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ახალგაზრდა მკვლევარები

Vol. 4 Issue 2, 2026

https://doi.org/10.52340/jr.2026.04.02.17



Functional Resilience and Surgical Risk: Revisiting Multilevel Anterior Cervical Discectomy and Fusion in Younger versus Elderly Myelopathic Patients.

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Abstract

Degenerative cervical myelopathy (DCM) is an aging related progressive disease characterized by chronic spinal cord compression secondary to degenerative changes in the spinal column. These changes include degenerative processes such as intervertebral disc degeneration, osteophytes, facet arthropathy, spinal stenosis, ligamentum flavum hypertrophy and ossification of the posterior longitudinal ligament. The neurologic deficits associated with the above process are due to static and dynamic insults leading to ischemia, demyelination and ultimately neuronal loss. Since neurologic improvement following decompressive surgery is not always achieved, chronological age is no longer viewed as an important determinant for surgery. Anterior cervical discectomy and fusion are one of the surgical options which may be used in multilevel diseases. It may be associated with improvement in alignment and ventral decompression although complications are common. These include dysphagia, pseudarthrosis and adjacent segment disease. This study aims to review literature in MEDLINE/PubMed, Embase and Scopus databases to find out whether outcomes are better in elderly (≥65 year) compared to younger (<65 year) patients undergoing multilevel anterior cervical discectomy and fusion. Data regarding patients having spondylosis, ligament hypertrophy, OPLL, disc herniation and subluxation were gathered. Inclusion criteria of this meta-analysis consisted of excluding patients with infection, neoplasm, inflammatory spondyloarthropathies and lumbar stenosis. These data included mJOA score, Nurick grade, NDI, SF-36, sagittal alignment (C2-C7 Cobb, SVA), fusion rates and complications. All the studies have reported that there are clinically significant improvements among both age groups after surgery. High fusion rates with almost 94-96% rates reported by certain groups were noticed. Older patients have shown greater impairment in their baseline functionality, comorbid conditions, complications in early stages, longer stay in hospitals and being discharged to homes. Dysphagia was common among octogenarians. Frailty and pre-operative functional dependence were better predictors of complication, mortality, long stay and discharge as compared to age only. However, common frailty scores cannot completely represent resiliency of patients. Multilevel ACDF is an efficacious procedure in both younger and elderly patients; however, it is necessary to consider

physiological reserves, frailty, dependence, disease severity and surgical complexity instead of age to help in determining risks and benefits.

Key words: Degenerative cervical myelopathy, Cervical spinal cord, Spinal cord injury, Neurological function.

Background

Degenerative cervical myelopathy (DCM) occurs as a gradual disease due to chronic Compression and impairment of the cervical spinal cord. It is frequently seen from a certain age. It usually occurs at a given age [1]. The degenerative condition of the intervertebral discs, osteophytes and the development of facets, facet-joint disease, cervical canal narrowing, and thickening of the ligamentum flavum. Posterior longitudinal ligament: ossification and. DCM is one of the most frequent diseases that affect the heart is an important cause of dysfunction in the spinal cord in adults and especially in the elderly [2]. It can present with neck pain or stiffness, numbness and hand clumsiness, weakness, poor fine motor function, balance problem, falls, and in late stages, Problems with the bladder or bowels. These symptoms can gradually make it increasingly difficult to move, slowly erode independence of day. In DCM, the spinal cord injury is the result of a double hit: A combination of static mechanical compression and dynamic damage with normal movement of the neck during flexion and extension. This chronic strain, over time, deprives the cord of blood, resulting in ischemia, Demyelination and permanent cell damage. Injury severity depends on aspects such as: Of the two patients with the same MRI diagnosis, one had a more favorable compression duration, and another had a healthier baseline tissue. May have entirely different functional impairments. Although mild DCM can be treated conservatively, guidelines strongly recommend surgical treatment for mild DCM. To avoid permanent neurological damage, moderate to severe cases should be treated [3]. The main goal of surgery is to decompress the spinal cord, halt further deterioration and enhancement, and surgery is to provide relief, prevent further damage and improve neurological function, disability and quality of life. Anterior cervical discectomy and fusion (ACDF) is a direct removal of the osteophytes and material from the ventral side of the disc, which re-aligns the disc, and segment stability. In patients with multiple levels of disease, ACDF can offer direct relief to the neck and shoulder area decompression and maintain/restore cervical alignment. In multilevel cases, However, there are increased risks of dysphagia, pseudarthrosis, and adjacent segment with ACDF disease [1,3].

Posterior methods are an alternative if there is more than one segment of stenosis or if there is no preserved section. Cohorts tend to be more severely affected with higher baseline deformity and disease, but lordosis, complexity. Thus, an anterior vs posterior decision should be made based on: On anatomical pattern of compression, cervical alignment, Number of involved levels, spinal stability, bone quality, comorbidity and expected risk. Comparisons between surgery for wound reconstruction is a successful procedure in reconstructing wounds. The surgery for wound reconstruction is a successful procedure as demonstrated by prospective multicenter studies. Decompression is known to be correlated with marked improvement of neurological function, and Disability and health related

quality of life following surgery but, decompression does not guarantee complete recovery. Patients with longstanding severe myelopathy may still have some trouble walking, feeling the sensations or using hands even after treatment. adequate decompression [4,5]. This is clinically relevant as it is a factor that determines the success or failure of surgery. Radiographic decompression/fusion should not be the sole criterion for judgment. A meaningful outcome may also involve better walking ability, increased independence and decreased need for caregivers. and the capacity to resume everyday routines: carefully, were selected. The disease or deformity found in posterior surgeries tends to be more severe than that found in surgeries for the front of the body.

ACDF, chronological age is important in surgery, but birth year is not valid. Metric [5]. While trial data (including the upcoming AOSpine study) is establishing that younger patients gain from meaningful improvement, even though they do not attain the highest overall recovery scores. functional improvement post-operatively. Worse performance is indicated by lower final recovery scores. baseline function instead of treatment failure. Avoiding surgery for only the elderly. Adverse decision to withhold surgery simply because the person is old. Is of little clinical meaning. A patient's physical reserve and ability. Age is of far less importance than it is to rebound from surgical stress. It is influenced by the activity is linked to the patient's mobility, muscle strength, nutritional status, cognition, as well as comorbidity and functional health. dependence, social support and baseline neurological status [6]. The disease has two patients of the same. The risk and potential for recovery may thus be quite different at different ages. Frailty is an important clinical marker of reduced functional resilience. It represents increased physiological vulnerability, due to reduced physiological reserve, evidence from many sources. We analyzed 41,369 patients who had undergone surgery for DCM and found that the frailty was a greater predictor of death than the other variables predictor than age of perioperative complications, mortality, prolonged hospital stays and non-home discharge [7].

Increasing frailty was associated with a greater effect on adverse outcomes than chronological age alone. Similarly, preoperative functional dependence has been associated with increased cardiopulmonary, renal and infectious complications and higher mortality after elective cervical spine surgery. Frailty is also relevant specifically to ACDF [7,8]. The five-factor modified frailty index, which includes selected medical comorbidities and functional dependence, has been associated with adverse outcomes after elective ACDF. Higher frailty scores have been linked with increased postoperative complications, readmission and mortality. However, the mFI-5 may not capture all important elements of resilience, such as gait speed, sarcopenia, cognition, nutritional status and social vulnerability. Newer tools, including the Risk Analysis Index, may provide additional information when predicting severe complications, mortality and non-home discharge. Although database studies show shorter stays and lower immediate morbidity with ACDF compared to posterior fusion in elderly patients, these administrative datasets fail to capture detailed neurological and imaging metrics. Posterior fusion is frequently chosen for patients with greater degrees of compression, deformity, instability or complex pathology. In Both anterior cervical decompression and fusion (ACDF) and posterior decompression and fusion (PDF) have yielded good results in the octogenarian patient population. neurological improvement, with a greater association for posterior surgery [8,9]. blood loss, higher treatment rates

and longer hospital stays. Relevant outcomes could be changed in mJOA score, Nurick grade, neck disability index, pain, hand function and gait. The results indicate that the use of an eating straw may positively impact on the quality of life, dysphagia, cardiopulmonary complications, and length of hospital stay. Readmission, reoperation, fusion and destination of discharge. By measuring frailty in conjunction with. To replace arbitrary age cutoffs, recovery metrics such as mJOA scores and NDI are used in this work. Based on objective and resilience-oriented risk stratification and targeted perioperative care. Preoperative optimization and those who may need enhanced rehabilitation and discharge support [10].

Current research in the field of DCM is based mainly on retrospective administrative data, and age inconsistencies and non-inclusion of essential mJOA scores, frailty indices and MRI markers. Moreover, numerous studies have been conducted and compared age groups without establishing whether they were similar or different. This is because the differences in outcome are attributable to frailty, and to inadequate preoperative functional status. The level of dependency, severity of disease or complexity of surgery [9,10]. Evidence specifically examining Comparing functional resilience of younger patients to elderly patients with multilevel ACDF. remains limited. This study seeks to revisit Multilevel Functional Resilience and Surgical Risk, "Functional Resilience and Surgical Risk. “Anterior Cervical Discectomy and Fusion in Younger versus Elderly Myelopathic Patients,” will be discussed. The discussion will focus on Anterior Cervical Discectomy and Fusion in Younger versus Elderly Myelopathic Patients. Determines if the differences in outcome after surgery are due to physiological reserve. More effective than age alone for multilevel ACDF cohorts. The main idea of this study is that older adults are not a homogenous group. Some are older. It is possible that patients are healthy, strong and independent, and recover well following multilevel ACDF, or Some younger patients may have significant comorbidity but disability or reduced functional capacity levels are not affected. physiological reserve. Functional resilience could be more clinically significant than age should not be the only factor to consider in predicting surgical risk and recovery [10]. The research can then be used to help support. The patient counselling, patient treatment choice and improved patient treatment were more accurate. Perioperative planning for patients with multilevel myelopathic cervical disease".

Methodology

This is a review of published literature to examine the outcomes of multilevel ACDF for cervical myelopathy across different age groups along with studies of frailty. Databases include MEDLINE (PubMed), Embase, and Scopus. Keywords include "anterior cervical discectomy and fusion", "ACDF", "multilevel", "degenerative cervical myelopathy", "cervical spondylotic myelopathy", "elderly", "geriatric", "octogenarian", "age", "outcomes", "complications", "fusion rate", "functional outcome", "frailty". Patient sample was divided into two groups: elderly (≥65 years) and younger patients (<65 years). They were included if they had myelopathy due variable reasons such as spondylosis, hypertrophy of the ligamentum flavum, OPLL, disc herniation, subluxation or a combination of these degenerative changes. Exclusion criteria included asymptomatic or diagnosed active infection, neoplastic disease, rheumatoid arthritis, ankylosing spondylitis or concomitant lumbar stenosis.

Outcomes included the results from mJOA score, Nurick grade, Neck Disability Index (NDI), Short Form-36 (SF-36), C2-C7 Cobb angle, C2-C7 sagittal vertical axis, fusion rates and a modified frailty index (mFI-5) were then compared to determine whether functional outcomes and surgical risks of multilevel ACDF differ by biological age independently and whether is it alone is a sufficient basis for surgical decision-making.

Discussion

Treatment for degenerative cervical myelopathy (DCM) in older adults is challenging and involves: Considering several interacting factors such as degree of cervical degeneration, Physiological reserve, surgical complexity, physiology, and neurological impairment. The degenerative process is characterized by changes that happen over time in the intervertebral discs. vertebral bodies, facet joints and supporting ligaments, that can ultimately affect the spinal cord and the spinal canal [11]. As the disease progresses, may involve more than one cervical level and the clinical presentation and operative may be complicated. strategy increasingly heterogeneous. Therefore, chronological age cannot be used alone to evaluate postoperative results in older patients, because age is often but not always correlated with variations in the type of disease, in the level of baseline disability and in general health. In patients with clinically significant DCM. The clinical practice guidelines outlined by Fehlings et al. suggest surgery as the most suitable treatment option. Treatment for moderate and severe DCM is intervention, but patients with mild disease can be treated with. or surgery, or supervised rehabilitation program, operative treatment. If there is deterioration in the nervous system, is recommended [11].

These recommendations Stress the importance of the severity and progression of the disease, not based on age. This is especially important in elderly people as neurological breakdown due to: Recovering from the compression of the cord may be restricted if it is persistent. The decision regarding Assessment of both the probable natural history of the disease and surgery, therefore, is required. and the ability of the patient to withstand intervention. Surgical treatment is well justified in patients with clinically significant DCM. Fehlings et al. have established clinical practice guidelines for moderate and severe DCM, with the option of either surgical correction or supervised rehabilitation in cases of mild disease; and surgery recommended if neurological deterioration occurs [12]. Disease severity and clinical progression are the focus of these recommendations and not age based. This is especially relevant in older adults as neurological deterioration because of chronic compression of the cord may restrict further recovery. Whether surgery is indicated then depends on the natural history of the disease and the patient's tolerance for surgery. Decompression has been shown to be effective in large prospective cohorts. Surgical decompression was found to be associated with significant improvements in neurologic function, disability, and health-related quality of life across levels of disease severity in the AOSpine North America prospective multicenter study of cervical spondylotic myelopathy. This will be helpful to consider when thinking about surgery [12].

In elderly patients: the goal of intervention is not just correction of radiographic compression, but prevention of neurological deterioration/improvement in functional status. However, the age distribution of the general DCM surgical literature is relatively varied and specific evidence for older patients is of particular importance [11,12]. The anterior cervical decompression and fusion (ACDF) is

a well-established option for anterior cervical decompression and fusion for cervical degenerative disease. Song and Choi looked at the development of ACDF techniques and reported its established effectiveness, and pointed to advances in graft materials, cages, anterior, and posterior. Effectiveness, with a focus on graft materials, cages, anterior and posterior. Other methods for enhancing fusion and decreasing complications, such as plating, are also employed.

Long term prospective data further support the notion of improvement after ACDF can be maintained [13]. Buttermann tracked 159 people for over a decade and discovered that, the results showed that there was sustained improvement in pain and disability measures, and neurological deficits which resolved almost in all patients and patient-reported procedural success of 85% to 95%. However, secondary long-term procedures were still applicable, especially for Pseudarthrosis and adjacent-segment degeneration [13,14]. In this way, the advantages of ACDF might be durable, but with subsequent structural complications possible, this should be included to be real. The age-related differences are most clearly apparent in the recovery of the nervous system, as shown in AOSpine International study of 479 patients concluded that prospective [15]. Elderly patients aged 65 years. Compared to younger people, those 30 years and older were sicker and more impaired on their general health measures. Those 30 years of age or older came to treatment with poorer general health and functional impairment than younger patients. They also had longer periods of decompression and were most of the patients treated with posterior methods. Younger patients (24 months). The mJOA scores were higher, and Nurick grades were lower in the had group. These variations continued after Adjustment for baseline and surgical factors was included and supported an association. A relationship between age and postoperative functional status was also found [13,14,15]. The study thus recommends that. Age may play a role in the extent of recovery from neurological dysfunction after decompression (Figure 1).

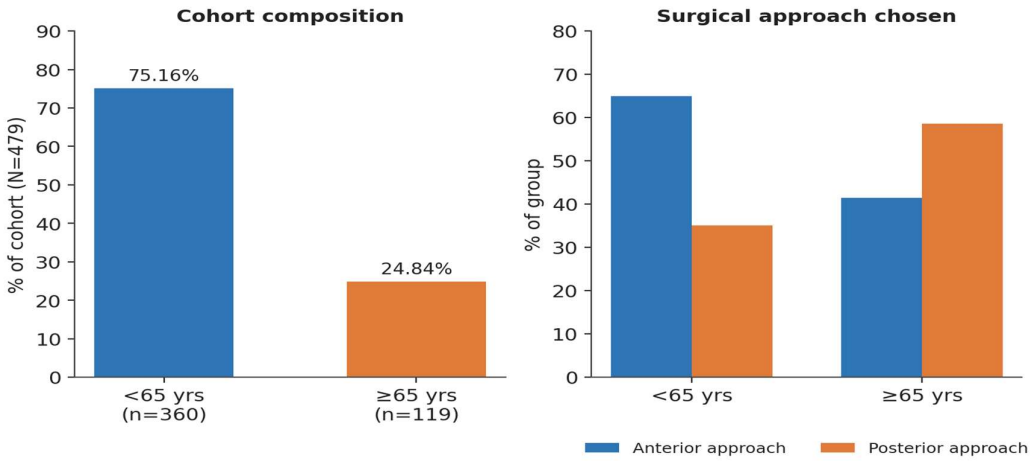


Figure 1: Cohort composition and surgical approach by age group

Within the elderly group, the amount of improvement is still clinically significant. The younger and older patients showed marked improvement after surgery and the older group had marked improvement in absolute scores but with only functionally meaningful improvement. This is relevant for the interpretation of age outcome studies. If the patient has made significant gains, a less favorable postoperative score doesn't necessarily mean that they weren't treated well. From a significantly challenged starting point. In addition, no statistically significant difference was seen in some patient-reported measures, indicating that there may be disparity in the trajectory of objective neurological recovery and perceived health status [15,16]. The relationship between age and outcome is complicated in the case of multilevel disease (Figure 2).

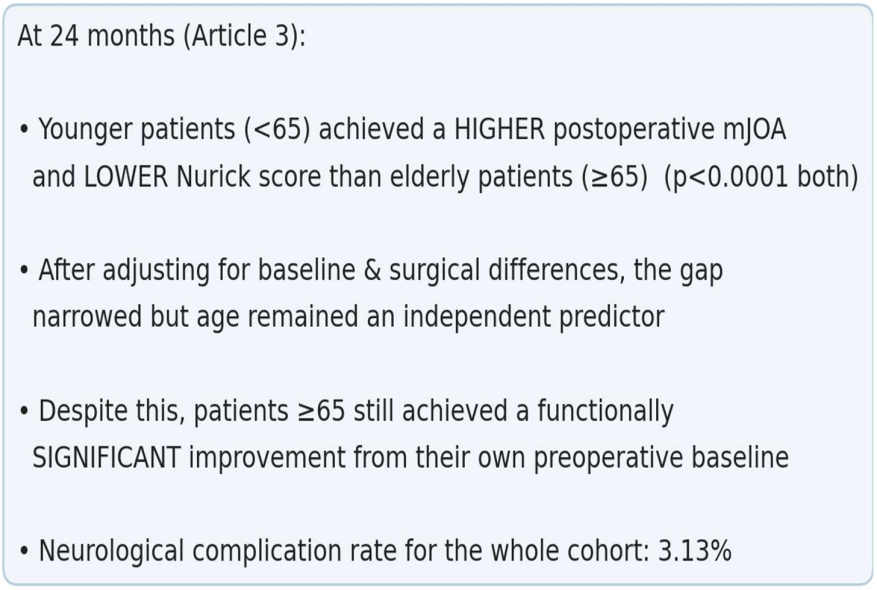


Figure 2. 24-month functional outcome summary

Luo et al. particularly assessed individuals that were receiving multilevel. ACDF for DCM and compared 18 patients who were 70 years and older vs. 45 younger patients. The elderly group was much more likely to have extensive comorbidities, with a mean Charlson Comorbidity Index of 4.3 versus 2.1 and a significantly higher percentage of ASA III patients. Short term complications were seen in 61.1% of elderly patients and 35.6% of patients younger than 65. However, overall, the JOA scores, recovery rate, modified Odom outcome and fusion rate were generally similar between groups. The percentage of elderly patients (94.4%) and younger patients (95.5%) who achieved fusion was comparable [16,17]. These In selected patients, findings indicate that extensive anterior reconstruction can be effective. Perioperative burden may be higher in older patients, but they do exist. The findings of Luo et al. are particularly relevant because they distinguish perioperative morbidity from neurological efficacy [17]. Although elderly patients experienced more short-term complications, their longer-term clinical and radiographic outcomes were not clearly inferior. However, the small sample

size, retrospective design, and single-centre/single-surgeon setting limit generalizability. With only 18 elderly patients, the study supports feasibility rather than establishing equivalence between age groups (Figure 3).

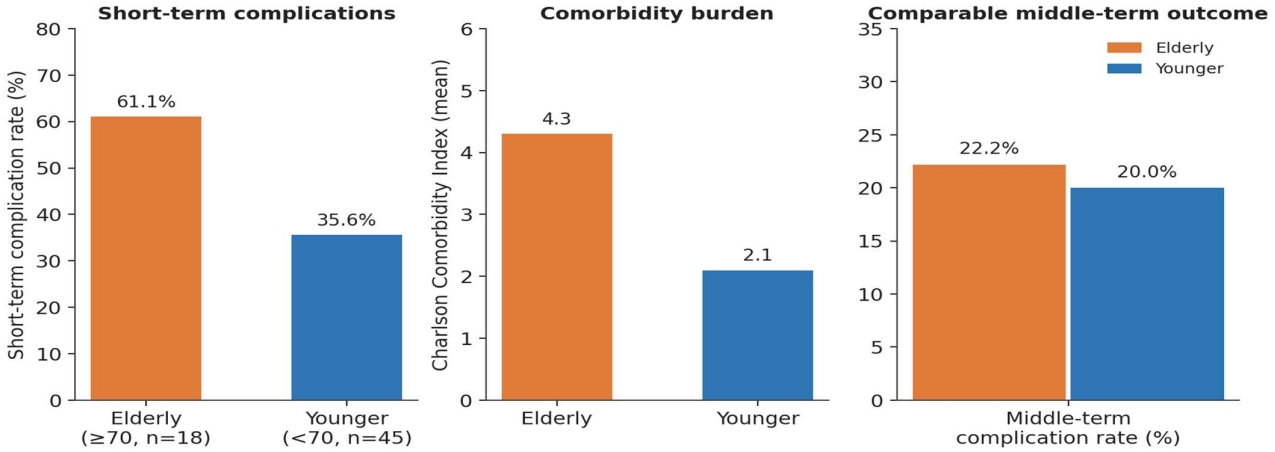


Figure 3. Elderly versus younger patients after multilevel ACDF

Similarly, Lee et al. found no significant differences in radiological or clinical outcomes between patients aged 65–74 and those aged ≥75 years following ACDF [18]. Although their cohort included only 48 patients, the findings suggest that chronological age alone does not necessarily predict fusion, alignment, pain, disability, or overall clinical outcomes. This highlights the importance of considering biological and functional differences among older adults rather than relying solely on age thresholds. Studies of elderly patients undergoing ACDF consistently indicate greater perioperative vulnerability, although the magnitude varies across cohorts [116,17,18]. Using the American College of Surgeons National Surgical Quality Improvement Program database, Buerba et al. reported increased complication risks among elderly patients [17,18]. While large databases help identify uncommon adverse events, retrospective designs and reliance on administrative coding limit their ability to account for individual differences in functional status and comorbidities. Therefore, these findings reflect population-level risks rather than individual prognoses [17,18].

Choi et al. further demonstrated differences in short-term perioperative outcomes between geriatric and younger patients undergoing surgery for multilevel degenerative cervical myelopathy (DCM). However, database studies cannot fully capture neurological severity, frailty, radiographic characteristics, or patient expectations, underscoring the value of integrating population-level evidence with clinical cohort studies. These concerns are particularly relevant for patients aged ≥80 years. Puvanesarajah et al. examined complications and mortality following one- or two-level anterior cervical fusion in this population and identified increased perioperative risks associated with very advanced age [19]. Respiratory complications and dysphagia are especially concerning because they may lead to aspiration, reintubation, prolonged hospitalization, or loss of independence. Thus, although advanced age should not automatically preclude surgery, its associated perioperative risks warrant

careful assessment. Another clinically relevant outcome is hospital utilization. It was found that octogenarian status was an independent predictor of prolonged hospitalization and non-routine discharge after elective ACDF for cervical spondylotic myelopathy (CSM) by Elsamadicy et al. [19]. For older patients, long-term hospital stays can lead to deconditioning, decreased mobility and loss of independence. Thus, outcome measures should consider the location of discharge and postoperative functional independence.

Tang et al. followed their patients for 11 years and found that age should not be used as a screening tool for surgery after ACDF. This is not contrary to other studies that have associated higher complications with older patients. People selected for elective ACDF constitute a specific population and comorbidities; functional status, procedural characteristics and institutional practices can significantly affect outcomes. Chronological age vs physiological reserve is thus critical. Frailty is a construct which looks at functional and physiological deficits and not just being old. Rockwood et al. developed the Clinical Frailty Scale as a simple measure of frailty in older patients and Makary et al. showed the relevance of the Clinical Frailty Scale to poor surgical outcomes and the predictive potential beyond chronological age and the traditional risk factors [20]. These results can help to account for the significant differences in postoperative results found within age groups of older people. Specific evidence supporting the importance of frailty in ACDF is further supported. Chung et al. used the 5-factor modified frailty index (mFI-5) to evaluate 45,991 elective ACDF patients and reported that higher scores correlated with higher rates of pneumonia, acute renal failure, UTI, acute coronary syndrome, sepsis, readmission, reoperation and death. The overall complication rates rose from 2.3% in patients with an mFI-5 score 0–11.1% in patients with an mFI-5 score ≥3 [20]. The results indicate the importance of measuring physiological vulnerability as an indicator of ACDF outcome. Functional dependence is especially important because it highlights the level of disability that is present and diminishes ability to recover from surgery. Among patients undergoing elective cervical spine surgeries, functional dependence was independently associated with sepsis, pulmonary, renal and cardiac complications and death, as described by Minhas et al. [21]. Therefore, functional status not only is a consequence of cervical myelopathy but also a key perioperative risk factor. Even if the surgery is technically a success, patients who have limited independence before surgery may need a lot of support afterwards.

With muscle reserve considered, frailty evaluation may be enhanced. Research on muscle properties and frailty in patients aged 75 and above having a fusion procedure may represent an area for future investigation with regards to the cervical region [21]. However, it would not be possible to apply the findings in ACDF as muscle depletion and low physical capacity can affect locomotion and recovery. Additional research needs to be conducted in the cervical region to determine the accuracy of the risk prediction based on the combination of frailty and muscle strength testing. Complexity of the procedure is another determinant of the findings. Arnautovic et al reviewed 15 studies that included 2,457 patients who had four-level ACDF. 46.9 13.1 % of these patients underwent surgery for spinal cord problems, and the overall rate of problems was 16.26 %. Difficulty swallowing was the most common issue, followed by bleeding, changes in the voice and a nerve problem in the neck. The joining

rate of the bones varied from 41.3 percent to 94 percent. The average age in those studies ranged from 52.2 to 61.3 years, so the findings are not fully applicable to patients [21]. Nevertheless, these findings reveal some technical and complications issues related to wide fusion. The extent of surgery impacts age comparisons as well. According to the study conducted by AOSpine, the older patients underwent spinal levels decompression compared to younger patients – 4.14 versus 3.50, respectively. Furthermore, the older patients were more likely to have posterior surgery. Controlling for other factors, the authors found age to be associated with postoperative functional results. The association became less significant when surgery was controlled for.

This is a critical point when it comes to multilevel DCM. Comparison of results following 3 or 4-level ACDF and posterior decompression with fusion was carried out by Lambrechts et al. [21]. Results were favorable using both techniques; however, the results turned out to be comparable between the two groups. Neck disability and pain scores showed greater improvement in the ACDF group. Nevertheless, age, burden of comorbidities, and disease were different in the two groups, which made it hard to compare the two procedures [18]. This shows how selection bias can occur due to anatomical considerations, alignment, disease severity, and compression. It also occurs in octogenarians. Comparison was conducted on results following ACDF and posterior decompression with fusion in cases of patients suffering from cervical myelopathy aged 80+ [20,21]. Posterior approach had more levels involved, more blood loss, and longer length of stay. Mortality rates and mJOA score improvements were comparable. Comorbidities were present, and they were significant predictors of post-operative complications. As a result, the procedure selected should depend on the anatomical considerations and general health status of the patient. It cannot be assumed that one procedure is safe for all octogenarians.

It appears that fusion in carefully selected elderly patients yields good results. For instance, a study by Luo et al. has reported high fusion rate for elderly patients (94.4%) and younger patients (95.5%) who were treated with multi-level ACDF [10]. No significant difference between 65-74-year-old patients and older than 75-year-old patients has been found by Lee et al. [22]. However, the heterogeneity was quite high in a study on four-level ACDF which proves that the technique used, the construct, bone quality and patient-related parameters influence fusion rates [22]. Long-term results have been also examined. Buttermann has performed a prospective study showing that patients kept their improvement clinically after 10 years of follow-up and there was no significant correlation between age and number of levels and results. However, 10% of patients required revision surgery because of pseudarthrosis formation and 21% needed surgery for symptomatic adjacent segment degeneration. It is evident that the success of an ACDF depends on not only the immediate impact on the body but also the long-term effects of the procedure on the body. The patient's health status and his/her longevity must be considered along with other factors [22].

Perioperative management can help in minimizing the risk posed by older age. Wang et al conducted a study employing an Enhanced Recovery After Surgery protocol on patients above the age of 60 who were undergoing an ACDF. They found out that there was a reduction in the length of stay, with no increase in complications or readmissions [22]. Since this was not a causative study, no firm conclusions

can be made; however, having a protocol and optimizing the patient before surgery through multimodal analgesia, mobilizing early, and proper discharge planning may be useful in the patient with less physiological reserve. In assessing the post-operative outcome of elderly patients after an ACDF, several criteria should be taken into account. Neurological scores indicate how the patient has done following the dysfunction of the spinal cord. Radiographic studies will tell us whether the spine has fused and what the alignment of the spine is. The complication rate is another criterion that tells us about the safety of the surgery [23].

Outcomes like functional outcomes and patient-reported outcomes can be assessed to assess how much benefit the patient has had from their surgery in their day-to-day life. These outcomes may not be correlated [24]. Patients may have excellent fusion and substantial reduction in pain, but they may not have any improvement neurologically. The procedure may be technically successful, yet the patient's time in the hospital will remain lengthy. It requires a few outcome measures to really assess the patient. There are some limitations of current evidence. Firstly, there is the problem of a retrospective nature of studies that causes bias and confounding. Secondly, the elderly population is defined differently, as the age cutoff is between 65 and 80 years. Thirdly, there is the usefulness of large database studies for providing complication rates; however, they lack data on neurological severity, radiography, frailty and patient preference. Fourthly, small elderly subgroups make the rare complications estimate imprecise [24].

Any future research should include validated methods of assessing frailty, nutritional status, sarcopenia, mobility, cognitive function, and dependence in pre-operative risk assessment models [25]. Research is needed that focuses on patients aged over 75 years and having 3 or 4-level ACDF. Long term patient outcome assessments and information about returning to their homes should be collected in addition to traditional neurological and radiological outcomes. All in all, elderly patients represent a very heterogeneous population; even though advanced age might influence the degree of illness, functional outcome, complications, length of hospitalization and discharge, it is hard to argue that surgery has no value in such patients [25]. Neurological improvement, successful fusion and long-term results have been shown in selected elderly patients with multi-level surgery. The decision-making process should include various factors such as neurological comorbidity and physiological reserves, frailty, dependence, comorbidity, operative complexity and postoperative care [25].

Table 1. Summary of key studies evaluating age, frailty, surgical complexity, and outcomes following ACDF or related cervical spine procedures.

Article	Comparison	Key finding	Effect size
3	<65 vs ≥65 (n=479)	Age independently predicts postop mJOA/Nurick	p<0.0001; still sig. after adj.
3	<65 vs ≥65	Neurologic complication rate, whole cohort	3.13%
10	≥70 vs <70, multilevel ACDF	Short-term complication rate	61.1% vs 35.6% (p<0.05)
10	≥70 vs <70	Charlson Comorbidity Index (mean)	4.3 vs 2.1 (p<0.001)
10	≥70 vs <70	Middle-term complications	22.2% vs 20.0% (n.s.)
12	65–74 vs ≥75 (n=48)	Fusion rate	76.2% vs 71.4% (n.s.)
14	mFI-5 score 0 vs 3+	Acute renal failure	OR 9.7 (p=.022)
14	mFI-5 score 0 vs 3+	Myocardial infarction	OR 6.9 (p<.001)
14	mFI-5 score 0 vs 2	30-day readmission	OR 1.5 (p<.001)
9	Pooled, 4-level ACDF, n=2,457	Overall complication rate	16.26% (95% CI 14.8–17.8%)
9	Pooled, 4-level ACDF	Most common complication (dysphagia)	4.56%
20	≥80 vs 65–79, 1–2 level fusion	90-day mortality	OR 4.34
20	≥80 vs 65–79	Aspiration pneumonitis	OR 3.17
21	≥80 vs younger, elective ACDF for CSM	Non-routine discharge	OR 2.46 (p=.001)
21	≥80 vs younger	Extended length of stay	OR 1.97 (p=.023)
22	70s vs 80s (propensity-matched)	Complication rate	No significant difference
22	60s vs 80s (propensity-matched)	Complication rate	No significant difference
17	Multilevel disease, age ≥65, n=23,129	Lowest mortality/morbidity approach	ACDF (vs LP, PCF)

Conclusion

Multilevel ACDF is safe and effective for both younger and elderly patients with degenerative cervical myelopathy. The main differences between the elderly and younger patients regarding recovery are lower preoperative mJOA scores in the elderly, less than full recovery, and increased rates of complications. The considerations about age-related studies for postoperative recovery after ACDF are uncertain as new frailty assessment tools are shown to better predict important clinical outcomes like complications, length of stay, and discharge status. Thus, the criterion of age should not be isolated when screening for ACDF surgery; rather functional reserve and frailty status should be kept in mind in clinical decision-making.

Acknowledgement

The authors confirm that all individuals listed as authors made substantial, equal contributions to the development of this work, including the abstract, introduction, methodology, discussion, and conclusion. The collaborative nature of this project reflects the shared responsibility and joint effort of all team members.

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