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Clinical Study

Evolution of patient-reported outcome measures, 1, 2, and 5 years after surgery for subaxial cervical spine fractures, a nation-wide registry study

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Abstract

BACKGROUND CONTEXT: A longer duration of patient follow-up arguably provides more reliable data on the long-term effects of a treatment. However, the collection of long-term follow-up data is resource demanding and often complicated by missing data and patients being lost to follow-up. In surgical fixation for cervical spine fractures, data are lacking on the evolution of patient reported outcome measures (PROMs) beyond 1-year of follow-up. We hypothesized that the PROMs would remain stable beyond the 1-year postoperative follow-up mark, regardless of the surgical approach.

PURPOSE: To assess the trends in the evolution of patient-reported outcome measures (PROMs) at 1, 2-, and 5-years following surgery in patients with traumatic cervical spine injuries.

STUDY DESIGN: Nation-wide observational study on prospectively collected data.

PATIENT SAMPLE: Individuals treated for subaxial cervical spine fractures with anterior, posterior, or combined anteroposterior approaches, between 2006 and 2016 were identified in the Swedish Spine Registry (Swespine).

OUTCOME MEASURES: PROMs consisting of EQ-5D-3L$_{index}$ and the Neck Disability Index (NDI) were considered.

METHODS: PROMs data were available for 292 patients at 1 and 2 years postoperatively. Five-years PROMs data were available for 142 of these patients. A simultaneous within-group (longitudinal) and between group (approach-dependent) analysis was performed using mixed ANOVA. The predictive ability of 1-year PROMs was subsequently assessed using linear regression.

RESULTS: Mixed ANOVA revealed that PROMs remained stable from 1- to 2-years as well as from 2- to 5-years postoperatively and were not significantly affected by the surgical approach ($p<0.05$). A strong correlation was found between 1-year and both 2- and 5-years PROMs ($R>0.7$; $p<0.001$). Linear regression confirmed the accuracy of 1-year PROMs in predicting both 2- and 5-years PROMs ($p<0.001$).

CONCLUSION: PROMs remained stable beyond 1-year of follow-up in patients treated with anterior, posterior, or combined anteroposterior surgeries for subaxial cervical spine fractures. The 1-year PROMs were strong predictors of PROMs measured at 2, and 5 years. The 1-year PROMs

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were sufficient to assess the outcomes of subaxial cervical fixation irrespective of the surgical approach. © 2023 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

Keywords: Patient-reported outcome measures; Subaxial spine fracture; Cervical spine; Fixation surgery

Introduction

Long-term patient follow-ups have been preferred in clinical research settings, as they provide more definite data on the effectiveness, durability, and reliability of a treatment [1]. However, the collection of consistent long-term follow-up data is not a simple task; in addition to the required resources and costs, it is often complicated by missing data and patients being lost to follow-up. In surgery for subaxial cervical spine fractures, a time point is yet to be defined at which the patient reported outcome measures (PROMs) stabilize.

In degenerative lumbar spine procedures, the outcomes tend to plateau after 1 year of follow-up [2,3]. However, similar studies after traumatic injuries in the subaxial cervical spine have not been performed. As suggested by the findings in lumbar procedures, we hypothesized that the PROMs would remain stable beyond 1-year of postoperative follow-up, regardless of the surgical approach.

Using the Swedish Spine Registry (Swespine) which provides PROMs at several time points, the aim of this study was to investigate whether 1-year PROMs were sufficient to estimate the outcome at 2 and 5 years after anterior, posterior, or combined anteroposterior (360°) fixation of subaxial cervical spine fractures.

Materials and methods

Study design

This observational study on prospectively collected data from 2006 to 2016 collected by the Swedish Spine Registry (Swespine) is in accordance with the STROBE guidelines (Supplementary File 1).

Sources and type of data

In 2016, Swespine had a coverage of 98% (46 of 47 spinal clinics), the completeness was approximately 75% (30%−90%), and the 1-year follow-up was performed in approximately 75%, covering all types of spinal surgical procedures [4]. Surgical approach, fracture type, any preoperative neurological impairment, operated levels, perioperative complications (thromboembolisms, urinary tract

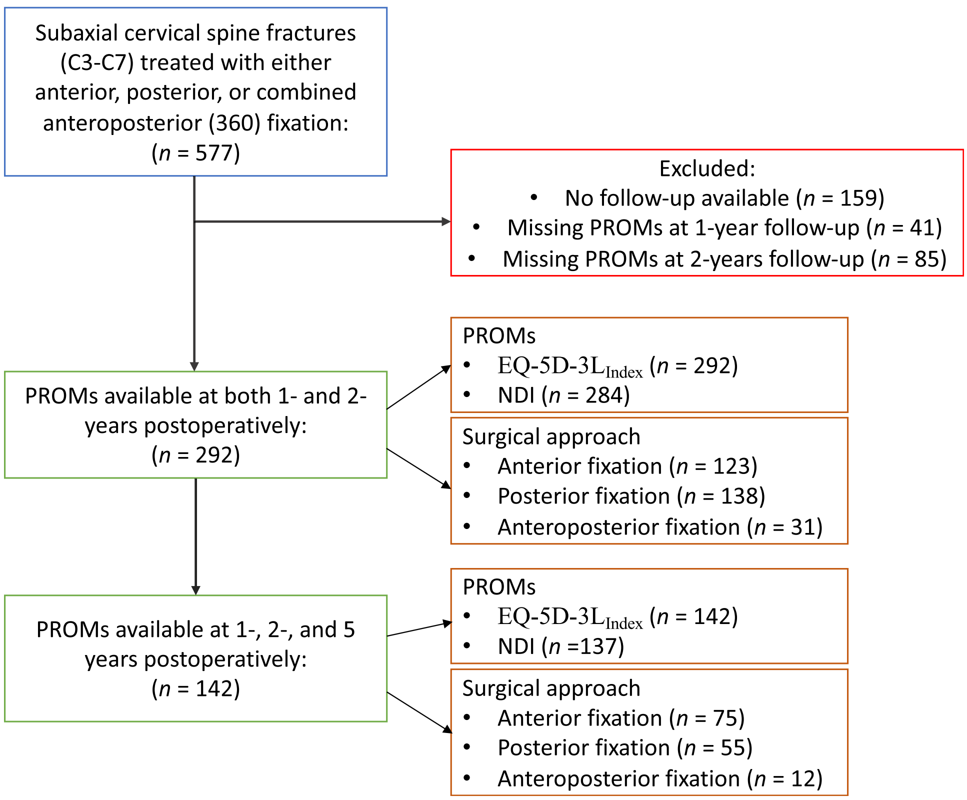

Fig. 1. Flowchart showing available and included patients.

infections, bleeding/hematomas, wound infections, iatrogenic dural tears, implant related events, and vascular injuries), and reoperations for various reasons are registered in Swespine by the treating physician. Additionally, patients are asked to fill out questionnaires 1, 2, 5 and 10 years after surgery. The follow-up questionnaires cover patient satisfaction, ambulatory function, use of pain medication, and 90-day postoperative complications. The questionnaires also include the Neck Disability Index (NDI) [5], and the health-related quality of life (HRQoL) survey EQ-5D-3L [6]. The NDI ranges from 0 (no disability) to 100 (maximal disability) and evaluates neck-related disability experienced by subjects in their everyday life. The EQ-5D-3L measures HRQoL and the respondents are asked to rate 5 different health-related dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) based on three severity levels (no, moderate, or severe problems) [7]. The answers can be translated to an index ranging from -0.56 (worst imaginable health) to 1.00 (best imaginable health) based on the UK-TTO tariff.

Study population and eligibility criteria

Patients surgically treated for a subaxial cervical spine fracture between 2006 and 2016 were identified using the Swedish Spine Registry (Swespine). All patients with a minimum postoperative follow-up of 1 year, with available PROMs were eligible for screening regardless of the surgical approach: anterior, posterior, or combined anteroposterior (360˚) fixation. (Fig. 1). Patients with available both 1- and 2-years PROMs were included in the analysis. Almost half (49%) of the patients also had PROMs at 5 years. In an attempt to evaluate attrition bias in our cohort, statistical analysis comparing patients with and without 5-years PROMs was performed. There were no statistically significant differences in terms of demographics, surgical approach, injury mechanisms, overall surgical complications, and 1-, or 2-year PROMs ($p \geq 0.05$).

Statistical analysis

The descriptive data is presented as numbers with percentages for categorical variables and medians (IQR) for continuous variables. For between-group statistical comparison of categorical variables the Chi-squared test was used while a one-way ANOVA was used for continuous variables. A mixed ANOVA was used to evaluate the effect resulting from the interaction of both follow-up time and surgical approach on the PROMs. Linear regression was used to assess the predictive ability of 1-year PROMs in predicting outcome at 2 and 5 years. All statistical analyses were performed in the SPSS statistics software, version 26, and p-values of < 0.05 were considered statistically significant.

Ethical considerations

Swespine uses the opt-out method, meaning that patient consent is not needed to be part of the quality registry, but answering the questionnaires is voluntary. This study was approved by the Regional Ethical Review Board of Stockholm (Dnr 2016/897−31/1).

Results

Patient characteristics

There were 292 patients that met the inclusion criteria. The entire cohort was divided into three groups depending on the surgical approach (Table 1): anterior (n = 123), posterior (n = 138), and combined anteroposterior (360˚) fixation (n = 31). Age ($p < 0.001$), but not sex ($p = 0.782$), differed significantly between groups. Patients in the

Table 1
Patient characteristics

	Entire cohort (n = 292)	Anterior fixation (n = 123)	Posterior fixation (n = 138)	Anteroposterior fixation (n = 31)	p-value
Age	62 (25)	55 (26)	65 (18)	60 (22)	**<0.001**
Male sex	212 (73%)	89 (72%)	102 (73%)	21 (68%)	0.782
Type of vertebral fracture					0.311
Compression	36 (12%)	15 (12%)	15 (11%)	6 (19%)	
Burst	172 (59%)	79 (64%)	78 (57%)	15 (48%)	
Distraction/translation/rotation	84 (29%)	29 (24%)	45 (33%)	10 (32%)	
Number of vertebrae injured (31 missing)	2.0 (0)	2.0 (1)	2.0 (0)	2.0 (0)	**0.016**
Number of anterior segments fixated (3 missing)	1.0 (1)	1.0 (1)	N/A	1.0 (1)	0.932
Number of posterior segments fixated (4 missing)	N/A	N/A	5.0 (4)	2.0 (3)	**0.004**
Perioperative complications	30 (10%)	8 (7%)	19 (14%)	3 (10%)	0.154
Length of hospital stay in days (5 missing)	3 (3)	3 (2)	3 (3)	4 (5)	**0.014**

Bold represents significant p-values.

posterior fixation group were the oldest, followed by those in the anteroposterior, and then the anterior group. The types of vertebral fractures did not differ between groups (p = 0.311). However, patients with a greater number of injured vertebrae were more likely to be managed with a posterior fixation (p = 0.016). Despite that, there were no significant differences between approaches in terms of neurologic function on admission, as measured in Frankel grades (p = 0.343). The rate of complications did not significantly differ between the groups (p = 0.154). Complications included implant related ones (n = 17) - encompassing implant dislocation, loosening, extraction, or the need of refusion - wound infections (n = 3), vascular injuries (n = 2), iatrogenic dural tears (n = 1), and others which were not specified (n = 7). The length of hospital stay was the longest for patients who were treated with an anteroposterior fixation, followed by those treated with a posterior fixation, and shortest for those treated with anterior fixation (p = 0.014).

PROMs

The median EQ-5D-3L$_{Index}$ score remained stable at 0.727 through 1-, 2-, and 5-years of follow-up. The median NDI scores at 1-, 2-, and 5-years follow-up were 20.0, 20.0, and 18.0, respectively (Table 2).

No significant changes in the postoperative PROMs were observed beyond the first year of follow-up on the longitudinal within-group analysis (Table 3). The PROMs remained stable through years 1, 2, and 5 postoperatively (Supplementary file 2; Figures A and B). As shown by the between-group analysis, surgical approach did not significantly affect PROMs (Table 3). However, between 2- and 5-years postoperatively, a marginally significant difference in EQ-5D-3L$_{index}$ values was seen among the groups. During that time, patients who were treated with an anterior fixation performed better than the rest (p = 0.043). However, the difference between groups failed to reach the minimal clinically important difference (MCID) of 0.24 [8].

According to the mixed ANOVA results, the interaction between both within- (time) and between-group (surgical approach) factors did not significantly affect the PROMs, meaning that overall, the PROM values evolved in a similar fashion between groups from 1- to 5-years postoperatively. After conduction of a similar analysis, we also found that the occurrence of postoperative complications did not have a significant impact on the evolution of EQ5D (p = 0.34; p = 0.14) or NDI scores (p = 0.61; p = 0.84; from 1 to 2, or 2 to 5 years postoperatively, respectively).

The correlation between 1-year and 2- or 5-year postoperative PROMs were all strong (R > 0.7 (Fig. 2). These results were true regardless of the surgical approach.

On linear regression analysis, 1-year postoperative EQ-5D-3L$_{index}$ score was an independent predictor of both 2-year and 5-year EQ-5D-3L$_{index}$ (both p < 0.001). The resulting prediction model revealed unstandardized beta-coefficients (B) of 0.796 (SE: 0.04) and 0.855 (SE: 0.06), respectively. The results remained significant regardless of the group being analyzed.

Likewise, the 1-year postoperative NDI score was also an independent predictor of both 2-year and 5-year NDI (both p< 0.001). The resulting prediction model revealed unstandardized beta-coefficients (B) of 0.803 (SE: 0.04) and 0.768 (SE: 0.06), respectively. The results remained significant regardless of the group being analyzed. The correlation between 1-year and 2- or 5-year postoperative PROMs were all strong (R > 0.7) regardless of the surgical approach (Fig. 2).

Discussion

The aim of this study was to assess the evolution of PROMs at 1-, 2- and 5-years follow-up after surgery for traumatic subaxial cervical spine fractures. The results of the analysis revealed that PROMs remained stable beyond one year of follow-up, regardless of the surgical approach.

The study population scored substantially worse on EQ-5D-3L$_{index}$ and NDI than published data on the general population [9−11]. This indicates that a substantial portion of patients do not return to baseline levels even after appropriate management. In fact, previous studies performed on the same registry showed that 44% of patients treated for traumatic subaxial spine injuries used pain medication several years after surgery [12,13]. Despite these findings, most of

Table 2
Median EQ-5D-3L$_{Index}$ and NDI scores (IQR) in the overall cohort as well as depending on the fixation approach

	Overall cohort	Anterior fixation	Posterior fixation	Anteroposterior (360) fixation
At 1-year FU	n_1=292 / n_2=284	n_1=123 / n_2=119	n_1=138 / n_2=136	n_1=31 / n_2=29
EQ-5D-3L$_{Index}$	0.727 (0.28)	0.760 (0.18)	0.727 (0.25)	0.725 (0.54)
NDI	20.0 (30.0)	16.0 (30.0)	21.0 (31.5)	28.0 (35.0)
At 2-years FU	n_1=292 / n_2=284	n_1=123 / n_2=119	n_1=138 / n_2=136	n_1=31 / n_2=29
EQ-5D-3L$_{Index}$	0.727 (0.21)	0.760 (0.23)	0.726 (0.28)	0.725 (0.60)
NDI	20.0 (31.5)	18.0 (30.0)	22.0 (32.0)	20.0 (35.0)
At 5-years FU	n_1=142 / n_2=137	n_1=75 / n_2=72	n_1=55 / n_2=54	n_1=12 / n_2=11
EQ-5D-3L$_{Index}$	0.727 (0.27)	0.760 (0.34)	0.725 (0.28)	0.743 (0.83)
NDI	18.0 (32.0)	15.0 (28.0)	25.0 (32.0)	16.0 (26.0)

n_1 = sample of patients with available EQ-5D-3Lindex, n_2 = sample of patients with available NDI.

Table 3
Mixed-ANOVA showing the interaction between a two-level time factor in the within-group analysis and surgical approach (anterior / posterior / anteroposterior), as the between-group variable on changes in PROMs

			Within-group		Between-group		Within- and between- group interaction	
PROM	Time points	Sample size	pη^2	p-value	pη^2	p-value	pη^2	p -value
EQ-5D-3L$_{Index}$	1y vs. 2y	123 / 138 / 31	< 0.001	0.947	0.014	0.125	0.007	0.349
	2y vs. 5y	75 / 55 / 12	0.003	0.539	0.044	**0.043**	0.004	0.781
NDI	1y vs. 2y	119 / 136 / 29	0.001	0.528	0.010	0.244	0.011	0.217
	2y vs. 5y	73 / 55 / 12	0.007	0.317	0.038	0.072	0.016	0.333

Bold represents significant p-values.

pη^2 = partial Eta-squared; the proportion of variance explained by a given variable of the total variance remaining after accounting for variance explained by other variables in the model.

The between-group comparisons consider the changes in PROMs based on the fixation approach. The within- and between group interaction considers the changes in PROMs relating to the joined interaction between time and fixation approach.

the patients were reportedly satisfied with the surgery [12,13].

Previous studies have evaluated pain [14−16], surgical [15−20], or functional [16,21−24] outcomes following surgery for traumatic subaxial cervical spine injuries. However, there are only a limited number of studies addressing neck disability and HRQoL outcomes in patients treated for subaxial cervical spine fractures. Available studies often have low response rates and fail to present a coherent picture due to methodological differences [19,25−28]. Nonetheless, the average NDI at 5-years follow-up recorded in this study (22.5), was very similar to previous reports [15,29]. In one study assessing the outcomes of surgical treatment following traumatic cervical spine instability, the average NDI at last follow-up reached around 20 [15]. In a study by Korovessis et al, [29] the average NDI at last follow-up (around 5 years) was 23.8. In that study, patients presenting with spinal cord injury had significantly worse NDI. Koller et al, [16] excluded patients with spinal

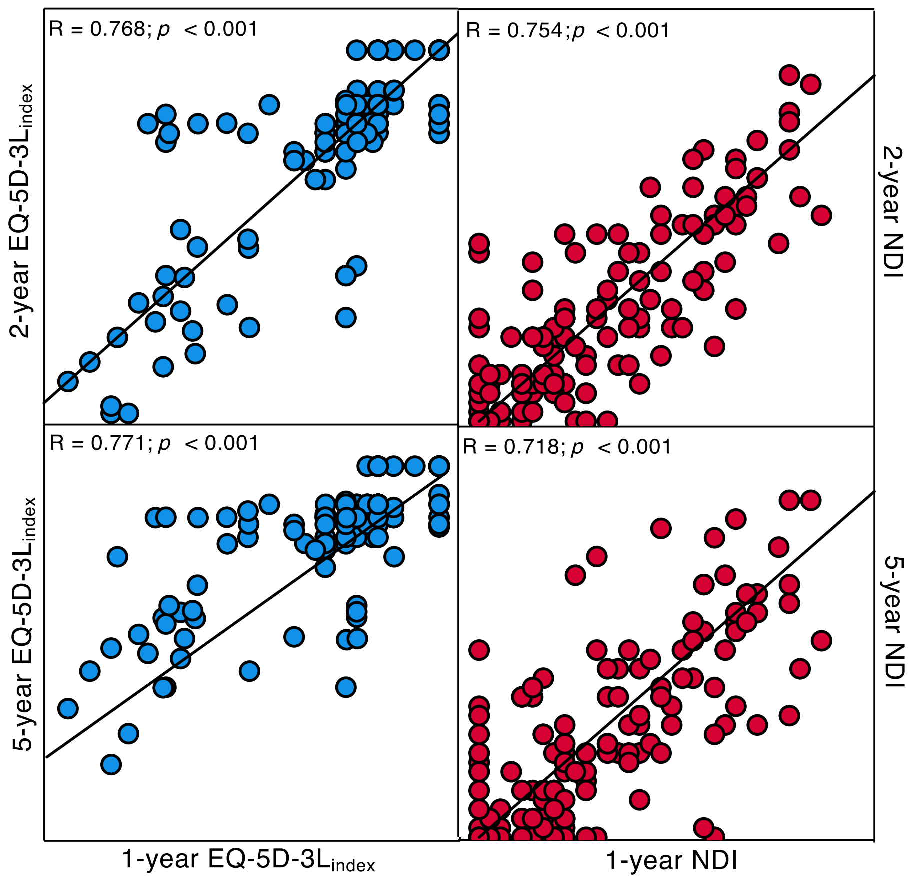

Fig. 2. Scatterplot matrix illustrating the correlation between 1-year and both 2- and 5-years PROMs.

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cord injury and found significantly better NDI scores (12.4) at 5.5 years follow-up.

In this study on subaxial spine fractures, no changes in the PROMs were seen beyond the first postoperative year. The findings are in line with published data for nontraumatic disease in the thoracic and lumbar spine, where PROMs are shown to stabilize within the first year [2,3,30]. In anterior cervical discectomy and fusion for nontraumatic disease, self-reported outcomes were stable for up to 10 years after initial improvements [31]. Similarly, Kandziora et al, [15] studying outcomes after surgery for traumatic cervical instability, found improvements in the reported NDI between the preoperative and the 6- and 12-months scores, but no further improvements beyond 12 months. Self-reported pain outcomes after surgery in the cervical spine also follow the same pattern [15,32]. Our data validate these findings and show that the effect remains stable also when comparing 2- and 5-years after surgery. Interestingly, the occurrence of postoperative complications did not affect the evolution of PROMs in our material. Patients with or without complications maintained their one-year PROM scores at 2 and 5-years. Moreover, the between group comparison did not reveal any significant differences in scores between those with and without complications. This strengthens the hypothesis that postoperative changes affecting the HRQoL measures seem to occur within the first-year post-surgery.

Strengths and limitations

While previous studies have established the validity of short-term follow-up outcomes as proxies for long-term outcomes for various spinal procedures, the corresponding data was unavailable for the subaxial cervical spine. This study is, to the best of our knowledge, the first study to present evidence for the utility of one-year PROMs in predicting longer-term outcomes after surgery for subaxial traumatic injuries. The large sample size with repeated postoperative follow-ups, the prospectively collected data, the nationwide character of the study, as well as the use of validated outcome questionnaires constitute the strengths of this study.

The study suffers from limitations due to the moderate loss to follow-up at 1 and 2 years and the more accentuated loss at 5 years postoperatively, which may induce a risk of attrition bias. However, previous studies on Swedish, Norwegian, and Danish spine registries have shown that the nonrespondents did not significantly influence the study outcomes [33−35]. Additionally, statistical analysis of our data revealed no differences between the patients that were lost to follow-up and those who were not, in terms of demographics, surgical approach, injury mechanisms, overall surgical complications, and 1-, or 2-year PROMs ($p \geq 0.05$). Moreover, stratification based on neurological function on admission was not performed due to the small sample size of the 5-year cohort. However, this parameter did not significantly differ between surgical approaches, and had minimal to no impact on the findings ($p= 0.343$). Furthermore, there are limitations inherent to patient-reported data originating from voluntary surveys; there may be a selection bias between those who respond to questionnaires and those who opt out. The Swespine registry has a nationwide coverage including 46 of 47 spinal clinics in the country. The registry is directed towards all types of spinal surgical procedures, and in the context of fractures, amasses all kinds of spine injuries regardless of the degree of severity. In other words, there are no exclusion criteria precluding the registration of any patient group. Prospective surgical data is entered by the operating surgeon, while patients are asked to fill out questionnaires at the different follow-up times, regardless of discharge disposition and functional status. Patients may however opt out from inclusion in the registry at any time. The large coverage of the registry and its wide inclusiveness minimize the risk of selection bias and ensure the generalizability of the resulting findings. Finally, the small sample size associated with the anteroposterior group warrants a cautious interpretation of the associated results.

Conclusion

PROMs remained stable beyond 1-year of follow-up in patients treated with anterior, posterior, or combined anteroposterior surgeries for acute subaxial cervical spine fractures. The 1-year PROMs were strong predictors of PROMs measured at 2, and 5 years. Our findings suggest that the 1-year PROMs are sufficient to assess the outcomes of cervical fixation following subaxial cervical spine fractures irrespective of the surgical approach.

Availability of data

The datasets generated during the current study are available from the corresponding author on reasonable request.

Code availability

No specific software codes used.

Ethical Considerations

Swespine uses the opt-out method, meaning that patient consent is not needed to be part of the quality registry, but answering the questionnaires is voluntary. The Regional Ethical Review Board in Stockholm has authorized the study and the use of the data collection (Dnr 2016/897−31/1).

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2023.04.014.

References

[1] Ahmad SS, Hoos L, Perka C, et al. Follow-up definitions in clinical orthopaedic research: a systematic review. Bone Jt Open 2021;2:344.
[2] Fekete TF, Loibl M, Jeszenszky D, et al. How does patient-rated outcome change over time following the surgical treatment of degenerative disorders of the thoracolumbar spine? Eur Spine J 2018;27:700–8.
[3] Parai C, Hägg O, Lind B, et al. Follow-up of degenerative lumbar spine surgery-PROMs stabilize after 1 year: an equivalence study based on Swespine data. Eur Spine J 2019;28:2187–97.
[4] Uppföljning av ryggkirurgi utförd i Sverige år 2016 [database online]. *Sweden: Swedish Society of Spinal Surgeons;* 2017.
[5] Vernon H, Mior S. The neck disability index: a study of reliability and validity. J Manip Physiol Ther 1991;14:409–15.
[6] Brooks R, de Charro F. EuroQol: the current state of play. Health Policy (New York) 1996;37:53–72.
[7] Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group. Ann Med 2001;33:337–43.
[8] Parker SL, Godil SS, Shau DN, et al. Assessment of the minimum clinically important difference in pain, disability, and quality of life after anterior cervical discectomy and fusion: clinical article. J Neurosurg Spine 2013;18:154–60.
[9] Kato S, Takeshita K, Matsudaira K, et al. Normative score and cut-off value of the neck disability index. J Orthop Sci 2012;17:687–93.
[10] Ackelman BH, Lindgren U. Validity and reliability of a modified version of the neck disability index. J Rehabil Med 2002;34:284–7.
[11] Janssen MF, Szende A, Cabases J, et al. Population norms for the EQ-5D-3L: a cross-country analysis of population surveys for 20 countries. Eur J Health Econ 2019;20:205–16.
[12] Fröjd Révész D, Norell A, Charalampidis A, et al. Subaxial spine fractures: a comparison of patient-reported outcomes and complications between anterior and posterior surgery. Spine (Phila Pa 1976) 2021;46:E926–31.
[13] Singh A, Blixt S, Edström E, et al. Outcome and health related quality of life after combined anteroposterior surgery vs anterior surgery alone in subaxial cervical spine fractures. Analysis of a national multicenter dataset. Spine (Phila Pa 1976) 2023. in Press.
[14] Reindl R, Ouellet J, Harvey EJ, et al. Anterior reduction for cervical spine dislocation. Spine (Phila Pa 1976) 2006;31:648–52.
[15] Kandziora F, Pflugmacher R, Scholz M, et al. Treatment of traumatic cervical spine instability with interbody fusion cages: a prospective controlled study with a 2-year follow-up. Injury 2005;36:S27–35.
[16] Koller H, Reynolds J, Zenner J, et al. Mid- to long-term outcome of instrumented anterior cervical fusion for subaxial injuries. Eur Spine J 2009;18:630.
[17] Hofmeister M, Bühren V. Therapeutical concept for injuries of the lower cervical vertebral column. Orthopade 1999;28:401–13.
[18] Henriques T, Olerud C, Bergman A, et al. Distractive flexion injuries of the subaxial cervical spine treated with anterior plate alone. J Spinal Disord Tech 2004;17:1–7.
[19] Dvorak MF, Pitzen T, Zhu Q, et al. Anterior cervical plate fixation: a biomechanical study to evaluate the effects of plate design, endplate preparation, and bone mineral density. Spine (Phila Pa 1976) 2005;30:294–301.
[20] Fraser JF, Härtl R. Anterior approaches to fusion of the cervical spine: a metaanalysis of fusion rates. J Neurosurg Spine 2007;6:298–303.
[21] Castro WHM, Sautmann A, Schilgen M, et al. Noninvasive three-dimensional analysis of cervical spine motion in normal subjects in relation to age and sex. An experimental examination. Spine (Phila Pa 1976) 2000;25:443–9.
[22] Hilibrand AS, Balasubramanian K, Eichenbaum M, et al. The effect of anterior cervical fusion on neck motion. Spine (Phila Pa 1976) 2006;31:1688–92.
[23] Kolstad F, Nygaard ØP, Leivseth G. Segmental motion adjacent to anterior cervical arthrodesis: a prospective study. Spine (Phila Pa 1976) 2007;32:512–7.
[24] Dmitriev AE, Kuklo TR, Lehman RA, et al. Stabilizing potential of anterior, posterior, and circumferential fixation for multilevel cervical arthrodesis: an in vitro human cadaveric study of the operative and adjacent segment kinematics. Spine (Phila Pa 1976) 2007;32:E188–96. https://doi.org/10.1097/01.BRS.0000257577.70576.07.
[25] Fisher CG, Dvorak MFS, Leith J, et al. Comparison of outcomes for unstable lower cervical flexion teardrop fractures managed with halo thoracic vest versus anterior corpectomy and plating. Spine (Phila Pa 1976) 2002;27:160–6.
[26] Reitman CA, Mauro KM, Nguyen L, et al. Intervertebral motion between flexion and extension in asymptomatic individuals. Spine (Phila Pa 1976) 2004;29:2832–43.
[27] Kwon BK, Fisher CG, Boyd MC, et al. A prospective randomized controlled trial of anterior compared with posterior stabilization for unilateral facet injuries of the cervical spine. J Neurosurg Spine 2007;7:1–12.
[28] Lang S, Neumann C, Fiedler L, et al. Does dynamic anterior plate fixation provide adequate stability for traumatic subaxial cervical spine fractures at mid-term follow-up? J Clin Med 2021;10:1–11.
[29] Korovessis P, Mpountogianni E, Syrimpeis V, et al. Quality of life in adult patients receiving cervical fusion for fresh subaxial cervical injury: the role of associated spinal cord injury. Biomed Res Int 2021;2021:9931535. https://doi.org/10.1155/2021/9931535.
[30] Glassman SD, Schwab F, Bridwell KH, et al. Do 1-year outcomes predict 2-year outcomes for adult deformity surgery? Spine J 2009;9:317–22.
[31] Buttermann GR. Anterior cervical discectomy and fusion outcomes over 10 years a prospective study. Spine (Phila Pa 1976) 2018;43:207–14.
[32] Hermansen A. Clinical and patient-reported outcomes after anterior cervical decompression and fusion surgery : a focus on functioning and daily life. 1443. [e-pub ahead of print May 22, 2015]. https://doi.org/10.3384/DISS.DIVA-117347. accessed February 2, 2023.
[33] Ingebrigtsen T, Aune G, Karlsen ME, et al. Non-respondents do not bias outcome assessment after cervical spine surgery: a multicenter observational study from the Norwegian registry for spine surgery (NORspine). Acta Neurochir (Wien) 2023;165:125–33.
[34] Elkan P, Lagerbäck T, Möller H, et al. Response rate does not affect patient-reported outcome after lumbar discectomy. Eur Spine J 2018;27:1538–46.
[35] Højmark K, Støttrup C, Carreon L, et al. Patient-reported outcome measures unbiased by loss of follow-up. Single-center study based on DaneSpine, the Danish spine surgery registry. Eur Spine J 2016;25:282–6.