North American Spine Society Journal (NASSJ) 12 (2022) 100174

Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

Comparison of postoperative outcomes in patients with and without osteoporosis undergoing single-level anterior cervical discectomy and fusion

Alexander J. Kammien[a], Anoop R. Galivanche[b], Peter Y. Joo[a], Ali Elaydi[a], Peter Whang[a], Comron Saifi[c], Jonathan N. Grauer[a], Arya Varthi[a,*]

[a] Department of Orthopaedics and Rehabilitation, Yale School of Medicine, New Haven, CT, USA
[b] Department of Orthopaedic Surgery, University of California San Diego Health System
[c] Department of Orthopedic Surgery, Houston Methodist

ARTICLE INFO

Key Words:
Osteoporosis
Fusion
Complications
Reoperation
Nonunion
ACDF

ABSTRACT

Background: Osteoporosis is ubiquitous in elderly populations, such as those undergoing ACDF. Short- and longer-term outcomes might be affected in the setting of osteoporosis related to graft subsidence, bony union, and stresses on adjacent segments. Better understanding the potential correlation of osteoporosis and outcomes after ACDF might affect patient counseling and surgical planning. The current study compares 90-day adverse events and 5-year reoperations following single-level anterior cervical discectomy and fusion (ACDF) between patients with and without osteoporosis.

Methods: Single-level ACDF procedures were identified in a national administrative database. Exclusion criteria included age under 18 years, less than 90 days of follow-up in the database, multi-level procedures, posterior concomitant procedures, and surgeries performed for trauma, neoplasm, or infection. After matching based on patient characteristics, 90-day perioperative adverse events were compared with multivariate analyses and five-year reoperations were compared with log-rank analysis. Reasons for reoperations were also evaluated.

Results: Relative to age, sex, and comorbidity-matched patients without osteoporosis, those with osteoporosis had a small but statistically greater incidence of experiencing any 90-day adverse event (10.9% vs 9.4%, $p < 0.001$) and 5-year reoperations (19.1% vs 17.0%, $p < 0.001$). Of those requiring reoperation, those in the osteoporosis group had a greater proportion for nonunion (7.5% vs 5.6% $p = 0.003$).

Conclusions: Following single-level ACDF, patients with osteoporosis experience slightly greater 90-day adverse events and 5-year reoperations. These results suggest the importance of recognizing osteoporosis in the ACDF population and accounting for this with surgical planning and patient counselling.

Background

Anterior cervical decompression and fusion (ACDF) is commonly considered to address degenerative conditions of the cervical spine [1–6]. Noting that osteoporosis may be present in those being considered for ACDF [7,8], the correlation of osteoporosis with ACDF short- and longer-term outcomes is of interest as it may be associated with graft subsidence, bony union, and stresses on adjacent segments [9–11].

Prior work investigating the postoperative course of osteoporotic patients following spine surgery has offered mixed evidence on whether osteoporosis is a risk factor for revision surgery and postoperative complications. Guzman et al analyzed all cervical spine cases (anterior, posterior, and circumferential) in the National Inpatient Sample and identified an association between osteoporosis and revision surgery [9]. However, this study was limited to hospital-based complications, as the National Inpatient Sample database does not track patients longitudinally

FDA device/drug status: Not applicable.

Author disclosures: ***AJK***: Nothing to disclose. ***ARG***: Nothing to disclose. ***PYJ***: Nothing to disclose. ***AE***: Nothing to disclose. ***PW***: Nothing to disclose. ***CS***: Nothing to disclose. ***JNG***: Other: NASSJ (D). ***AV***: Nothing to disclose.

Given his role as Editor in Chief, Jonathan Grauer, MD had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to Tobias Mattei, MD.

* Corresponding author at: Department of Orthopaedics and Rehabilitation, Yale School of Medicine, New Haven, CT, USA.
E-mail address: arya.varthi@yale.edu (A. Varthi).

https://doi.org/10.1016/j.xnsj.2022.100174
Received 5 August 2022; Received in revised form 24 September 2022; Accepted 26 September 2022
Available online 1 October 2022

following discharge. Further, the study reported differences in surgical approach based on osteoporosis but did not isolate ACDF patients or performed matching to account for potential confounding factors such as age, sex, or comorbidities.

In contrast, Althoff et al reported on more than 7,000 patients undergoing lumbar fusions within the Mariner database, and found no difference in revision rates between osteoporotic and non-osteoporotic patients, though patients with osteoporosis were found to have increased odds of minor adverse events [12]. However, the reoperation rate was only tracked over two years, and the definition of "revision surgery" was not clearly defined in the study. Further, this type of comparative analysis has not yet been reported for patients undergoing cervical spine procedures.

Better understanding of the potential correlation of osteoporosis and outcomes after ACDF might affect patient counselling and surgical planning. The present work aims to use the large sample size and longitudinal claims within the PearlDiver database to understand whether osteoporotic patients are at higher odds of postoperative complications and revision surgery following ACDF.

Methods

Dataset and study population

The current study used the MSpine dataset within PearlDiver. MSpine contains national administrative claims data from 2010 through 2020 Q3 for 1.2 million orthopedic patients with spine surgery in their records. Our Institutional Review Board has granted exemption for PearlDiver studies because all output from the database is deidentified.

Current Procedural Terminology (CPT) and International Classification of Disease (ICD) codes were used to define the study population. ACDF cases were identified with CPT-22551, CPT-22554, or CPT-63075 (anterior cervical arthrodesis or discectomy). Multi-level ACDF cases were excluded using CPT-22552, CPT-22585, and CPT-63076 (anterior cervical arthrodesis and discectomy, each additional interspace). Additional exclusion criteria were age under 18 years, fewer than 90 days of database follow-up, surgery performed for trauma, neoplasm, or infection, and concomitant cervical surgery (CPT-63001, CPT-63015, CPT-63020, CPT-63035, CPT-63040, CPT-63043, CPT-63048, CPT-22600, CPT-22614, CPT-22840, CPT-22842, CPT-63050, CPT-63051).

The inclusion and exclusion criteria produced a study population of 77,133 patients. Patient age, sex, and Elixhauser comorbidity index (ECI) score were determined. To control for potential confounding variables, the two cohorts were matched using PearlDiver's matching function. Age, sex, and comorbidities are widely considered to be important confounding variables in surgical outcomes. Prior to matching, there were statistically significant differences in age, sex, and ECI score. ECI score is a validated index that helps control for over thirty comorbidities and was chosen to represent general comorbidity burden in place of matching for individual comorbidities [13]. Thus, patients were matched 4:1 for age, sex, and ECI score, which produced a final study population of 32,090 patients.

Data collection

The following 90-day adverse events were identified: surgical site infection, sepsis, pulmonary embolism, deep vein thrombosis, pneumonia, myocardial infarction, acute kidney injury, urinary tract infection, wound dehiscence, transfusion, and hematoma. These were also aggregated into a category of any adverse event.

Revisions were determined based on the occurrence of subsequent cervical surgery within 5 years of index ACDF. Subsequent cervical surgeries were defined by the following CPT codes: CPT-22855, CPT-22551, CPT-22554, CPT-63075, CPT-22552, CPT-22585, CPT-63076, CPT-63001, CPT-63015, CPT-63020, CPT-63035, CPT-63040, CPT-63043, CPT-63048, CPT-22600, CPT-22614, CPT-22840, CPT-22842, CPT-63050, CPT-63051, CPT-63081, CPT-63082, CPT-63045, CPT-22590, CPT-22845, CPT-22846, CPT-22855, CPT-22800, CPT-22802, CPT-22804. For additional insight into reoperations, the primary diagnosis code (ICD-9-D or ICD-10-D) was extracted for each subsequent cervical surgery.

Data analysis

All statistical analyses were performed using PearlDiver's built-in statistical programming with significance defined as p-value less than 0.05. Patient age and ECI score were compared using Welch's T-test, and sex was compared with Pearson's chi-squared test. 90-day adverse events were compared using Pearson's chi-squared test. Revision surgeries were analyzed using Kaplan-Meier survival analysis, and those without and with osteoporosis were compared with log-rank analysis.

Results

Study population

A flow diagram of the study cohort designation is shown in Fig. 1. Prior to matching, the single-level ACDF population consisted of 77,133 patients. As shown in Table 1, those with osteoporosis were older, were more likely to be female, and had greater comorbidity burden than those without osteoporosis ($p < 0.001$). After matching 4:1, the total population was 32,090 patients. These groups had no residual statistically significant difference age, sex, or ECI score between patients with and without osteoporosis.

Outcomes

Ninety-day adverse events by osteoporosis status in Table 2. Patients with osteoporosis were more likely to have any adverse event within 90 days of single-level ACDF (10.9% vs 9.4%, $p < 0.001$). Patients with osteoporosis were slightly more likely to experience most adverse events (difference of 0.2-0.7%), with the exceptions of surgical site infection, acute kidney injury, wound dehiscence, and hematoma.

Five-year reoperation data is shown in Table 3 and Fig. 2. Patients with osteoporosis had a greater incidence of repeat cervical surgeries at five years (19.1% vs 17.0%, $p < 0.001$) as well at each yearly interval. Additionally, patients with osteoporosis had reoperations for nonunion/pseudoarthrosis at greater rates than patients without osteoporosis (7.5% vs 5.6%, $p = 0.003$).

Discussion

As the elderly population in the United States continues to expand, osteoporosis will become an increasingly important consideration for spine surgery because the stability of grafts and fixation require bone purchase, which may be compromised. However, it remains poorly understood whether osteoporosis is a risk factor for adverse events and revision surgery following cervical fusion, particularly ACDF.

Prior to matching, patients with osteoporosis were older, were more likely to be female, and had greater ECI score. These are expected findings as osteoporosis becomes more likely with age and many more females develop osteoporosis than males [14]. The greater comorbidity burden in osteoporotic patients may be due to greater age. After matching, cohorts were similar in important characteristics other than osteoporosis status.

Patients with osteoporosis were slightly more likely to experience adverse events such as sepsis, pulmonary embolism, deep vein thrombosis, pneumonia, myocardial infraction, urinary tract infection, and to receive a transfusion, which is concordant with prior studies investigating perioperative outcomes in osteoporotic patients. However, the differences in the current study were all quite small and ranged from 0.1%

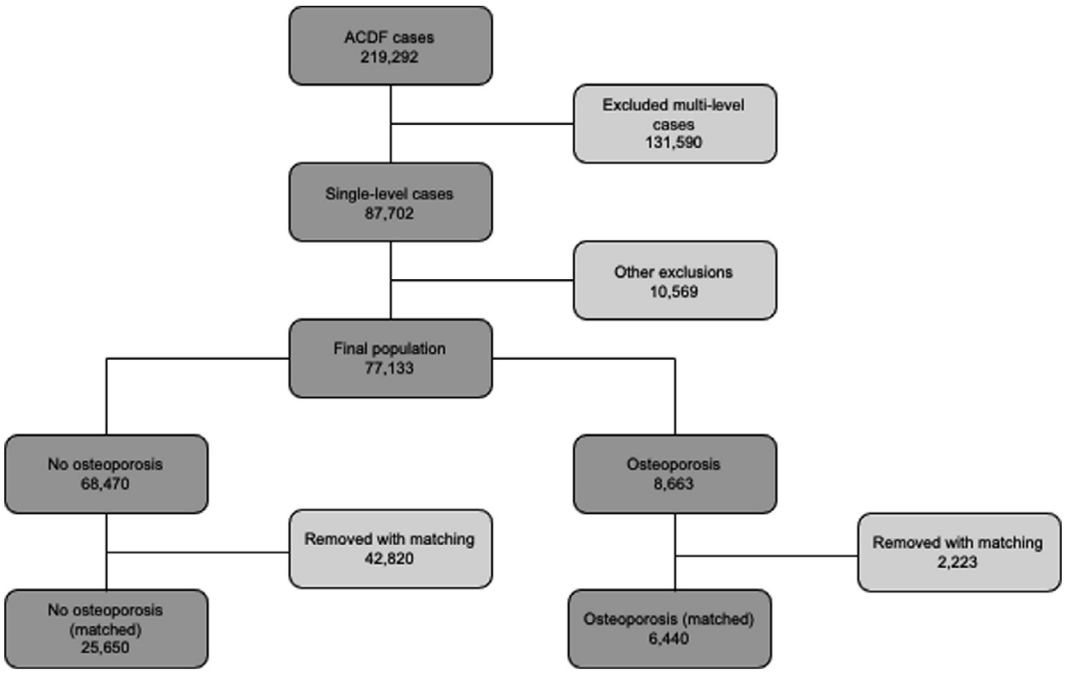

Fig. 1. Flow diagram showing designation of study cohort.

Table 1
Characteristics of single-level ACDF patients by osteoporosis status.

N	Unmatched			Matched		
	No Osteoporosis	Osteoporosis	*p*-value	No Osteoporosis	Osteoporosis	*p*-value
	68,470 (88.8%)	8,663 (11.2%)		25,650 (79.9%)	6,440 (20.1%)	
Age (mean ± stdev)	52.7 ± 11.6	61.0 ± 10.1	**<0.001**	58.2 ± 9.8	58.4 ± 9.8	0.262
Sex			**<0.001**			1.000
Female	34,861 (50.9%)	7,113 (82.1%)		19,594 (76.4%)	4,919 (76.4%)	
Male	33,609 (49.1%)	1,550 (17.9%)		6,056 (23.6%)	1,521 (23.6%)	
ECI (mean ± stdev)	3.3 ± 3.1	4.8 ± 3.9	**<0.001**	4.2 ± 3.5	4.3 + 3.6	0.552

Table 2
Incidence of 90-day adverse events following single-level ACDF by osteoporosis status.

	No Osteoporosis	Osteoporosis	*p*-value
N	25,650 (100%)	6,440 (100%)	
Any adverse event	2,412 (9.4%)	701 (10.9%)	**<0.001**
Surgical site infection	204 (0.8%)	57 (0.9%)	0.528
Sepsis	239 (0.9%)	71 (1.1%)	**<0.001**
Pulmonary embolism	146 (0.6%)	50 (0.8%)	**<0.001**
Deep vein thrombosis	267 (1%)	85 (1.3%)	**<0.001**
Pneumonia	542 (2.1%)	183 (2.8%)	**<0.001**
Myocardial infarction	108 (0.4%)	29 (0.5%)	**0.015**
Acute kidney injury	373 (1.5%)	88 (1.4%)	**<0.001**
Urinary tract infection	1,128 (4.4%)	294 (4.6%)	**<0.001**
Wound dehiscence	68 (0.3%)	26 (0.4%)	0.056
Transfusion	86 (0.3%)	30 (0.5%)	**<0.001**
Hematoma	134 (0.5%)	28 (0.4%)	0.278

Table 3
5-year reoperations following single-level ACDF by osteoporosis status.

	No Osteoporosis	Osteoporosis	*p*-value
N	25,650 (100%)	6,440 (100%)	
1 year	2,026 (7.9%)	599 (9.3%)	**<0.001**
2 years	3,001 (11.7%)	857 (13.3%)	**<0.001**
3 years	3,565(13.9%)	1,024 (15.9%)	**<0.001**
4 years	4,027 (15.7%)	1,146 (17.8%)	**<0.001**
5 years	4,361(17.0%)	1,230 (19.1%)	**<0.001**

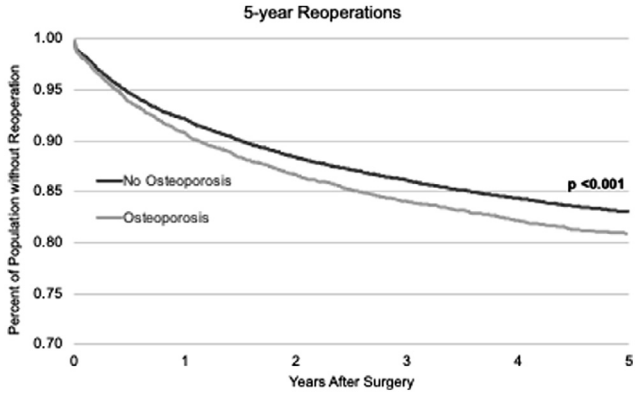

Fig. 2. 5-year revision rates for single-level anterior cervical discectomy and fusion (ACDF) patients with and without osteoporosis matched for age, sex, and Elixhauser Comorbidity Index (ECI) score. Log-rank analysis was performed with *p*-value <0.001.

to 0.7% differences [9,12]. In other words, while statistically different and notable, these differences are each of questionable clinical significance individually. Together, they suggest that the risk of any adverse event is increased in patients with osteoporosis.

Osteoporotic patients were also more likely to have a reoperation within five years of surgery. The difference in revisions increases until year three but remains the same for the remainder of the five-year

period. This may indicate that osteoporosis primarily increases risk for reoperation in the first few years following surgery. Following this time point, patients with and without osteoporosis may experience similar rates of revision. While the difference in reoperations is not particularly large, this finding again points to greater risks for those with osteoporosis and seems concordant with the finding that they were also more likely to have nonunion or pseudoarthrosis as the primary diagnosis for reoperation. These findings make intuitive sense because decreased bone mineral density in osteoporotic vertebrae decreases the likelihood of interbody fusion [10,15]. This is supported by a study that found osteoporosis to be associated with higher rates of cage subsidence and screw loosening following single-level posterior lumbar fusion [16]. Another study found osteoporosis to be associated with greater incidence of nonunion [17]. Additional perioperative management of osteoporosis may improve outcomes, and several studies have shown that medical management of osteoporosis can improve fusion rates and reduce mechanical complications following spine surgery [11,18,19].

There are several limitations to the current study. First, errors may exist in administrative data due to the coded nature of patient factors, osteoporosis diagnosis, and reasons for reoperation. Further, the degree of osteoporosis could not be quantified. However, the use of the large administrative database afforded the power for observations otherwise difficult to detect. As a retrospective study, we cannot determine causation, only association.

Conclusion

In conclusion, patients with osteoporosis have a slightly greater number of multiple 90-day adverse events and more 5-year reoperations, with an increase in incidence of nonunion and pseudoarthrosis. As the US population ages and osteoporosis becomes more prevalent, it will become increasingly important to pay additional attention to high-risk patients and implement proven medical therapies to improve outcomes of spinal surgery.

Declaration of Competing Interest

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms.

Short summary sentence

Patients with osteoporosis are more likely to experience complications and reoperations, particularly for nonunion, following single-level ACDF

References

[1] 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 2019;44(8):543–9.
[2] Fu MC, Gruskay JA, Samuel AM, Sheha ED, Derman PB, Iyer S, et al. Outpatient anterior cervical discectomy and fusion is associated with fewer short-term complications in one- and two-level cases: a propensity-adjusted analysis. Spine 2017;42(14):1044–9.
[3] Galivanche AR, Gala R, Bagi PS, Boylan AJ, Dussik CM, Coutinho PD, et al. Perioperative outcomes in 17,947 patients undergoing 2-level anterior cervical discectomy and fusion versus 1-level anterior cervical corpectomy for treatment of cervical degenerative conditions: a propensity score matched national surgical quality improvement program analysis. Neurospine 2020;17(4):871–8.
[4] Joo PY, Zhu JR, Kammien AJ, Gouzoulis MJ, Arnold PM, Grauer JN. Clinical outcomes following one-, two-, three-, and four-level anterior cervical discectomy and fusion: a national database study. Spine J 2022;22(4):542–8.
[5] Ondeck NT, Bohl DD, Bovonratwet P, Geddes BJ, Cui JJ, McLynn RP, et al. General health adverse events within 30 days following anterior cervical discectomy and fusion in US patients: a comparison of spine surgeons' perceptions and reported data for rates and risk factors. Global Spine J 2018;8(4):345–53.
[6] Samuel AM, Grauer JN, Rihn JA, Labrum JTt. Two-level Anterior cervical discectomy and fusion: an outpatient surgery? J Spinal Disord Tech 2015;28(10):349–51.
[7] Sarafrazi N, Wambogo EA, Shepherd JA. Osteoporosis or low bone mass in older adults: United States, 2017-2018. NCHS Data Brief 2021(405):1–8.
[8] Cheng H, Gary LC, Curtis JR, Saag KG, Kilgore ML, Morrisey MA, et al. Estimated prevalence and patterns of presumed osteoporosis among older Americans based on Medicare data. Osteoporos Int 2009;20(9):1507–15.
[9] Guzman JZ, Feldman ZM, McAnany S, Hecht AC, Qureshi SA, Cho SK. Osteoporosis in cervical spine surgery. Spine 2016;41(8):662–8.
[10] Hassanzadeh H, Puvanesarajah V, Dalkin AC. Medical management of osteoporosis for elective spine surgery. Clin Spine Surg 2016;29(4):134–40.
[11] Govindarajan V, Diaz A, Perez-Roman RJ, Burks SS, Wang MY, Levi AD. Osteoporosis treatment in patients undergoing spinal fusion: a systematic review and meta-analysis. Neurosurg Focus 2021;50(6):E9.
[12] Althoff AD, Kamalapathy P, Vatani J, Hassanzadeh H, Li X. Osteoporosis is associated with increased minor complications following single level ALIF and PSIF: an analysis of 7,004 patients. J Spine Surg 2021;7(3):269–76.
[13] Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care 1998;36(1):8–27.
[14] Aspray TJ, Hill TR. Osteoporosis and the Ageing Skeleton. Subcell Biochem 2019;91:453–76.
[15] Makino T, Tsukazaki H, Ukon Y, Tateiwa D, Yoshikawa H, Kaito T. The Biological Enhancement of Spinal Fusion for Spinal Degenerative Disease. Int J Mol Sci 2018;19(8).
[16] Cho JH, Hwang CJ, Kim H, Joo YS, Lee DH, Lee CS. Effect of osteoporosis on the clinical and radiological outcomes following one-level posterior lumbar interbody fusion. J Orthop Sci 2018;23(6):870–7.
[17] Andersen T, Christensen FB, Langdahl BL, Ernst C, Fruensgaard S, Ostergaard J, et al. Fusion mass bone quality after uninstrumented spinal fusion in older patients. Eur Spine J 2010;19(12):2200–8.
[18] Buerba RA, Sharma A, Ziino C, Arzeno A, Ajiboye RM. Bisphosphonate and teriparatide use in thoracolumbar spinal fusion: a systematic review and meta-analysis of comparative studies. Spine 2018;43(17):E1014–E1e23.
[19] Ide M, Yamada K, Kaneko K, Sekiya T, Kanai K, Higashi T, et al. Combined teriparatide and denosumab therapy accelerates spinal fusion following posterior lumbar interbody fusion. Orthop Traumatol Surg Res 2018;104(7):1043–8.