Evaluation of Surgical Treatment for the Herniated Cervical Disc: a Retrospective Review

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ABSTRACT

Introduction: Cervical disc herniation (CDH) is a common clinical scenario in modern society. Patients with CDH typically present with neck pain, arm pain, or both which mainly attributed to compression that may trigger local ischemia and inflammation of the cervical nerve root due to disc herniation. Anterior cervical discectomy and interbody fusion (ACDF) is the most common surgical treatment. Although ACDF procedure carries low mortality rates, this procedure still has significant morbidity rates varying from 13.2%-19.3%. Objectives: This study attempts to assess the effectiveness of intervention for treating cervical disc herniation, to determine if our practice is safe and efficacious.

Methods and patients: This study was designed as a single-centre, retrospective case-control analysis. Medical archives were retrieved and reviewed from the electronic medical record database. The institutional ethics committee reviewed and approved the study (34/3/2022).

Results: Over the study period, we noticed an overall rate of infection of 14.285% in entire population, the rate was 18.421% in the control group, and 9.375% in the vancomycin group. Independent elements that correlated with increased rates of SSIs included obesity, smoking, urgent surgeries, duration of surgery, blood loss, and diabetes mellitus. A statistically significant decrease in staphylococcal infections was found in the vancomycin cohort (3.125%) compared to the control cohort (10.526%; p = 0.029). No adverse events associated with vancomycin were observed. Our results show that this strategy was effective in decreasing the rate of SSI and cases of methicillin-resistant S. aureus (MRSA).

Conclusion: Spine SSIs may lead to heavy medical and financial burdens. This review has shown that peri-operative intrawound application of vancomycin is clinically safe and reduces the post-operative incidence of SSI without any noteworthy adverse effects.

Keywords: Cervical radiculopathy, Disc herniation, Non-operative management, ACDF, Cervical disc arthroplasty, Posterior cervical decompression.

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INTRODUCTION

Cervical disc disease (CDD) is a common clinical scenario in modern society. Patients with CDD typically present with neck pain, arm pain, or both which mainly attributed to compression that may trigger local ischemia and inflammation of the cervical nerve root due to disc herniation [1]. Neck complaints are among the most prominent causes of disability worldwide [2].

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Although, most of the patients presenting with symptomatic cervical disc herniation's associated with radiculopathy initially present with intense pain and moderate levels of disability. However, considerable improvements have a propensity to occur within the first 4 to 6 months post-onset. Time to complete recovery ranged from 24approximately of 83% of patients. Patients with a workers' litigation claim seemed to have a poorer prognosis [3]. Conservative treatment including pain analgesia, physiotherapy, and local injections might help in this phase. However, prominent sensorimotor deficits or intractable radiculopathy mandate surgical treatment [4]. The anterior cervical discectomy and interbody fusion (ACDF) is the most frequent surgical treatment option used [5,6]. Since its first reported application by Smith and Robinson in 1955, this approach has been considered a less invasive alternative to the traditional posterior technique [7]. Anterior approaches often generated reasonable outcomes with less morbidity, minimal interference of the spinal canal, and superior fusion rate [8,9]. Although ACDF procedure carries low mortality rates, this procedure still brings considerable morbidity rates varying from 13.2%-19.3% [10]. Consequently, patient selection is of paramount significance. This study attempts to assess the effectiveness of intervention for treating cervical disc herniation, to evaluate the morbidities related to cervical disc surgery in our institution, and to determine if our practice is safe and efficacious.

MATERIALS AND METHODS

Ethics

Patient reports from the electronic hospital database over a 3-year period (2019 - 2021) were analyzed. This study was registered by the Institutional ethics committee, Royal Medical Services (IRB: 15/9/2022) on the 18th of October, 2022. As this study was a retrospective analysis, the requirement for patient consent was waived. Patients' records and data processing has been accomplished according to the Declaration of Helsinki (2013) and the Health Insurance Portability and Accountability (HIPAA) actions.

Patients

As the protocol of management in our Centre, all patients were initially evaluated clinically, followed by radiological evaluation, after which a trial of conservative treatment is given, in absence of sensorimotor deficits or intractable radiculopathy. In these cases, included in our study, surgical decision based on clinical and radiological evaluations was made. All patient data were documented, including the extensive comprehensive history including demographic features (age, gender, body mass index ［BMI］), co-morbidities and the clinical picture. A meticulous neurological evaluation and examination was then performed. Several confirmatory investigations were performed: magnetic resonance imaging (MRI), computed tomographic scan, dynamic x-ray, to confirm the diagnosis and exclude secondary causes leading to neck and arm pain (Fig. 1).

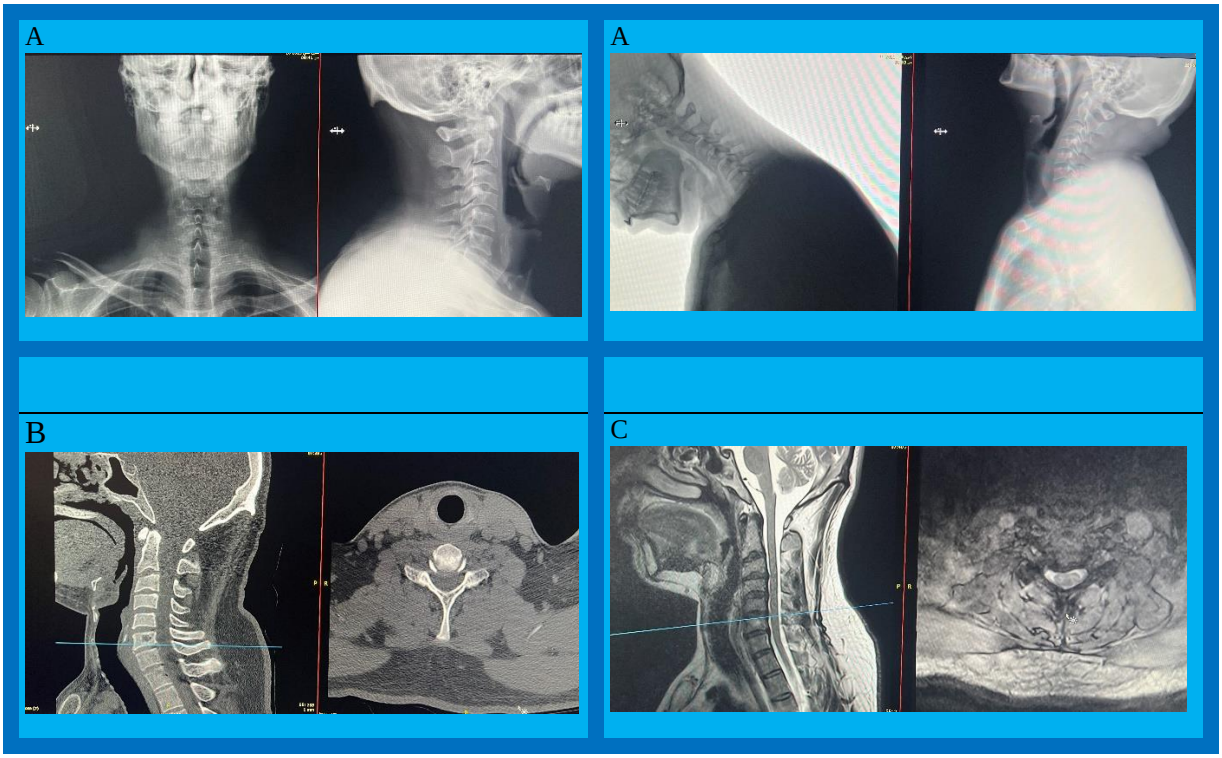

Figure. I: Shows the pre-operative radiological evaluation for patients presented with signs and symptoms of cervical disc disease. A) X-rays (antero-posterior & dynamic, B) Ct scan (sagittal & axial), C) MRI scan (sagittal and axial).

Study Design

This retrospective chart analysis was conducted by revising all consecutive patients and their medical files for whom intervention for treating cervical disc herniation was conducted.

Inclusion/exclusion criteria

Inclusion criteria:

1. Adult age > 18 years.
2. One or more cervical disc herniation.
3. A minimum follow-up period of 3- months.

Exclusion criteria:

1. Oncology cases scheme.
2. Age < 18 years
3. Patients with spinal infection.
4. Lack of radiological evaluation, or clinical data.
5. Previous cervical spine surgery.
6. Ossification of posterior longitudinal ligament.
7. Patients with posterior instrumentation.

Surgical technique

The microsurgical procedure of ACDF is a surgery to remove a herniated or degenerative disc in the neck. Procedure was performed in a standardized manner following certain surgical steps. Patient under general endotracheal anesthesia was placed in supine position, and the damaged level was marked with X-ray control. The region was prepped with alcohol, betadine scrub, and betadine paint prior to incision and draped in a sterile fashion in all patients. The skin incision is one to two inches on right hand side of the neck. The incision is made horizontally within a natural skin crease, although occasionally a more vertical incision is used for multilevel cases. The platysma is then split in line with the skin incision, and the plane between the sternocleidomastoid muscle and the strap muscles is then entered. Next, a plane between the trachea/esophagus and the carotid sheath is entered. The pre-vertebral fascia is then dissected away from the disc space. Fluoroscopy was then used to reconfirm the level. After the correct disc space has been identified, the disc is then removed by first cutting the outer annulus fibrosis and removing the nucleus pulposus.

With an anterior cervical discectomy, the entire disc is removed. The cartilage endplates on the vertebral bones are also removed to reveal the hard cortical bone underneath. Dissection is conducted from the front to back of the posterior longitudinal ligament, then the ligament is gently removed to allow access to the spinal canal to remove any disc material that may have extruded through the ligament, which may be contributing to spinal stenosis. The uncinate processes partially removed as well. Cervical fusion is done following the cervical discectomy. The insertion of a cage into the evacuated disc space prevents disc space collapse and promotes a growing together of the two vertebrae into a single unit. Plate is used for all patients with three levels and more ACDF and some of patients with 2- levels, attached with screws into each of the vertebral bones. An operating microscope was used in all the cases.

Statistical analysis

Data were registered into the Microsoft Excel sheet, and analysis was performed using statistical software SPSS Statistics Version 28.0. The categorical data were demonstrated in frequency and percentages, while the scale data were stated employing illustrative statistics such as mean and standard deviation for continuous variables. An Independent sample t-test was used to evaluate mean differences between scale data. Moreover, the chi-square test was used for the association between categorical data, a binomial test was used to assess sample proportion with hypothetical proportion, Alpha level set at 0.05 deemed statistically significant.

RESULTS

This study was conducted at KHMC and included 165 patients who had been diagnosed initially with degenerative disc disease and admitted for ACDF. Patients were included if they met the established diagnostic criteria for CDD. Of those, four patients were disqualified due to additional posterior instrumentation, six patients underwent corpectomy, and three patients were eliminated due to incomplete data. The final study group therefore contained 152 patients to be considered for the final analysis, with 193 cervical levels operated (Fig. II). Of the final cohort, 57.24% of the patients were males (87/152), with a mean age at diagnosis of 45.31 ± 10.89 years (range 25–69 years). The females had a mean age at diagnosis of 48.67 ± 9.93 years (range 23–73 years) as shown in Table 1.

Statistical analysis of the data revealed significant differences in terms of the number of levels operated between the two groups and the peak age. On the other hand, our study had several complications; our overall morbidity rate was 16.58% (*P* = 0194).

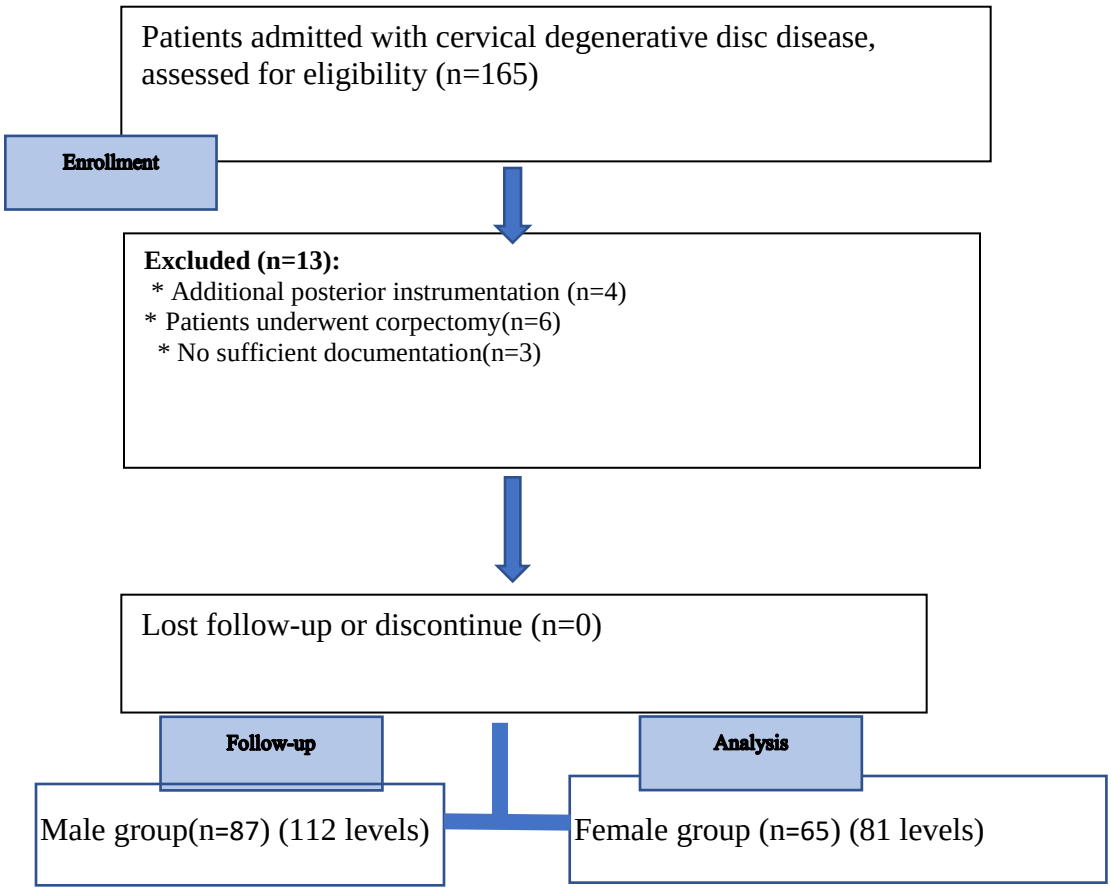

Figure. II: Study flowchart

Table 1 Demographic and surgery data of the patients.

Parameters	Male group	Female group	p value
Number of cases	87	65	
Number of levels	112	81	
Age (years)	45.31± 10.89	48.67±9.93	
Body mass index (kg/m2)	29.0 ± 4.7	28.6 ± 5.9	
Diabetes	29.88%	32.30%	
Smoker	31.03%	27.69%	
Peak age group	30-39	40-49	
Surgery duration (min)	119 ± 73	126 ± 77	
Blood loss (ml)	198 ± 172	146 ± 105	
Duration of drainage (days)	2.3 ± 0.6	2.4 ± 0.6	
Number of levels operated	1.278 ± 0.51	1.276 ± 0.43	
Mean follow up (months)	**13.44±2.88**	**15.14±4.6**	

DISCUSSION

CDD is a universal disabling medical condition in modern society and the estimated prevalence reaches 95% by the age of 65 years (11, 12). Patients with cervical disc degeneration commonly present with neck pain, radiculopathy resulting from nerve root compression, which is mainly attributed to degeneration from natural aging, trauma, or occupational hazards (13). Degenerative CDD is most frequently reported in the age group between 35 and 55 years, and the estimated incidence is around 5.5 patients per 100,000 of the population; it leads to a surgical intervention in 26% of these individuals (14, 15). According to many publications, females are less susceptible to developing this condition (16-23), while a higher incidence of spondylotic changes in the population are correlated with increasing age and with gender (17). In national studies of the Indian population, the main risk factors that precipitate for cervical spondylosis are age and gender (19, 20). In our review, 87 of our patients were male, a slight predominance; the male-to-female ratio was 1.34:1. In the male group, predominantly the patients were in the age group of 30–39 years (36.8%) followed by the age group 40–49 years (28.7%), while in the female group in most instances the patients were in the age group 40–49 years (44.6%), followed by the age group 50–59 years (27.7%) (Fig. III). The most reported cervical disc herniation levels are C4/5, followed by C5/6, and

lastly C6/7 (24). Nevertheless, our results showed that almost half of the study population (49.74%) presented with degenerative disc disease at the C5–C6 disc level, followed by C6–C7 level (22.79%) (Fig. IV).

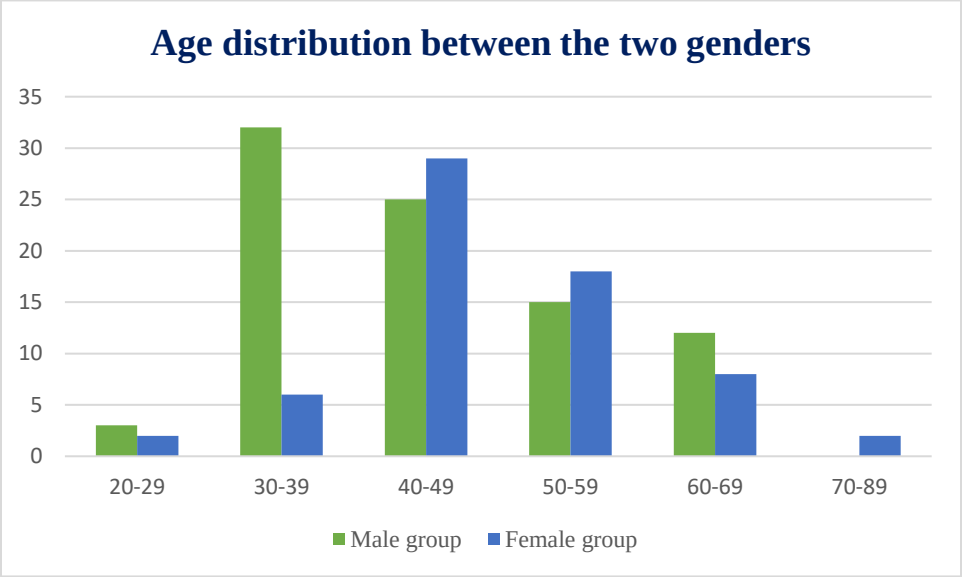

Figure. III: Shows the age distribution between the two groups.

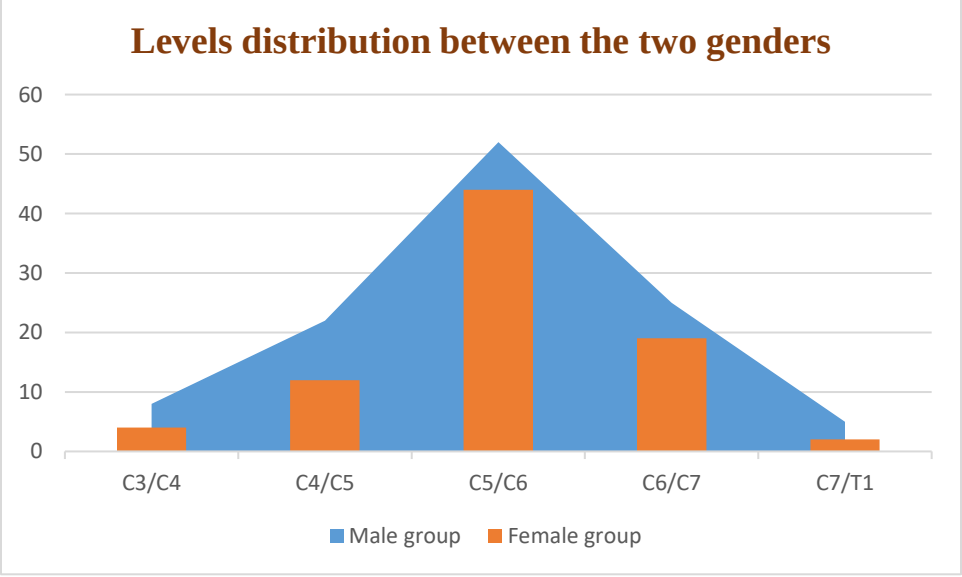

Figure. IV: Shows the cervical disc distribution between the two groups.

Clinical presentation in patients with CDD is still ambiguous. Although neck pain is the cardinal symptom, its source is still a matter of debate and uncertainty (25, 26). Discogenic pain is also another issue that has no clear definition and evidence to provoke neck pain, although in most cases of cervical disc herniation there is associated neck pain (27-30). In our review, a tingling sensation was the cardinal symptom, followed by neck pain, while sphincteric dysfunction was the least reported complaint reported by our patients (Fig. V).

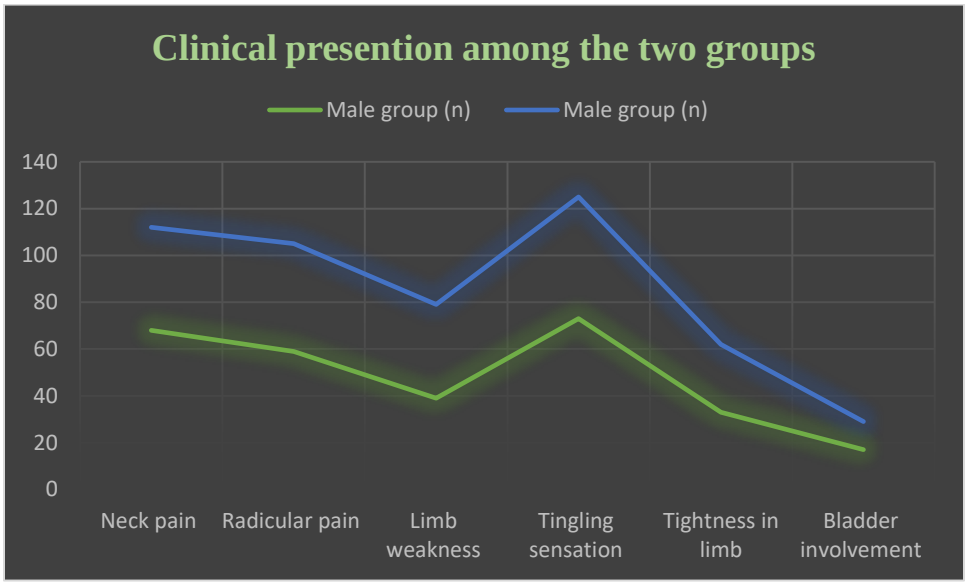

Figure. V: Shows the clinical presentation among the two groups.

In the diagnosis of degenerative disc disease, there is a correlation between the clinical picture and radiological imaging. In our day-to-day practice it might be challenging to discriminate between the pain resulting from joint and muscle (mechanical pain) and cervical radicular pain, but differentiation between the two entities is of great value. For cases of cervical radiculopathy, established guidelines recommend earlier neurosurgical referral, imaging study, and the use of neuropathic medications (31). Crucial tools are a dedicated musculoskeletal examination and neurological evaluation to distinguish between referred pain, radicular pain, and myelopathy. Supplementary shoulder joint evaluation will help to rule out a principal shoulder problem (32). Patients presenting with radicular symptoms, upper limb myotomes, and dermatomes should be examined (33). In our practice, we apply these guidelines. If the clinical presentation is suggestive of persistent cervical radicular pain for a period of more than 4 to 6 weeks, imaging evaluation should be ordered (31).

Imaging modalities of the cervical segment of the spine have dramatically evolved in the last decades, especially with the development of technologies, and play an essential role in the process of identification and lateralization of cervical radicular pain. The primary examination that is normally done is a plain X-ray. Antero-posterior and lateral exposures are beneficial for gaining an idea about the global alignment of the cervical spine including the existence of any recognizable spondylotic alterations of the facet joints. Lateral dynamic (flexion and extension) exposures are effective to analyze any instability that might not be identifiable on a static radiographic image. A thin slice computed tomography (CT) scan providing high-resolution sagittal and coronal reformats allows for a comprehensive assessment of the vertebral column degenerative process. A CT scan is used to detect bone details

in terms of bony lesions, abnormal bone formation, or any osteophyte development in addition to any deceptive process that may cause nerve root impingement (Fig. VI). MRI has become the procedure of choice for evaluation of the spinal cord and surrounding soft tissues when a reliable neurologic examination cannot be performed, or further evaluation is needed (34). MRI has the highest capability to demonstrate the detailed soft tissue configurations besides the nerve root course from cord to its exit from the foramen (35). Electrophysiologic testing is an additional diagnostic tool that can be utilized to assist in diagnosis of radicular pain (36).

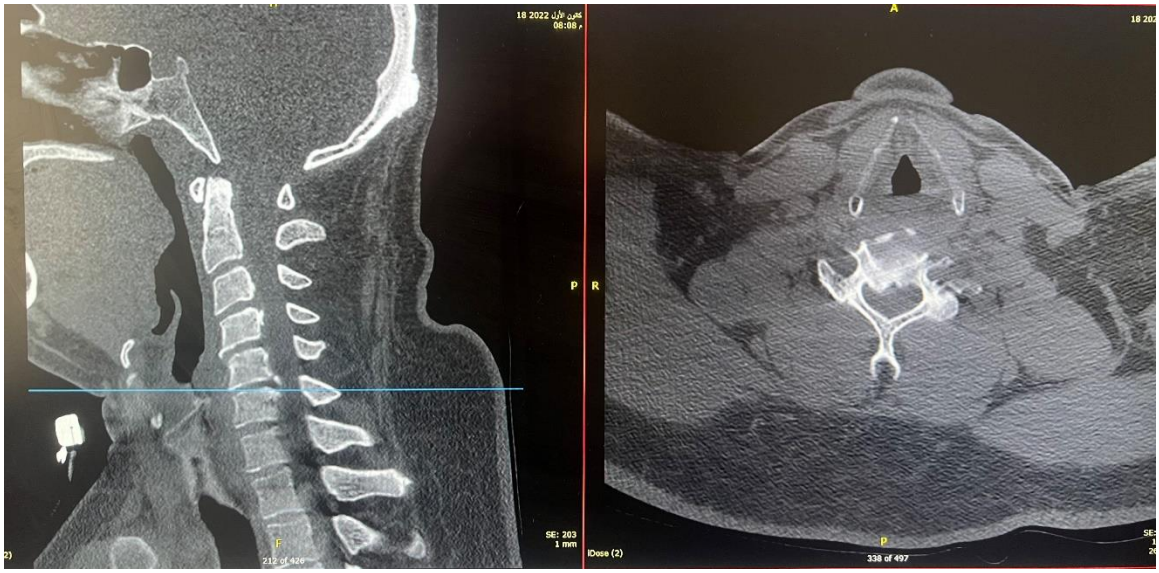

Figure. VI: A CT scan evaluation (sagittal and axial cuts) of C5/C6 degenerative cervical disc disease, shows osteophyte formation

Once the diagnosis is established and in the absence of sensorimotor deficit, physiotherapy for 6 weeks is recommended, although the mechanism of pain reduction is still unclear. Non-operative management will improve pain in 75%–90% of patients presented and diagnosed with cervical radicular pain (37, 38). Thus, physiotherapy substantially reduces neck and arm pain, its cardinal aim being to reestablish neck musculature range of motion and strengthening (39, 40). The National Institute for Health and Care Excellence (NICE) has established a series of recommendations: analgesic agents (ibuprofen, paracetamol, or codeine) added to a provisional course of neuropathic drugs (amitriptyline, pregabalin, or gabapentin) for patients developing minor neurological signs or for patients with symptoms lasting more than 4 weeks (31).

It has also been recommended that patients with non-specific neck pain lasting more than 12 weeks are referred to a pain management clinic, with or without a trial of neuropathic agents (31).

For patients with a failed trial of conservative management course or who develop reasons for surgery, such as a major neurological deficit or interactable pain, several valid options are available for the surgical intervention of cervical radicular pain (41).

Some factors, such as spinal alignment, stability, and balance, play a role in a surgeon's decision to use a preferred technique. Surgical approaches can be allocated into two large categories: anterior and posterior approaches to the spine.

Anterior approach with graft provides the capability to reestablish cervical segmental lordosis, stabilize the vertebral spine, enhance bone fusion, works as weight shearing device, and certainly decompress the nerve roots directly and indirectly (42, 43). This procedure achieves removal of the whole intervertebral disc along with any

osteophytes formed at the posterior element of the vertebral body. Historically, the removed intervertebral disc was then replaced by either autologous bone graft material or even left with nothing (44-49). In recent times, restoration of normal intervertebral disc height with bone grafts or cages has gained ground (50-52). The ACDF procedure was one of the most performed spinal techniques in the U.S.A. in the period between 2006 and 2013, with a median of 137,000 cases of ACDF per year (total cases in 7 years 1,059,403) (53).

In our daily practice, we adopted the ACDF technique as the procedure of choice. Following this technique and with the introduction of an allograft, we aim to enhance the rate of fusion and to increase the degree of postoperative lordosis (54-57). Additionally, introduction of a graft permits indirect decompression of neural elements by increasing the cephalocaudal height of the intervertebral space (58).

Although ACDF has a huge success rate in achieving fusion, restoration of disc space height and lordosis, and indirect decompression of nerve roots, still have their complications. We carried out a dedicated analysis of the ACDF cases performed in our center and assessed the complications encountered and registered (Table 2).

Table 2 Overall complications encountered.

Complication	Percentage	Literature percentage	P Value
Dural penetration	1.55%	1.7%	**0.584**
Superficial wound infection	2.07%	1.6%	**0.373**
Cage mechanical failure	2.07%	3.21%	**0.255**
Horner's syndrome	1.04%	1.1%	**0.581**
Isolated postoperative dysphagia	3.63%	9.5%	**0.002***
Postoperative hematoma required surgical intervention	1.04%	5.6%	**0.001***
Symptomatic recurrent laryngeal nerve palsy	1.55%	3.1%	**0.001***
Esophageal perforation	0%	00.9%	---
Adjacent intervertebral disc	2.59%	9.0%	**0.001***
Pseudoarthrosis	1.04%	9.1%	**0.001***
Overall morbidity	16.58%	19.3%	**0.194**
**** Statistically significant***			

Several analyses have documented the morbidity/complication rates of the ACDF procedure; they range from 13.2% to 19.3% (59-61). In our review, the overall morbidity encountered was 16.58%, which was statistically comparable to the literature ($P = 0.194$). Morbidity rates are demonstrated in Table 2.

We compared each complication we encountered with those reported in the literature to evaluate our efficacy and safeness. Some of these complications might be encountered perioperatively, while others may evolve later.

Esophageal perforation, one of the major and fatal complications that might be faced, has been reported in literature in 0.3%–0.9% of cases (61-63). Luckily, we have not had any.

Unintended dural breach, a rare but still serious complication, occurred in three of our patients (1.55%). In none of our cases did a cerebrospinal fluid (CSF) fistula develop postoperatively. None of our patients needed further actions other than the primary closure or applying a fibrin sealant patch with glue. Patients had no additional consequences. Our results are in line with the literature which shows 0.5%–1.7% incidence of dural breach (59, 61, 64) ($P = 0.584$).

Dysphagia, one of the most frequent postoperative complications, was reported in seven patients (3.63%) and was resolved spontaneously within 2 weeks. Worldwide reports show a wide range of dysphagia rates (1.7%–9.5%) (65-67). Our study showed a statistically significantly lower rate ($P = 0.002$).

Another common complication is recurrent laryngeal nerve (RLN) palsy. Previous studies have revealed that RLN palsy incidence is understated (68, 69). Unilateral vocal paralysis results in dysphonia and/or hoarseness, which are the most common clinical manifestations, while respiratory insufficiency might develop due to bilateral RLN palsy (69, 70). In our analysis, symptomatic RLN palsy was reported in 1.55% of our cases. The incidence of spontaneous, asymptomatic, preoperative RLN palsy in the literature is about 1.6% (71, 72). However, around 1.1%–3.1% of patients undergoing anterior cervical spine surgery develop symptomatic RLN palsy (59, 73). Our study a showed significantly lower rate ($P = 0.001$).

Both superficial and deep surgical site infections exist among the complications of anterior cervical surgery. Reported rates of surgical site infection are around 0.9%–1.6% (64-66, 74). Our review identified four cases of superficial wound infections (2.07%), which were treated with simple dressing and empirical antibiotics, with no significant difference compared with the literature ($P = 0.373$).

Although postoperative hematoma arises rarely in ACDF, it might be a possibly life-threatening complication. Its immediate detection and surgical evacuation are vital in order to avoid any potential airway compromise. The reported incidence in previously published reviews is around 0.2%–2.4% (59, 61, 75, 76). Postoperative hematoma might develop in an acute or delayed fashion; the majority develop in a delayed fashion, at an average of 6 days postoperatively (76, 77). Meticulous intraoperative hemostasis and drain insertion play a cardinal role in preventing a postoperative hematoma (76). Postoperative wound hematoma that required surgical evacuation occurred in two cases (1.04%) in our series, which was significantly lower than in reports in the literature ($P < 0.001$).

Degeneration of adjacent intervertebral discs develops due to alteration of the regional biomechanics, increased stress, and instability of loads to the adjacent intervertebral discs (78-82). Although not considered a complication of ACDF, there is still a strong correlation. Recently stated data demonstrate that the incidence of adjacent segment degeneration after ACDF is around 12.2%, and consequently grows to 25% after a second ACDF (83, 84). Other studies concluded that 9% of adjacent level disease develops within 6 years after ACDF, and 7.4% of cases require a reoperation. The annual incidence of degeneration is around 2.9% per year (85, 86). Our review revealed five cases (2.59%) with adjacent level disease within 3 years of the primary surgery, a statistically significant lower rate that in the literature ($P < 0.001$).

A well-documented but rare complication encountered in anterior approaches to the subaxial cervical spine is Horner's syndrome (87). Horner's syndrome is characterized by ipsilateral pupillary miosis, facial anhydrosis, and ptosis, resulting from damage to the cervical sympathetic trunk. Horner's syndrome rarely manifests with significant clinical impairment, but the cosmetic effect may cause considerable concern (88). Several studies have shown very low incidence, with rates between 0.02% and 4.0%. Our analysis showed two cases (1.04%). Symptoms totally resolved in one patient using steroids and speech therapy, while one female patient suffered from incomplete resolution.

The main aim after decompression of the spine and nerve roots via ACDF is to achieve fusion. Fusion rates stated in the literature for one- to two-level ACDF were higher following one-level vs. two-level ACDF and were also higher when using an autograft (89, 90). The criteria to support bone fusion are the presence of a trabecular bridging bone formation between the cage and vertebral endplate documented by CT scan, and a lack of motion confirmed by dynamic cervical X-ray of the fused levels (91). Studies show fusion rates of 90.1%–100% (92-95). We achieved a fusion rate of 97.93%, while that for pseudoarthrosis was significantly lower at 2.07%, confirmed in four cases ($P < 0.001$).

The accumulative complication rate encountered in our analysis was 16.58%, with no mortality occurring. The complications developed were more prominent with increased age, smoking, and multilevel cases. However, good diagnosis and preoperative evaluation in addition to good technique would improve outcome.

Although this study shows good results, it still carries substantial limitations. First, the present analysis is a retrospective study, hence holding possible biases of retrospective studies that could compromise the analysis. Moreover, the small sample size of our cohort may weaken the statistical power of the conclusions. Nevertheless, the intention of our analysis was to evaluate treatment of a degenerative cervical disc via the ACDF procedure, in addition to the associated complications, as many of them are correlated with the anterior approach per se. Nonetheless, supplementary studies are still needed to optimize the necessary management approaches and treatment and to avoid or minimize these complications.

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CONCLUSION

This study to evaluate the ACDF procedure for degenerative disk herniation has revealed good or excellent outcomes in most cases. However, the existence of disruptive complications, although rare, requires consideration. The study failed to distinguish possible changeable and modifiable preoperative risk factors that can minimize or eliminate any complications. The cardinal factors for enhancing the good result for these patients and their quality of life are a high awareness level, early identification, and appropriate direct management, which have vital consequences.

Conflicts of interest: The author certifies that he has no affiliation with or any direct or indirect involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

Future work: We need a prospective, study and a larger population.

Availability of data and materials: All data generated or analyzed during this study are included in this published article.

Authors' contributions: *all authors contributed substantially to different article milestones.*

AR: acquisition of data, writing manuscript, approving final manuscript, acquisition of data, analysis and interpretation of data. AD: acquisition of data, analysis and interpretation of data. AI: acquisition of data, analysis and interpretation of data, HS: analysis and interpretation of data, writing manuscript, QR: analysis and

interpretation of data, drafting manuscript, conception and design, writing manuscript, approving final manuscript, tables, diagrams.

Final approval of manuscript: All authors
Agree to be accountable for all aspects of the work: All authors.
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Ethical Approval

We declare that the Ethics Committee of Royal Medical Services (No. 9/7/2022) have approved this study

Informed Consent

Patient's informed consent was waived as this is a retrospective study.

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REFERENCES

1-Abbed KM, Coumans JV. Cervical radiculopathy: pathophysiology, presentation, and clinical evaluation. *Neurosurgery*. 2007;60(1 Supp1 1):28-34.

2-Taso M, Sommernes JH, Kolstad F, et al. A randomised controlled trial comparing the effectiveness of surgical and nonsurgical treatment for cervical radiculopathy. *BMC Musculoskelet Disord*. 2020;21(1):171.

3- Wong JJ, Côté P, Quesnele JJ, Stern PJ, Mior SA. The course and prognostic factors of symptomatic cervical disc herniation with radiculopathy: a systematic review of the literature. *Spine J*. 2014;14(8):1781-1789.

4- Schnake KJ, Hoffmann CH, Kandziora F. Der zervikale Bandscheibenvorfall [Cervical disc herniation]. *Z Orthop Unfall*. 2012;150(6):657-673.

5- Carette S, Fehlings MG. Clinical practice. Cervical radiculopathy. NEJM. 2005;353(4):392–399.

6-Nesterenko SO, Riley LH, 3rd, Skolasky RL. Anterior cervical discectomy and fusion versus cervical disc arthroplasty: current state and trends in treatment for cervical disc pathology. *Spine.* 2012;37(17):1470–1474.

7-The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. Smith GW, Robinson RA. *J Bone Joint Surg Am.* 1958;40:607–624.

8- Current anterior techniques for single-level cervical disc disease. Kale S, Cahill DW. *Contemp Neurosurg.* 2002; 24:1–6.

9- Surgical management of cervical soft disc herniation. A comparison between the anterior and posterior approach. Herkowitz HN, Kurz LT, Overholt DP. *Spine (Phila Pa 1976)* 1990; 15:1026–1030.

10- Epstein NE. A Review of Complication Rates for Anterior Cervical Diskectomy and Fusion (ACDF). *Surg Neurol Int*. 2019; 10:100.

11- Brinjikji W, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. *AJNR Am. J. Neuroradiol.* 2015;36(4):811–816.

12- Theodore N. Degenerative cervical spondylosis. *NEJM.* 2020; 383:159–168.

13- Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative Cervical Myelopathy: Epidemiology, Genetics, and Pathogenesis. Spine (Phila Pa 1976). 2015;40(12):675-693.

14- Mostofi K, Khouzani RK. Reliability of cervical radiculopathy, its congruence between patient history and medical imaging evidence of disc herniation and its role in surgical decision. *Eur J Orthop Surg Traumatol*. 2016;26(7):805-808.

15- Srikhande NN, Kumar VAK, Sai Kiran NA, et al. Clinical presentation and outcome after anterior cervical discectomy and fusion for degenerative cervical disc disease. J Craniovertebral Junction Spine. 2019;10(1):28-32.

16- Basques BA, Hijji FY, Khechen B, Haws BE, Mayo BC, Massel DH, et al. Sex differences for anterior cervical fusion: Complications and length of stay. Spine (Phila Pa 1976) 2018;43:1025–30.

17- Sasaki T, Kadoya S, Iizuka H. Roentgenological study of the sagittal diameter of the cervical spinal canal in normal adult Japanese. Neurol Med Chir (Tokyo) 1998;38:83–8.

18. Hukuda S, Kojima Y. Sex discrepancy in the canal/body ratio of the cervical spine implicating the prevalence of cervical myelopathy in men. Spine (Phila Pa 1976) 2002;27:250–3.

19- Singh S, Kumar D, Kumar S. Risk factors in cervical spondylosis. J Clin Orthop Trauma. 2014;5:221–6.

20- Gupta SK, Roy RC, Srivastava A. Sagittal diameter of the cervical canal in normal Indian adults. Clin Radiol. 1982;33:681–5.

21- Lee HM, Kim NH, Kim HJ, Chung IH. Mid-sagittal canal diameter and vertebral body/canal ratio of the cervical spine in Koreans. Yonsei Med J. 1994;35:446–52.

22- Liguoro D, Vandermeersch B, Guérin J. Dimensions of cervical vertebral bodies according to age and sex. Surg Radiol Anat. 1994; 16:149–55.

23- Wiegand R, Kettner NW, Brahee D, Marquina N. Cervical spine geometry correlated to cervical degenerative disease in a symptomatic group. J Manipulative Physiol Ther. 2003;26:341–6.

24- Czervionke LF, Fenton DS. Imaging painful spine disorders. 1st ed. Philadelphia: Elsevier Health Sciences; 2011.

25- Fujimoto K, Miyagi M, Ishikawa T, et al. Sensory and autonomic innervation of the cervical intervertebral disc in rats: the pathomechanics of chronic discogenic neck pain. Spine. 2012;37(16):1357–1362.

26- Yang L, Yang C, Pang X, et al. Mechanoreceptors in Diseased Cervical Intervertebral Disc and Vertigo. Spine. 2017;42(8):540–546.

27- Binder AI. Cervical spondylosis and neck pain. *BMJ.* 2007;334(7592):527–531.

28- Carragee EJ, Hurwitz EL, Cheng I, et al. Treatment of neck pain: injections and surgical interventions: results of the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. *J Manipulative Physiol Ther.* 2009;32(2 Suppl):176–193.

29- Evans G. Identifying and treating the causes of neck pain. *Med Clin North Am.* 2014;98(3):645–661.

30- Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. *BMJ.* 2017; 358:3221.

31- National Institute for Health and Care Excellence. Neck pain — cervical radiculopathy. 2015. https://cks.nice.org.uk/neck-pain-cervical-radiculopathy#!scenario.

32- Artus M, Holt TA, Rees J. The painful shoulder: an update on assessment, treatment, and referral. Br J Gen Pract. 2014.

33- McCartney S, Baskerville R, Blagg S, McCartney D. Cervical radiculopathy and cervical myelopathy: diagnosis and management in primary care. Br J Gen Pract. 2018;68(666):44-46.

34- van Den Hauwe L, Sundgren PC, Flanders AE. Spinal Trauma and Spinal Cord Injury (SCI). In: Hodler J, Kubik-Huch RA, von Schulthess GK, eds. Diseases of the Brain, Head and Neck, Spine 2020–2023: Diagnostic Imaging. Cham (CH): Springer; February 15, 2020.231-240.

35- Jagannathan J, Shaffrey CI, Oskouian RJ, et al. Radiographic and clinical outcomes following single-level anterior cervical discectomy and allograft fusion without plate placement or cervical collar. J Neurosurg Spine. 2008;8(5):420–428.

36- Nardin RA, Patel MR, Gudas TF, Rutkove SB, Raynor EM. Electromyography and magnetic resonance imaging in the evaluation of radiculopathy. Muscle Nerve. 1999;22(2):151–155.

37- Radhakrishnan K, Litchy WJ, O'Fallon WM, Kurland LT. Epidemiology of cervical radiculopathy. A population-based study from Rochester, Minnesota, 1976 through 1990. Brain. 1994;117(Pt 2):325–335.

38- Sampath P, Bendebba M, Davis JD, Ducker T. Outcome in patients with cervical radiculopathy. Prospective, multicenter study with independent clinical review. Spine (Phila Pa 1976) 1999;24(6):591–597.

39- Kuijper B, Tans JT, Beelen A, et al. Cervical collar or physiotherapy versus wait and see policy for recent onset cervical radiculopathy: randomised trial. BMJ. 2009;339: b3883.

40- Rosomoff HL, Fishbain D, Rosomoff RS. Chronic cervical pain: radiculopathy or brachialgia: noninterventional treatment. Spine 1992;17(10 suppl):362-6.

41- Fessler RG, Sekhar LN. Atlas of neurosurgical techniques: spine and peripheral nerves. New York: Thieme; 2006.

42- Cloward RB. The anterior approach for removal of ruptured cervical disks. J Neurosurg. 1958;15(6):602–617.

43- Estridge MN, Smith RA. Anterior Cervical Fusion; Solution of a Particular Problem. J Neurosurg. 1963; 20:441–444.

44-Abd-Alrahman N, Dokmak AS, Abou-Madawi A. Anterior cervical discectomy (ACD) versus anterior cervical fusion (ACF), clinical and radiological outcome study. Acta Neurochir (Wien). 1999;141(10):1089–1092.

45- Barlocher CB, Barth A, Krauss JK, Binggeli R, Seiler RW. Comparative evaluation of microdiscectomy only, autograft fusion, polymethylmethacrylate interposition, and threaded titanium cage fusion for treatment of single-level cervical disc disease: a prospective randomized study in 125 patients. Neurosurg Focus. 2002;12(1):4.

46- Bohlman HH, Emery SE, Goodfellow DB, Jones PK. Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy. Long-term follow-up of one hundred and twenty-two patients. J Bone Joint Surg Am. Sep. 1993;75(9):1298–1307.

47- Heary RF, Ryken TC, Matz PG, et al. Cervical laminoforaminotomy for the treatment of cervical degenerative radiculopathy. J Neurosurg Spine. 2009;11(2):198–202.

48- Madawi AA, Powell M, Crockard HA. Biocompatible osteoconductive polymer versus iliac graft. A prospective comparative study for the evaluation of fusion pattern after anterior cervical discectomy. Spine (Phila Pa 1976) 1996;21(18):2123–2129.

49- Watters WC, 3rd, Levinthal R. Anterior cervical discectomy with and without fusion. Results, complications, and long-term follow-up. Spine (Phila Pa 1976) 1994;19(20):2343–2347.

50- Jho HD. Microsurgical anterior cervical foraminotomy for radiculopathy: a new approach to cervical disc herniation. J Neurosurg. 1996;84(2):155–160.

51- Jho HD, Kim MH, Kim WK. Anterior cervical microforaminotomy for spondylotic cervical myelopathy: part 2. Neurosurgery. 2002;51(5 Suppl): S54–S59.

52- Johnson JP, Filler AG, McBride DQ, Batzdorf U. Anterior cervical foraminotomy for unilateral radicular disease. Spine (Phila Pa 1976) 2000;25(8):905–909.

53- Saifi C, Fein AW, Cazzulino A, Lehman RA, Phillips FM, An HS, Riew KD. Trends in resource utilization and rate of cervical disc arthroplasty and anterior cervical discectomy and fusion throughout the United States from 2006 to 2013. Spine J. 2018;18(6):1022–1029.

54- Boakye M, Mummaneni PV, Garrett M, Rodts G, Haid R. Anterior cervical discectomy and fusion involving a polyetheretherketone spacer and bone morphogenetic protein. J Neurosurg Spine. 2005;2(5):521–525.

55- Fraser JF, Hartl R. Anterior approaches to fusion of the cervical spine: a metaanalysis of fusion rates. J Neurosurg Spine. 2007;6(4):298–303.

56- McGuire KJ, Harrast J, Herkowitz H, Weinstein JN. Geographic Variation in the Surgical Treatment of Degenerative Cervical Disc Disease: American Board of Orthopedic Surgery (ABOS) Quality Improvement Initiative; Part II Candidates. Spine (Phila Pa 1976). Feb 2011.

57- Uribe JS, Sangala JR, Duckworth EA, Vale FL. Comparison between anterior cervical discectomy fusion and cervical corpectomy fusion using titanium cages for reconstruction: analysis of outcome and long-term follow-up. Eur Spine J. 2009;18(5):654–662.

58- Samartzis D, Shen FH, Lyon C, Phillips M, Goldberg EJ, An HS. Does rigid instrumentation increase the fusion rate in one-level anterior cervical discectomy and fusion? Spine J. 2004;4(6):636–643.

59- Fountas KN, Kapsalaki EZ, Nikolakakos LG, Smisson HF, Johnston KW, Grigorian AA, et al. Anterior cervical discectomy and fusion associated complications. Spine (Phila Pa 1976) 2007;32(21):2310–7.

60- Bovonratwet P, Fu MC, Tyagi V, Bohl DD, Ondeck NT, Albert TJ, et al. Incidence, Risk Factors, and Clinical Implications of Postoperative Hematoma Requiring Reoperation Following Anterior Cervical Discectomy and Fusion. Spine (Phila Pa 1976) 2018Sep 21.

61-Tasiou A, Giannis T, Brotis AG, Siasios I, Georgiadis I, Gatos H, et al. Anterior cervical spine surgery-associated complications in a retrospective case-control study. J Spine Surg. 2017;3(3):444–459.

62-Vrouenraets BC, Been HD, Brouwer-Mladin R, et al. Esophageal perforation associated with cervical spine surgery: report of two cases and review of the literature. Dig Surg 2004; 21:246-9.

63- Newhouse KE, Lindsey RW, Clark CR, et al. Esophageal perforation following anterior cervical spine surgery. Spine (Phila Pa 1976) 1989;14:1051-3.

64- Wang MC, Chan L, Maiman DJ, et al. Complications and mortality associated with cervical spine surgery for degenerative disease in the United States. Spine (Phila Pa 1976) 2007;32:342-7.

65- Daniels AH, Riew KD, Yoo JU, et al. Adverse events associated with anterior cervical spine surgery. J Am Acad Orthop Surg 2008; 16:729-38

66- Riley LH, Vaccaro AR, Dettori JR, et al. Postoperative dysphagia in anterior cervical spine surgery. Spine (Phila Pa 1976) 2010;35:S76-85.

67-Edwards CC, Karpitskaya Y, Cha C, et al. Accurate identification of adverse outcomes after cervical spine surgery. J Bone Joint Surg Am 2004;86-A:251-6.

68- Netterville JL, Koriwchak MJ, Winkle M, et al. Vocal fold paralysis following the anterior approach to the cervical spine. Ann Otol Rhinol Laryngol 1996; 105:85-91.

69- Winslow CP, Meyers AD. Otolaryngologic complications of the anterior approach to the cervical spine. Am J Otolaryngol 1999; 20:16-27.

70- Kriskovich MD, Apfelbaum RI, Haller JR. Vocal fold paralysis after anterior cervical spine surgery: incidence, mechanism, and prevention of injury. Laryngoscope 2000; 110:1467-73.

71-Curley JW, Timms MS. Incidence of abnormality in routine 'vocal cord checks'. J Laryngol Otol 1989; 103:1057-8.

72- François JM, Castagnera L, Carrat X, et al. A prospective study of ENT complication following surgery of the cervical spine by the anterior approach (preliminary results). Rev Laryngol Otol Rhinol (Bord) 1998; 119:95-100.

73- Jung A, Schramm J. How to reduce recurrent laryngeal nerve palsy in anterior cervical spine surgery: a prospective observational study. Neurosurgery 2010; 67:10-5.

74- Veeravagu A, Cole T, Jiang B, et al. Revision rates and complication incidence in single- and multilevel anterior cervical discectomy and fusion procedures: an administrative database study. Spine J 2014; 14:1125-31.

75- Bertalanffy H, Eggert HR. Complications of anterior cervical discectomy without fusion in 450 consecutive patients. Acta Neurochir (Wien) 1989;99:41-50.

76- O'Neill KR, Neuman B, Peters C, et al. Risk factors for postoperative retropharyngeal hematoma after anterior cervical spine surgery. Spine (Phila Pa 1976) 2014; 39:246-52.

77- Yu NH, Jahng TA, Kim CH, et al. Life-threatening late hemorrhage due to superior thyroid artery dissection after anterior cervical discectomy and fusion. Spine (Phila Pa 1976) 2010; 35:739-42.

78- Prasarn ML, Baria D, Milne E, et al. Adjacent-level biomechanics after single versus multilevel cervical spine fusion. J Neurosurg Spine 2012; 16:172-7.

79- Puttlitz CM, Rousseau MA, Xu Z, et al. Intervertebral disc replacement maintains cervical spine kinetics. Spine (Phila Pa 1976) 2004;29:2809-14.

80- Rihn JA, Lawrence J, Gates C, et al. Adjacent segment disease after cervical spine fusion. Instr Course Lect 2009; 58:747-56.

81-. Nunley PD, Jawahar A, Kerr EJ, et al. Factors affecting the incidence of symptomatic adjacent-level disease in cervical spine after total disc arthroplasty: 2- to 4-year follow-up of 3 prospective randomized trials. Spine (Phila Pa 1976) 2012;37:445-51.

82. Terai T, Faizan A, Sairyo K, et al. Operated and adjacent segment motions for fusion versus cervical arthroplasty: a pilot study. Clin Orthop Relat Res 2011; 469:682-7.

83- Xu R, Bydon M, Macki M, et al. Adjacent segment disease after anterior cervical discectomy and fusion: clinical outcomes after first repeat surgery versus second repeat surgery. Spine (Phila Pa 1976) 2014;39:120-6.

84- Bydon M, Xu R, Macki M, et al. Adjacent segment disease after anterior cervical discectomy and fusion in a large series. Neurosurgery 2014;74:139-46; discussion 146.

85-Bohlman HH, Emery SE, Goodfellow DB, et al. Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy. Long-term follow-up of one hundred and twenty-two patients. J Bone Joint Surg Am 1993; 75:1298-307.

86- Hilibrand AS, Carlson GD, Palumbo MA, et al. Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. J Bone Joint Surg Am 1999;81:519-28.

87- Lubelski, Daniel et al. "Horner Syndrome After Anterior Cervical Discectomy and Fusion: Case Series and Systematic Review." World neurosurgery vol. 133 (2020): 68-75.

88- Traynelis VC, Malone HR, Smith ZA, et al. Rare Complications of Cervical Spine Surgery: Horner's Syndrome. Global Spine Journal. 2017;7(1_suppl):103-108.

89- Sharma A, Kishore H, Singh V, Shawky Abdelgawaad A, Sinha S, Kamble PC, et al. Comparative Study of Functional Outcome of Anterior Cervical Decompression and Interbody Fusion with Tricortical Stand-Alone Iliac Crest Autograft Versus Stand-Alone Polyetheretherketone Cage in Cervical Spondylotic Myelopathy. Global Spine J. 2018;8(8):860–865.

90- Epstein NE. Efficacy and outcomes of dynamic-plated single-level anterior diskectomy/fusion with additional analysis of comparative costs. Surg Neurol Int. 2011; 2:9.

91- Pereira EAC, Chari A, Hempenstall J, Leach JD, Chan ran H, cadoux-Hudson TA. Anterior cervicaldiscectomy plus intervertebral polyetheretherketone cage fusion over three and four levels without plating is safe and effectivelong-term. journal of Clinical Neuroscience. 2013;20:1250–1255.

92- Acharya S, Kumar S, Srivastava A, Tandon R. Early results of one-level cervical discectomy and fusion with stand-alone cervical cage and bone marrow soaked tricalcium phosphate. Acta Orthop Belg.2011; 77(2):218–223.

93- Fiere V, Greff G, Mosnier T, Faline A. New cervical compressive staple: in vitro testing and early clinical results. J Spinal Disord Techn. 2013; 26(7):385–392.

94- Grasso G, Giambartino F, Tomasello G, Iacopino G. Anterior cervical discectomy and fusion with ROI-C peek cage: cervical alignment and patient outcomes. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc.2014; 23(Suppl 6):650–657.

95- Ha BY, Sim HB, Lyo IU, Park ES, Kwon SC, Park JB Comparisons of two-level discectomy and fusion with cage alone versus single-level corpectomy and fusion with plate in the treatment of cervical degenerative disc disease. Korean J Spine. 2012; 9(3):197–204.