention of these complications. However, optimal surgical procedure has not yet been clarified. More high-quality studies are needed to fully elucidate the best fusion method and approach in order to maximize the benefit for the treatment of these patients.

Key Words: Cervicothoracic junction spinal injury, Spinal fusion

Introduction

The cervicothoracic junction (CTJ) includes the C7 vertebra, the T1 vertebra, the C7 – T1 intervertebral disc and the adjacent ligaments. Representing the connection between the fairly mobile and lordotic cervical spine and the fairly rigid and kyphotic thoracic spine, it possesses unique biomechanical properties [1]. The thoracic spine has limited mobility because of the rib cage, exerting significant stress on the CTJ in the static and dynamic states. CTJ is vulnerable to instability be-

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cause of traumatic disruptions to associated structures causing significant and devastating spinal cord injury (SCI).

CTJ injuries represent 2% - 9% of all cervical spinal injuries. Their diagnosis, based on plain x-rays, is difficult, as the region is often obstructed by the shoulders [2-3]. So, in case a CTJ injury is suspected, a CT or MRI of the cervical spine should always be performed. CTJ injuries usually include fractures or dislocations; most commonly ligamentous injuries, burst fractures, and facet fractures [4]. Neurologic symptoms due to CTJ injuries are common, probably due to the small canal size of the CTJ, and vascular insufficiency [5].

Established management of CTJ injuries usually involves initial closed reduction, followed by fusion with instrumentation. Spinal fusion is usually performed within the first 3 days of injury [6]. Due to its unique and diverse anatomical characteristics, the approach of CTJ for stabilization is challenging. Anterior access is difficult, because of the deep location of the C7 and T1 vertebral body and the presence of multiple vital organs and blood vessels. The choice of anterior versus posterior stabilization depends on the surgeon's choice as well as on the pathologic findings of fractures [7]. The gold standard approach for fixation of CTJ injuries is through a posterior approach and this may be combined with anterior fixation [5]. Although some studies have shown that posterior-only fixation may be sufficient to stabilize CTJ injuries that include the anterior column, such as burst fractures, cadaveric studies have shown that in a 3-column injury, posterior fixation is not sufficient to restore the innate spinal stiffness [8]. Other biomechanincal studies have observed that a 3-column CTJ injury may be fixed by posterior-only instrumentation, with the addition of 2 cross-links [9]. So, the optimal way of spinal fusion for CTJ injuries is a matter of debate.

The purpose of this study is to review the neurological and functional outcome of the spinal fusion in CTJ injuries with neurological signs.

Material and method

This is a simple literature review using the Pubmed internet database. Papers were searched with the use of the following keywords: ("cervicothoracic" OR "C7-T1") AND ("injury" OR "fracture" OR "dislocation" OR "spondylolisthesis") AND ("fusion" OR "fixation" OR "instrumentation")

Results

The search retrieved a total of 199 papers (see figure 1). After screening of titles and abstracts, 158 articles were rejected. Of the 41 publications evaluated, 25 were rejected, leaving 16 studies for the present review. There were 3 prospective studies, 4 retrospective studies and 9 case reports.

No matter what surgical fusion technique is chosen, the primary aims are similar: stable internal fixation, placement of appropriate bone grafts, restoration of acceptable anatomic position, and decompression of neural structures. As a result of CTJ anatomical issues, initial attempts of CTJ fusion was based on spinous process wiring and lamina hooks rather than pedicle screws [10-11]. However, failure of fusion was frequent, as wiring did not provide the same stability as a rod or plate system. Moreover, both the spinous processes and the laminae are often removed during spinal surgery. A lamina hook may intrude into the spinal canal, in patients with spinal stenosis [10]. Screw-rod systems have provided strong fixation to the CTJ in biomechanical studies [8, 12-13]. Modern rod-screw systems are flexible enough and may achieve immediate rigid internal fixation with high rates of fusion. Rod-wire systems remain a simple, low-cost, and low-profile way of achieving CTJ fixation. [6].

Cadaveric studies have shown that C7 pedicle screw fixation is superior compared with lateral mass fixation at C7 in all biomechanical tests, providing high stiffness for stabilizing the CTJ [12]. The risks of medial or inferior C7 pedicle violation and associated neurologic injury must be balanced with the risk of injury or construct failure secondary to poor fixation in the C7 lateral mass [14]. The use of pedicle screws and lateral mass fixation at the CTJ is safe with a reported incidence of breaching of the pedicle to be estimated at 3% - 9%, while reported incidence of radiculopathy is 1% - 2% [15-16]. As a result, the possibility of a stiff and stable fusion of the CTJ region is increased. The concept of anterior instrumentation and fusion is performed less frequently at the CTJ region. Both cadaveric and clinical studies suggest that the results of such techniques are inferior to techniques that use posterior

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only or anteriorposterior fixation [17-18].

Prospective studies

The outcomes of plate screw fixation of the CTJ have been documented in separate studies. A prospective study by Anderson *et al* reported the efficacy of posterior spinal fusion with AO reconstruction plates and autogenous bone graft. Among the studied patients, two suffered from C7-T1 injury and associated tetraplegia and were treated with a C5-T1 or C5-T2 fusion. After a 17.8 months follow-up, one of the two patients showed significant neurological improvement [19].

A more recent prospective multicenter study by Ramieri et al, included 21 patients with CTJ injury. There were 8 ASIA A, 2 ASIA B, 6 ASIA C and 5 ASIA D patients. Using the combination of cervical lateral mass screws, thoracic pedicle screws and hooks, 16 patients were managed with posterior fixation and fusion, 3 patients underwent posterior fixation and fusion along with anterior body replacement and 2 patients received anterior body replacement alone. Eight patients experienced neurological improvement, 12 patients remained with the same neurological deficit and one polytrauma patient died because of severe brain injuries. Authors concluded that there is no type of instrumentation more effective than other [20].

When patients with ankylosing spondylitis, sustain a CTJ fracture, they are at a high risk of developing complications. A prospective cohort study by Robinson et al included 41 patients with CTJ fractures related to ankylosing spondylitis. All patients were treated with posterior fusion and instrumentation and were followed up for 2 years. Mean survival was 52 months, affected by patient age, sex, smoking, and SCI. Complication included postoperative infections (n = 5), respiratory tract infections (n = 3) and cerebrovascular fluid leakage (n = 1) [21].

Retrospective studies

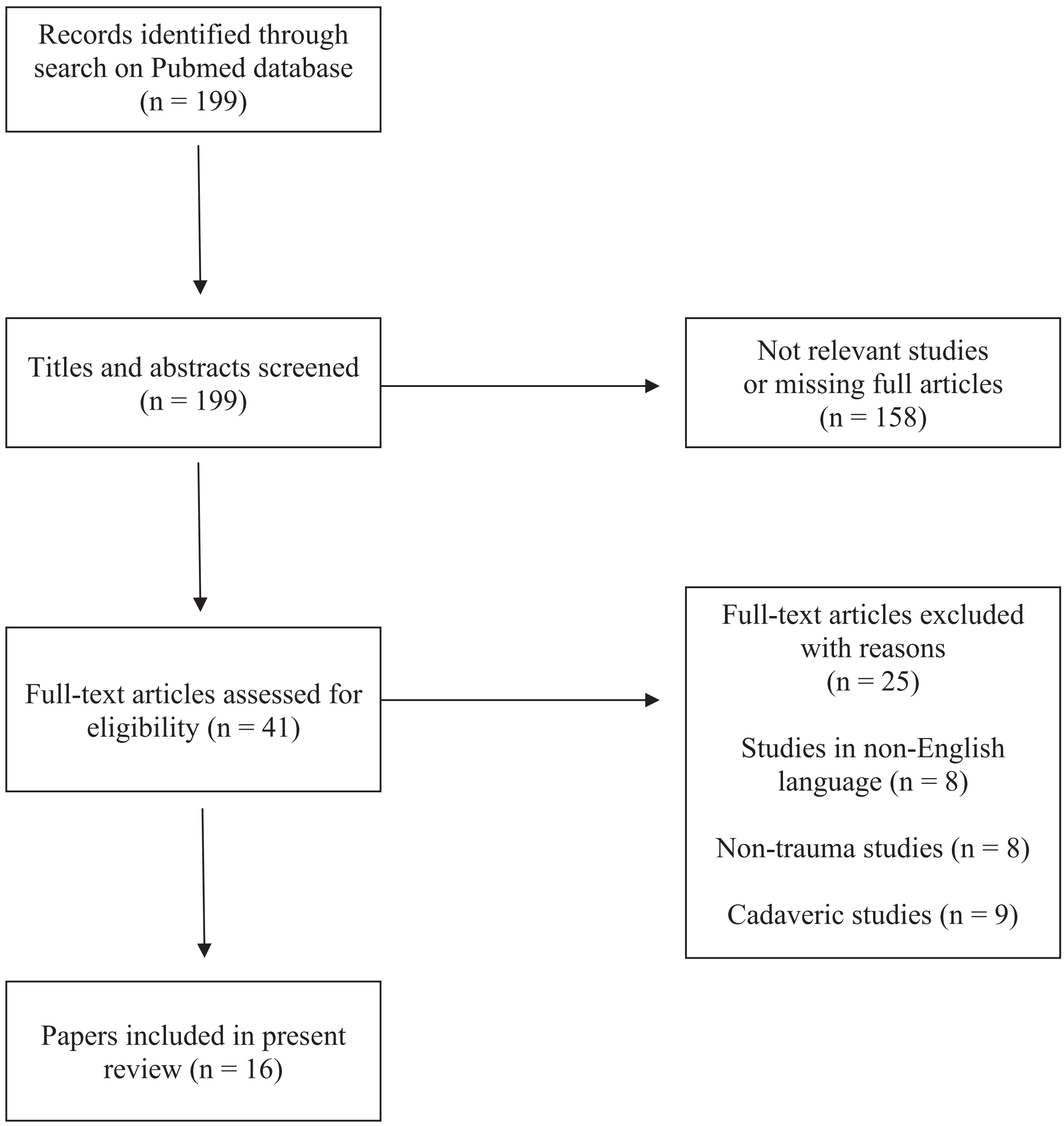
Another retrospective study by Chapman *et al* reported 14 patients with traumatic instability of C7-T4 region and associated SCIs, which were treated with posterior AO reconstruction plate and screw fixation and fusion between the lower cervical and upper thoracic spine involving two to three levels for a burst fracture but more in case of ligamentous injuries. Preoperatively, 7 patients had a complete and 7 patients had an incomplete SCI. All patients achieved a solid arthrodesis based on flexion-extension radiographs. All cases of incomplete tetraplegia improved at least one Frankel grade, while 2 patients with complete tetraplegia experienced neurological improvement. There were no neurovascular, pulmonary or hardware complications [22].

A retrospective study by An et al included 15 patients with traumatic CTJ injuries (10 C7 fractures, 4 C7-T1 dislocations, 1 T1 fracture). Among them, there were 10 complete SCIs, 4 incomplete SCIs, while one patient had a root deficit. Ten patients underwent posterior fusion, while 5 patients underwent combined fusion and corpectomy, with anterior approach. Reported results were excellent in 1 patient, good in 10 patients, fair in patients and poor in 1 patient. Patients with complete tetraplegia had no appreciable improvement in neurological function. Half of the patients with incomplete lesions improved. The authors observed the occurrence of complications, including C6–C7 subluxation after C7–T2 fusion, pseudomeningocele, vocal cord paralysis, dysphagia, and Horner's syndrome. Other complications included wound infections, urinary and respiratory tract infections and deep vein thrombosis [1].

Another retrospective study by Sapkas et al included 6 patients with C7-T1 fracture / dislocation. Two patients had incomplete SCI, one patient had a complete SCI, whereas 3 patients had root deficits. All patients underwent laminectomy and posterior fusion with various implants such as plates, clamps and wires. The reported postoperative results were excellent (n = 2), good (n = 2) and fair (n = 2). After 22 months follow-up, patients with incomplete SCI significantly improved their neurologic function by at least one or two Frankel grades. All patients with root deficits improved, and at nearly 6 months post-operatively they were restored completely. There was no improvement in neurologic function in the patient with complete SCI [5].

In 2006, Lenoir et al published a retrospective study including 30 patients (22 male – 8 female) who underwent surgical treatment for unstable fracture at the CTJ. Lesion level was C7 (n = 18), T1 (n = 5), T2 (n = 2) and T3 (n = 5). Upon initial clinical evaluation, patients were classified as Frankel A (n = 16), Frankel B (n = 6),

Figure 1. Flowchart



Frankel C (n = 2) and Frankel D (n = 6). Patients underwent posterior stabilization with rod-screw systems (n = 3), plate-screw fixation (n = 25) and combined rods and screws at the thoracic level linked to plate-screw at the cervical level (n = 2). After a mean follow-up of 18 months, reductions were satisfactory in 27 patients, while bony fusion was observed in 100% of the patients on CT scans. Among the 14 patients with partial lesions, 10 patients experienced complete or partial neurological recovery. None of the patients, initially classified as Frankel A recovered neurological function. Authors suggested plate-screw fusion in fractures that do not require fusion beyond T2, whereas rod-screw systems are preferred for superior thoracic injuries. Complete SCIs resulted in increased mortality of the operated patients [23].

Case reports

Shah and Rasjshekhar reported a case of a 40-year-old man with a traumatic total spondyloptosis at C7-T1 level, with impaired motion and sensation at all four limbs. The patient underwent ventral decompression and uninstrumented in situ fusion, with a good neurologic outcome [24]. An old study by Pick and Segal reported a case of a 46-year old man with a C7-T1 dislocation treated with surgical stabilization. Patient was permitted to ambulate immediately after surgery [25]. The case of a 70-year-old man with an unstable C7-T1 dislocation was reported by Alsofyani et al. Clinical examination revealed parethesia at C7 and C8 dermatomes bilaterally. The patient underwent anterior cervical discectomy and fusion of C6-T2. At one-year follow-up, x-rays showed bony fusion at C7-T1 level and the patient had no major disability [26]. Another case of C7 on T1 traumatic spondyloptosis in a 60-year-old man with initial bilateral upper extremities paresthesias was reported by Nguyen et al. The patient was subjected to posterior C6-T1 decompression, bilateral C7 facetectomies, C4 to T2 posterior fixation and C7-T1 anterior fixation. At 6 months follow-up, his motor and sensory examination was normal, with a slight paresis of vocal cords [27]. Kim et al reported two cases of traumatic C7-T1 dislocation with tetraparesis treated successfully with single posterior approach and short segment fusion, with the use of cervical pedicle screws. Authors observed improvement of clinical condition [28]. The combined posterior-anterior stabilization was favored by another study by Schmidt-Rohlfing et al, who reported a case of 36-year-old patient who sustained a unilateral fracture-dislocation C7-T1 involving all three columns. The patient was initially treated with posterior fixation and the, at second operation, underwent anterior C7-T1 fusion with a tricortical bone graft and instrumentation [29].

The case of a 41-year old woman with a C7-T1 fracture-dislocation was published by Kyrylenko et al. After anterior plating and interbody C6-T1 arthrodesis with iliac crest bone graft, the patient survived with no neurological impairment [30]. A similar case was reported by Acicbas et al, where a 42-year-old man sustained a total traumatic C7-T1 spondyloptosis after a motor vehicle accident. The patient was initially treated with a C7-T1 discectomy and anterior fusion with a peek cage and allografts and a titanium plate. After 3 days, the patient underwent posterior C4-T3 stabilization with C4-C5 lateral mass screws and T2-T3 transpedicular screws and rod constructs. Complete fusion was observed with no neurological deficit [31]. Mata-Gomez et al reported a case of a 33-year old woman with a traumatic C7-T1 spondylolisthesis and spinal cord signal change, 9 months after a motor vehicle accident. The patient underwent spinal fusion with combined anterior and posterior approach. Initially, with a posterior approach, lateral masses screws were placed in C4-C6 and pedicle screws were placed in T2-T3. Then a partial T1 corpectomy and laminectomy was performed. In a second stage, through an anterior approach, authors performed a C7-T1 discectomy and fusion with iliac graft crest and C5-T2 anterior cervical plate. After a follow-up of 18 months, the patient had a complete neurological recovery [32].

Conclusions

Because of its biomechanical characteristics, CTJ is a unique spinal region, with difficult anterior access. The evolution of surgical techniques and hardware has facilitated the approach and the instrumentation of the CTJ, allowing for low profile, rigid fixation. Complications of operations around the CTJ are frequent and the associated morbidity is significant. Appropriate training along with meticulous preoperative planning, surgical technique and postoperative care are essential for the prevention of these complications. However, optimal surgical procedure has not yet been clarified. More high-quality studies are needed to fully elucidate the best fusion method and approach in order to maximize the benefit for the treatment of these patients.

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