

Outcome of Surgical Fixation to Cervicothoracic Junction: A Systematic Review of Literature

Mohamed Fawzy Khattab, MD., Wassim Abouzeid Fooz, MD., Mohamed Ahmed Maziad, MD.

Orthopedic Surgery Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt.

ABSTRACT

Background Data: Surgical fixation of the cervicothoracic junction (CTJ) is difficult due to the complex anatomy and biomechanical properties of this area. Several important vascular, visceral, and soft tissue structures make access to this region challenging; therefore, knowledge of these structures is essential for decompression and fixation. The posterior approach is commonly used in many diseases of the spine but is inadequate when targeting the anterior spinal elements; thus, it can result in a higher complication rate and can disturb spinal stability. For these reasons, different posterolateral and anterior approaches have been developed.

Study Design: Systematic review of the literature

Purpose: To compare these different anterior and posterior surgical approaches to the CTJ, indicating pathologies, outcomes, and complications.

Patients and Methods: This review was done using the standard methodology outlined in the Cochrane Handbook and reported the findings in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines. An initial search has been carried out using PubMed, Embase, Cochrane Library, Ovid, Scopus, and Google Scholar databases using the following keywords; cervicothoracic junction, C7/T4, surgical fixation; posterior approach; anterior approach.

Results: Our systematic review yielded 12 studies with 419 patients that met our inclusion criteria, including seven studies using the anterior and five posterior approaches for treating different spinal pathologies. In this review, most patients with traumatic and neoplastic injuries were treated through the anterior approach, and those with degenerative and infectious diseases were treated through the posterior one. Assessment of the reported neurological status change pre- and postoperatively showed a significant difference between the anterior and posterior groups favoring the anterior one, and the rate of complications of the posterior approach was higher than that in the anterior approach.

Conclusion: The data in this review may demonstrate both the effectiveness and safety of the anterior approach compared to the posterior one. These data indicate that patients who underwent the anterior approach have a higher incidence of improvement in their neurological functions and that complications in the anterior group are relatively less than those in the posterior one.

Keywords: Cervicothoracic junction; Surgical fixation; Posterior approach; Anterior approach.

Address correspondence and reprint requests: Wassim Abouzeid Fooz, MD.
Orthopedic Surgery Department, Faculty of Medicine, Ain shams University, Cairo, Egypt.
Email: wassimfooz@hotmail.fr

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INTRODUCTION

Surgical fixation of the cervicothoracic spine is difficult due to the complex anatomy and biomechanical properties of this area.^{26,27,29,38} Several important vascular, visceral, and soft tissue structures make access to this region challenging, and knowledge of these structures is essential for decompression and fixation.^{1,13} Pathologies at the cervicothoracic junction (CTJ) are relatively uncommon but include infections, trauma, primary bone tumors, meningeal tumors, disc disease, and congenital connective tissue and skeletal disorders.⁴ Up to 15% of patients with spinal neoplasms have lesions of the upper thoracic vertebrae, and 10% of spinal metastases arise from T1 to T4.³¹ Up to 80% of the unstable cervicothoracic pathologies can be accompanied by neurological deficit and require surgical treatment. Unfortunately, injuries to this area are often missed in routine radiological studies.^{3,16,17} The posterior approach is commonly used in many diseases of the spine; however, it may be inadequate when targeting anterior spinal elements resulting in a higher complication rate and disturbing spinal stability. For these reasons, different posterolateral and anterior approaches have been developed.^{31,39,41} Lateral extracavitary approach provided a better exposure to the middle and lower thoracic spine with fewer complications and morbidity rates. However, it was limited by the shoulder girdle for exposure of the upper thoracic spine.³⁰ The lateral parascapular extrapleural approach provides exposure to the upper thoracic spine up to the C7 endplate.²¹ Anterior supraclavicular approaches to the cervicothoracic junction were described in 1923.⁸ Moreover, the tansclavicular and transmanubrial approaches were developed in 1984 and modified later in 1990 because the presence of the clavicle restricted exposure of the thoracic region.^{7,44} Although the general treatment goals such as neural decompression, immediate stabilization, and maintenance of anatomical alignment are valid for

this unique spinal region, yet the selection of the type of surgical approach is controversial.^{7,20,24,44}

In this study, we conducted this systematic review of the literature to compare different surgical approaches to CTJ, indicating pathologies, outcomes, and complications.

PATIENTS AND METHODS

Search Strategy:

This review was conducted by searching the online databases Cochrane, Embase, PubMed, Ovid, Scopus, and Google Scholar in accordance with the Preferred Reporting Information for Systematic Reviews and Meta-Analyses (PRISMA) to identify all relevant studies between 1996 and 2020. The study was approved by our IRB. We searched for the following keywords: (1) cervicothoracic junction; (2) C7/T4; (3) surgical fixation; (4) posterior approach; (5) anterior approach.

Inclusion/Exclusion Criteria:

Inclusion criteria of studies in our systematic review were as follows: (1) patients with cervicothoracic junction fixation (C7 to T4); (2) comparison between anterior and posterior approach; (3) studies from 1996 up to 2020; (5) postoperative neurological outcomes and complications. On the other hand, exclusion criteria were as follows: (1) fixation that does not include cervical 7 or thoracic 1 vertebra; (2) cadaveric specimens studies; (3) studies that did not include neurological outcomes and complications; (4) case reports; (5) combined approach.

Data Extraction:

Two investigators extracted the data independently, and differences and disagreements were resolved by the research meeting. The data were recorded using a standard data extraction form, including the basic information of studies (the last author's name, date of publication, and sample size), the basic participants' information (age, sex, and type of the surgery), clinical data (type of surgical approach, patient pathology, hospital stay,

pre- and postoperation clinical outcomes, and complication encountered).

Publication Bias:

Evidence of publication bias has been sought using the funnel plot method. A funnel plot is a simple scatter plot of the intervention effect estimates from individual studies against some measure of each study's size or precision.³³

Study Selection:

The study has followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. 253 studies have been identified between 1996 and 2020. Of these, 60 duplicates, 90 after abstract reviews, and 94 after full-text reviews, including irrelevant study, combined anterior and posterior surgery, cases reports, and reviews were excluded. Three more studies were added to the remaining nine articles from further search in the reported articles. As a result, a total of twelve articles were included in the systematic review. These articles search was performed by two authors; in case of discrepancy, a third author reviewed the search process, The final selection was resolved by consensus. The methodology of our literature search is summarized in Figure 1.

RESULTS

Patients and Study Characteristics

We analyzed the articles and grouped them according to the approach used for fixation. Seven studies used the anterior fixation technique with a total of 325 patients and five studies used the posterior fixation technique with 94 patients. Regarding the type of included studies, eight studies were retrospective, whereas four studies were prospective. The total number of patients in all the included studies was 419; 234 were males (55.8%) and 185 were females (44.2%). The average age of all patients was 47 years, with the youngest mean age being 28.1 years in Dalbayrak et al.¹⁴ and the oldest mean age 63 years in Falavigna et al.¹⁹ The average follow-up time of all patients was 40 months. The

summary of patients and study characteristics is shown in Table 1.

Pathologies Treated by Posterior and Anterior Approach:

Four pathologies could be identified in the articles reported in this systematic review as follows: traumatic injuries were the most predominant (69.2%), followed by neoplastic (10.3%), infection (11.9%), and finally degenerative pathologies (8.6%) (Table 2). Regarding the approach used for the treated pathology, 77.6% of traumatic patients and 66% of those with neoplastic lesions were treated via anterior approach, while most patients with infectious and degenerative injuries were treated with the posterior approach.

Patient-Reported Functional Outcomes:

In the 12 studies included in this systematic review, different grading systems have been used to assess patients before and after surgery, except for some authors who only used subjective clinical judgment without specifying a grading system. After analyzing the postoperative patient-reported functional outcomes in this review, most patients treated via an anterior approach were shown to have improved postoperatively except seven patients in Gao et al.'s²³ study who deteriorated postoperatively. Meanwhile, after the posterior approach, 72% of patients showed improvement, 16 % remain unchanged, and 11% deteriorated postoperatively. In general, assessing the reported neurological status changes between pre and postoperatively showed a significant difference between the anterior and posterior groups favoring the anterior one. The summary of patient-reported functional outcomes in both approaches is depicted in Table 1. It must be mentioned that most patients that remain unchanged after surgery were intact neurologically at the preoperative status, while others had irreversible neurological damage caused by pathology.

Complications:

Complications were collected from all articles and stratified in Table 3. Eleven complications were documented in patients treated via anterior approach and 10 in those treated posteriorly.

After the anterior approach, wound complications, followed by right laryngeal nerve (RLN) palsy, were the most documented complications. Wound problems were mostly in the form of poor cosmetic results. Mihir et al.³⁷ have documented 11 patients with unacceptable cosmetic results and superficial infections that mostly healed within a week after surgery with regular dressings and proper antibiotics. On the other hand, almost all patients who experienced RLN palsy postoperatively showed complete recovery within months except two patients, one in Mihir et al.³⁶ study and another in Flavigna et al.¹⁴ study who did not recover from RLN palsy.

In contrast, after the posterior approach, complications were mostly due to lung affection. In fact, out of 106 patients treated posteriorly, 23 experienced a prolonged ICU stay due to respiratory insufficiency, ten patients had a lung

infection, and eight needed tracheostomies. Wound complications of the posterior approach were seen in about 7.5% of patients, which is more than those treated via the anterior approach (7.3%). In addition, two patients in Lenoir et al.'s³⁴ study and another one in El Qazaz et al.'s¹⁴ study needed surgical debridement and drainage following wound infection. Moreover, it is important to note that in the posterior approach group, one patient died due to pulmonary embolism in Lenoir et al.³⁴ study and two patients from respiratory problems in Chapman et al.¹⁰ study.

Altogether, this review demonstrates that the rate of complications of the posterior approach was higher than that of the anterior approach. In fact, 55.7% of patients who underwent the operation posteriorly encountered complications compared to only 18.2% in those operated via an anterior approach.

Table 1. Summary of patients and study characteristics.

N	Approach	Study ID	Age/ years	Sex (M/F)	Patients No.	Type of study	Outcome/ Scale	Follow- up/ months	Neurologic outcome		
									Improved	Unchanged	Deteriorated
1	Anterior	Mihir et al., 2006 ³⁷	31.35	12/30	42	Prospective	Nurick's grade	24	42		
2		Falavigna et al., 2009 ²⁰	63	7/7	14	Prospective	VAS scale	---	14		
3		Falavigna et al., 2014 ¹⁹	54.26	11/8	19	Retrospective	MRC classification	27.05	19		
4		Gao et al., 2018 ²³	42.6	121/97	218	Retrospective	Odom's criteria	106.8	211		7
5		Liu et al., 2009 ³⁵	41.4	8/3	11	Retrospective	---	31	11		
6		Dalbayrak et al., 2014 ¹⁴	28.1	7/1	8	Retrospective	ASIA scale	104	6	2	
7		Lee et al., 2016 ³²	55.5	8/5	13	Retrospective	Frankel grade	10.2	12		1
8	Posterior	Obeidat et al., 2019 ⁴⁰	57	7/5	12	Prospective	---	12	10		2
9		Elqazaz, 2015 ¹⁵	40	6/4	10	Retrospective	Frankel grade	---		7	3
10		Cho et al., 2010 ¹¹	55.5	10/9	19	Prospective	---	---		16	3
11		Chapman et al., 1996 ¹⁰	47	15/8	23	Prospective	Frankel grade	15	13	10	
12		Lenoir et al., 2006 ³⁴	49	22/8	30	Retrospective	Frankel grade	30	20	7	3
Total			47	234/185	NA	NA		40	358	42	19

VAS: Visual Analogue Scale.

MRC: Classification of the Medical Research Council.

ASIA: American Spinal Injury Association Impairment scale

Table 2. Types of reported pathologies in this review.

N	Approach	Study	Total	Type of pathology			
				Traumatic	Neoplastic	Infection	Degenerative
1	Anterior	Mihir et al., 2006 ³⁷ (Ant)	42	---	---	42	---
2		Falavigna et al., 2009 ²⁰ (Ant)	14	---	10	---	4
3		Falavigna et al., 2014 ¹⁹ (Ant)	19	---	---	---	19
4		Gao et al., 2018 ²³ (Ant)	218	218	---	---	---
5		Liu et al., 2009 ³⁵ (Ant)	11	4	7	---	---
6		Dalbayrak et al., 2014 ¹⁴ (Ant)	8	3	2	3	---
7		Lee et al., 2016 ³² (Ant)	13	---	---	---	13
8	Posterior	Obeidat et al., 2019 ⁴⁰ (Post)	12	7	2	3	---
9		Elqazaz, 2015 ¹⁵ (Post)	10	5	3	2	---
10		Cho et al., 2010 ¹¹ (Post)	19	---	19	---	---
11		Chapman et al., 1996 ¹⁰ (Post)	23	23	---	---	---
12		Lenoir et al., 2006 ³⁴ (Post)	30	30	---	---	---
Total			419	290	43	50	36
Percentage (%)			100	69.2	10.3	11.9	8.6

Table 3. Types and the total number of complications reported in this review.

Anterior approach (N = 312)			Posterior approach (N = 106)		
Complications	No.	%	Complications	No.	%
Wound complications	23	7,3	Prolonged ICU stay	23	21,6
Right laryngeal nerve palsy	20	6,4	Lung infection	10	9,4
Instrumentation failure	3	0,9	Tracheostomy	8	7,5
Dysphagia	3	0,9	Wound complications	6	5,7
Revision surgery	2	0,6	Early mortality	5	4,7
Lung infection	1	0,3	Instrumentation failure	3	2,8
Thoracic duct injury	1	0,1	Paraplegia	2	1,9
Hematoma	1	0,1	Revision surgery	2	1,9
Progressive kyphosis	1	0,1	Pulmonary embolism	1	0,9
Instability	1	0,1	Total	59	55.7
Wrong level	1	0,1			
Total	57	18.2			

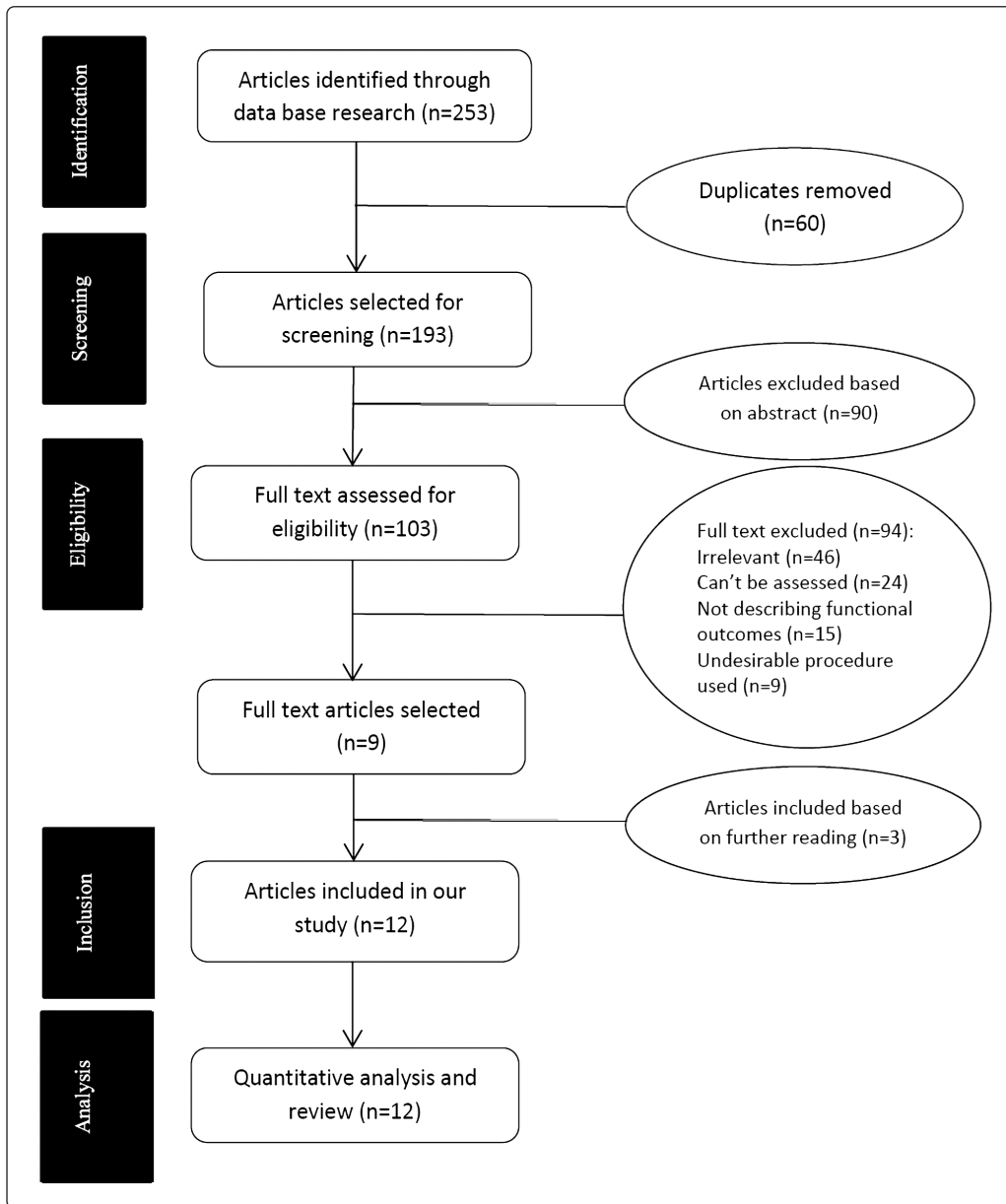


Figure 1. PRISMA flowchart for study selection.

DISCUSSION

The CTJ has been a challenging area for spinal surgeons. Bony obstacles like the sternum, clavicles anteriorly, two scapulae posteriorly, and rib cage surrounding and protecting vital organs and structures stand in the surgeon's way when approaching the CTJ during fixation. Surgeons have developed and pioneered different approaches and routes throughout surgical history, and they are still, to date, modifying and improving

approaches to the CTJ. These approaches follow different routes to the CTJ from anterior to posterior direction, passing through lateral and posterolateral ones.²⁴

This systematic review aimed to explore the studies of different CTJ approaches to evaluate the quality of evidence for outcome and complications they offer. The literature search strategy resulted in 253 records, which, after applying the aforementioned selection criteria, yielded 12 studies reported in this systematic review. All the studies were case series with high bias risk. They had a wide geographical

distribution of over 10 countries from 4 continents and distributed through 13 years, with the most recent one in 2019.

Approaches Used according to the Treated Pathologies:

In our study, most patients with traumatic and neoplastic injuries were treated through the anterior approach, and most of the patients with degenerative and infectious diseases were treated using the posterior one. The general management goal of any spinal injury is immediate stabilization, maintenance of anatomical alignment, and early rehabilitation. It is more important to reestablish the main side of pathology causing instability than the superior side using the fixation system.⁴² Concerning traumatic injury at the CTJ, a study done by Eugene et al.¹⁶ has shown that the anterior approach is valuable in treating burst fractures at C7 and facet dislocations at the cervicothoracic junction are best treated with a posterior lateral mass and pedicle screw fixation or with a combined approach. On the other hand, the study of Hoang et al.²⁵ has suggested that malignancies involving the CTJ are best treated via a posterior approach due to the biomechanical advantage of posterior instrumentation over anterior plating. In the case of degenerative disc lesion involving the cervicothoracic junction, Keyvan et al.'s²⁸ study of 21 patients has suggested that the anterior approach is more difficult to carry out, especially in large patients, and that the posterior approach is suitable for all types of patients except in case of medial disc herniation.

Clinical Outcome:

When evaluating clinical effectiveness in the reported studies, several variables were consistently available for comparison, specifically neurological outcomes measured by the different grading systems. A significant difference between the outcomes of the anterior and posterior group in favor of the anterior one has been noted. In a study by Alessandro and Maurizo,² reporting 33 patients who underwent spinal fusion following CTJ neurological lesion, patients who underwent the anterior approach showed a better postoperative neurological outcome than those who underwent

the posterior approach. Wen-jie et al.⁴⁵ have compared three surgical approaches for treating CTJ tuberculosis and showed that the anterior approach provided the best clinical outcome with the least complication rate compared to the posterior and combined approach. The results of the previous studies support our review results. Nevertheless, with a total of 20 patients, Arvind et al.⁵ and Fady et al.¹⁸ demonstrated that posterior decompression and fixation provide good neurological outcomes. In fact, 18 out of 20 patients improved after surgery. At last, regarding the functional outcome, Bueff et al.⁹ have demonstrated that anterior fixation provided a better functional outcome than posterior instrumentation. In fact, the study showed that hook/rod system provided up to six times the stiffness of the intact spine while anterior plating provided the same stiffness of an intact spine.

Complications:

In our systematic review, the most common complication noted during the anterior approach was wound-related cosmetic results followed by RLN palsy, which was transient in most cases. Fountas et al.²² have noted that the incidence of postoperative wound infections was 0.1%–1.6%, while Claudia et al.¹² have reported that when using median sternotomy, wound complications may reach 5.8%, which was close to our result. Most reported RLN palsy was due to instrumentation during surgery; the incidence may reach 11%, as indicated by Heeneman,²⁵ which is much higher than our results (6.4%).

Most complications seen in posterior groups were related to lung affection, including respiratory dysfunction, infection, and embolism. Likewise, Badhiwala et al.⁶ conducted a propensity score-matched analysis of data and demonstrated that posterior cervical fusion was associated with a higher rate of various complications, including myocardial infarction, pulmonary embolism, and deep venous thrombosis, than that of the anterior procedure.

After further study of complications seen in both groups, the rate of complication of the posterior

group was found to be much higher than that of the anterior one. Other studies^{36,43} have reported that posterior cervical fusion was associated with over three times more complications than anterior cervical procedures, 15.4% vs. 4.1% and a higher rate of mortality 1.4% vs. 0.3%.

A different way to look at complications was to link them to pathologies that could not be treated properly due to the lack of this association in reported data. Although these data may be poorly represented in some studies, it could link complications to pathologies' polarized peaks in others. In the anterior approaches, the complication of RLN injury was equally reported with the highest rates in degenerative and neoplastic patients. In contrast, the main complication of the posterior group is prolonged ICU stays, solely reported from traumatic patients' studies. However, as mentioned before, this may not be accurate due to the lack of complete data from all studies, which means that the results could be completely different if all patients were represented in the analysis.

Limitations of This Systematic Review:

Our search was limited in many aspects, including the limited numbers of available studies generally and the prospective or randomized control studies especially, the diversity of methods of assessing the clinical outcome of the patients, and the heterogeneity of diagnoses reported by each study. We have to recommend an initiative to start analytical studies with fewer bias levels and bigger scales to further collect and produce data. The ultimate goal is to reach high-level evidence regarding criteria and guidelines to help surgeons choose the most appropriate surgical approach for CTJ patients with different pathologies and clinical conditions.

CONCLUSION

The data in this review may demonstrate both the effectiveness and safety of the anterior approach compared to the posterior one. This study

indicates that patients treated with the anterior approach have a higher incidence of improvement of neurological functions and a relatively fewer complications than the posterior one. More high-quality multicentered randomized controlled trials with larger sample size and longer follow-up period, especially on the posterior approach, are warranted to support our current conclusion.

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الملخص العربي

دراسة منهجية عن نتائج التثبيت الجراحي في منطقة التقاء الفقرات العنقية والصدريّة

البيانات الخلفية: التثبيت الجراحي في منطقة مفرق الفقرات العنقية والصدريّة قد يشكل تحدي كبير للجراح، نظرا لصعوبة الوصول لهذه المنطقة ولوجود أعضاء وأنسجة حيوية حولها من وجهة نظر الميكانيكية الحيوية. العديد من الاوعية الدموية و الانسجة الحشوية و الناعمة الهامة المتواجدة بهذه المنطقة تشكل تحديا يعتبر العلم به ضروريا للتدخل لتخفيف الضغط و التثبيت. التدخل الجراحي الخلفي يستخدم في العديد من امراض العمود الفقري ولكنه غير ملائم لعلاج الاجزاء الامامية مما قد يؤدي الى زيادة نسب حدوث المضاعفات ويؤثر على ثبات العمود الفقري. ولهذا السبب تم وضع بعض النهج الجراحية الاخرى مثل الجراحات الخلفية الوحشية و الامامية للعمود الفقري.

تصميم الدراسة: دراسة منهجية.

الغرض: استكشاف ومقارنة الأدلة بالمنشورات الطبية بشأن النهج الجراحية المختلفة لعلاج الأمراض التي تصيب مفرق الفقرات العنقية والصدريّة و تحليل النتائج لتحديد مدى تحقيق الأهداف الجراحية ونسبة الأضرار والمضاعفات المصاحبة لكل نهج.

المرضي و الطرق: تم إجراء البحث باستخدام قواعد بيانات «أوفيد ميدلاين»، «بوب ميد»، «سجل كوكرين المركزي للتجارب ذات الشواهد»، «قاعدة بيانات كوكرين للمراجعات المنهجية»، من تواريخ إنشائها وحتى وقت إجراء البحث.

النتائج: أسفرت الدراسة عن مطابقة 419 مريض و 12 ورقات علمية للمواصفات المطلوبة. منها 7 دراسات للنهج الجراحي الامامي و 5 دراسات للنهج الخلفي. تم استخدام النهج الامامي لأغلب المرضى الذين عانوا من اصابات او اورام و النهج الخلفي للأمراض التنكسية و المعدية. تقييم حالة الاعصاب قبل و بعد الجراحة اوضحت ان استخدام النهج الامامي افضل من النهج الخلفي كما ان مضاعفاته اقل.

الخلاصة: أسفرت هذه الدراسة عن أن النهج الجراحي الامامي أفضل من الخلفي من حيث الفاعلية و درجة الأمان. نظرا لارتفاع معدل تحسن الحالة العصبية عند استخدام النهج الجراحي الامامي كما ان مضاعفاته أقل من استخدام النهج الجراحي الخلفي.