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Received, December 9, 2019.

Accepted, August 12, 2020.

Published Online, December 28, 2020.

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2020.

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Occurrence, Risk Factors, and Time Trends for Late Reoperations due to Degenerative Cervical Spine Disease: A Finnish National Register Study of 19 377 Patients Operated on Between 1999 and 2015

BACKGROUND: Surgery for degenerative cervical spine disease has escalated since the 1990s. Fusion has become the mainstay of surgery despite concerns regarding adjacent segment degeneration. The patient-specific trends in reoperations have not been studied previously.

OBJECTIVE: To analyze the occurrence, risk factors, and trends in reoperations in a long-term follow-up of all the patients operated for degenerative cervical spine disease in Finland between 1999 and 2015.

METHODS: The patients were retrospectively identified from the Hospital Discharge Registry. Reoperations were traced individually; only reoperations occurring >365 d after the primary operation were included. Time trends in reoperations and the risk factors were analyzed by regression analysis.

RESULTS: Of the 19 377 identified patients, 9.2% underwent a late reoperation at a median of 3.6 yr after the primary operation. The annual risk of reoperation was 2.4% at 2 yr, 6.6% at 5 yr, 11.1% at 10 yr, and 14.2% at 15 yr. Seventy-five percent of the late reoperations occurred within 6.5 yr of the primary operation. Foraminal stenosis, the anterior cervical decompression and fusion (ACDF) technique, male gender, weak opiate use, and young age were the most important risk factors for reoperation. There was no increase in the risk of reoperations over the follow-up period.

CONCLUSION: The risk of reoperation was stable between 1999 and 2015. The reoperation risk was highest during the first 6 postoperative years and then declined. Patients with foraminal stenosis had the highest risk of reoperation, especially when ACDF was performed.

KEY WORDS: Cervical spine, Degeneration, Population-based, Register study, Reoperation, Risk factors

Neurosurgery 88:558–573, 2021

DOI:10.1093/neuros/nyaa464

www.neurosurgery-online.com

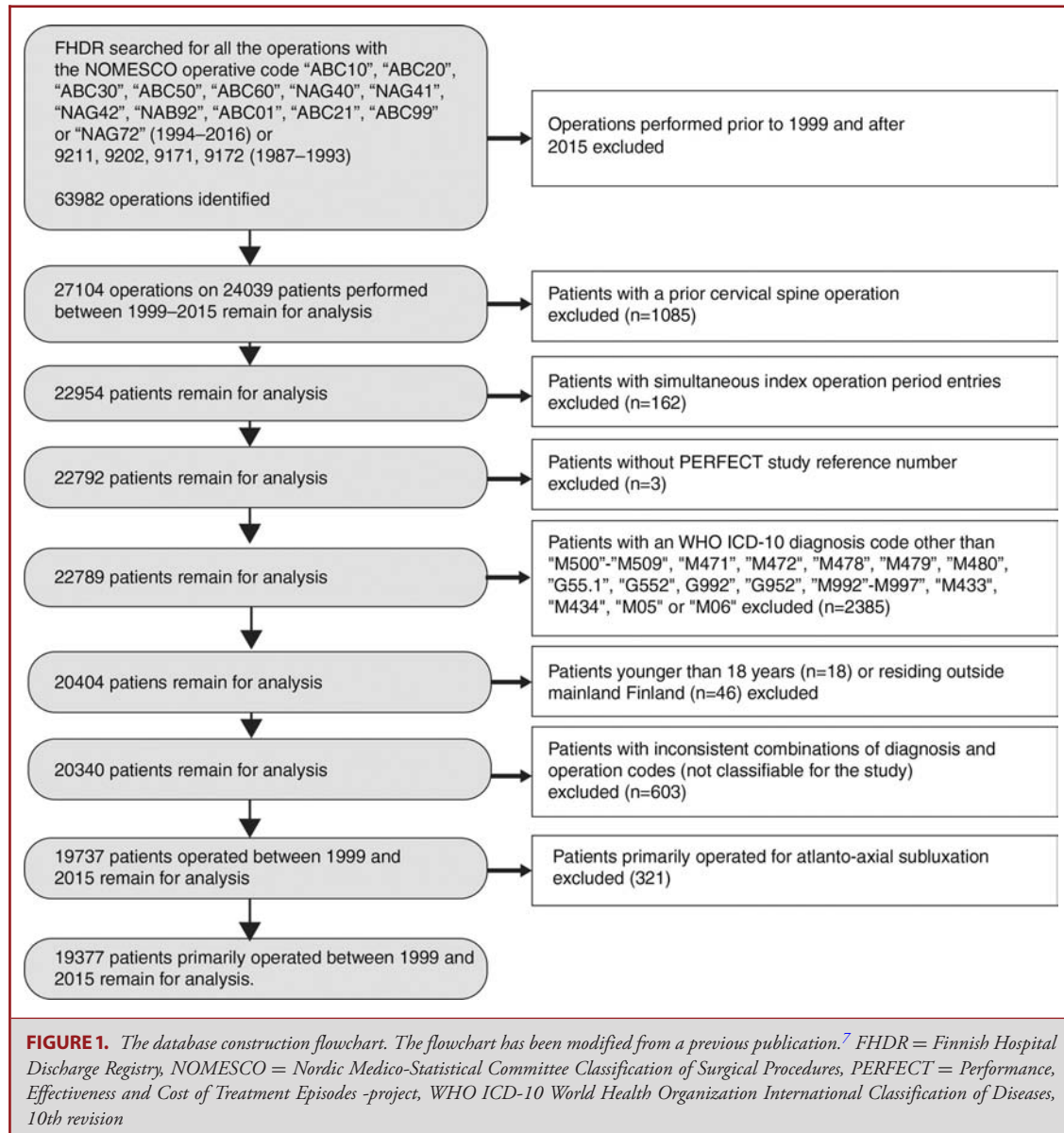
Surgery for degenerative cervical spine disease (DCSD), especially fusion surgery,^{1–4} has escalated in the United States (US),^{2,5} Norway,⁶ and Finland.⁷ Annual reoperation rates have varied from 2.3% to 2.9%.^{8–11} Anterior cervical decompression and

fusion (ACDF) surgery especially has been suspected of increasing the risk of symptomatic degeneration in the adjacent levels (sASD).¹² The increase in the incidence of revision cervical fusion surgery has been slightly higher compared to primary surgery in the US between 2002

ABBREVIATIONS: ACDF, anterior cervical decompression and fusion; ASD, adjacent segment disease; ATC, anatomical therapeutic chemical; COPD, chronic obstructive pulmonary disease; DCSD, degenerative cervical spine disease; FHDR, Finnish Hospital Discharge Register; HR, hazard ratio; IQR, interquartile range; PDF, posterior decompression and fusion; PIC, personal identity code; RA, rheumatoid arthritis; sASD, symptomatic adjacent segment disease; SII, social insurance institute; US, United States

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and 2009¹³; beyond that, data on the trends in reoperations for DCSD are lacking.

The purpose of this study was to assess the occurrence, risk factors, and time trends of late reoperations covering every patient undergoing their first surgery for DCSD in Finland between 1999 and 2015. Only reoperations occurring more than 1 yr after the primary operation were included.

METHODS

Study Design and Data Sources

Every primary operation performed in Finland for degenerative or rheumatoid cervical spine disease between 1999 and 2015 was

retrospectively identified based on the operative codes from the Finnish Hospital Discharge Register (FHDR).⁷ Figure 1 illustrates the construction of the database, which has been described in detail previously.⁷ The FHDR was subsequently queried for any reoperations using the personal identity codes (PIC), the operative and diagnosis codes, as well as separate complication codes (see **Table, Supplemental Digital Content 1** for details). Data on comorbidities, prescription medicines, and deaths were acquired from the registries of the Social Insurance Institute (SII) of Finland and the Cause of Death Register.⁷

The Ethics Committee of the National Institute for Health and Welfare approved the study and the creation of the database (THL 496/6.02.00/2011). The combining of the data was approved by the respective authorities. Informed consent was considered redundant as patients were not contacted and all the data were anonymized. The article

TABLE 1. The Combinations of the Diagnosis (World Health Organization International Classification of Diseases, 10th revision) and Operative (Nordic Medico-Statistical Committee Classification of Surgical Procedures) Codes Used to Classify the Patients Into the Diagnosis and Technique Groups (Adapted From a Previous Publication)⁷

Diagnosis group	Diagnosis codes	Technique groups and the operative codes used		
		Decompression	Anterior decompression and fusion or arthroplasty	Posterior decompression and fusion
Disc protrusion	M50.0	ABC01	NAG40	
	M50.1	ABC10	NAG41	
	M50.2	ABC20	NAB92	
	M50.3	ABC30		
	M50.8	ABC50		
	M50.9	ABC60		
Foraminal stenosis	G55.1			
	M47.2	ABC30	NAG40	NAG42
	G55.2	ABC50	NAG41	
	M99.6	ABC99		
Spinal canal stenosis	M99.7			
	M47.1	ABC30 ^a	ABC21	NAG42
	M47.8	ABC50	NAG40	
	M47.9	ABC60	NAG41	
	M48.0	ABC99	NAG72	
	M99.2			
	M99.3			
	M99.4			
	M99.5			
G95.2				
G99.2				

^aSix hundred eighty-eight cases with diagnosis codes consistent with spinal canal stenosis and the operative code ABC30 for foraminotomy, mostly from one hospital, were also included in the spinal canal stenosis group.

was constructed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Study Setting and Patients

Only the patients operated for DCSD were included in this study. The operative and the diagnosis codes were cross-linked to classify the patients into 3 diagnostic groups (disc protrusion, foraminal stenosis, spinal canal stenosis) and 3 technique groups (decompression; ACDF; posterior decompression and fusion, PDF) (Table 1).⁷ Only reoperations occurring >365 d after the primary operation were included. Patients with a previous cervical spine operation between 1986 and 1998 were excluded. The other exclusion conditions were patients younger than 18 yr of age, not residing in mainland Finland or with cancer, inflammatory spondylitis, other secondary spondylarthropathies, osteoporotic fracture, congenital spinal deformity, osteochondrodysplasia, or trauma as the indication for surgery. The data on the comorbidities and the use of analgesics were collected from the FHDR and the registries of the SII utilizing the medication reimbursement codes and anatomical therapeutic chemical (ATC) codes (see **Table, Supplemental Digital Content 2** for the classification of the analgesics and the ATC codes).⁷ The comorbidities were grouped into 8 groups (Table 2).

Statistical Analyses

The Pearson χ^2 test was used to analyze differences in the reoperation rate between the groups. Differences in the follow-up time and the time to reoperation were analyzed using the Kruskal-Wallis independent samples test. P -value < .05 was considered statistically significant. Kaplan-Meier analysis was used to estimate the unadjusted rate of reoperations. For risk factor analysis and comparisons of reoperation risk between the groups, Cox regression analysis was used, with late reoperation as the dependent variable. Factors affecting the time to late reoperation were analyzed using the Cox regression model, with time to reoperation as the dependent variable. Patients were followed until the first reoperation, death or the end of the follow-up (December 31, 2017), and censored at death or at the end of the follow-up in the survival analysis. Statistical analyses were conducted using the IBM SPSS Statistics software version 26 (IBM Corporation, Armonk, New York).

RESULTS

Patients

From the FHDR, 19 377 patients with a primary operation for DCSD between 1999 and 2015 were identified. The follow-up data were complete for all the patients. The baseline

TABLE 2. Grouping of the Comorbidities

Comorbidity group	Comorbidity
Rheumatoid arthritis	Rheumatoid arthritis
Metabolic syndrome	Hypertension Diabetes Hypercholesterolemia
Cardiovascular	Atrial fibrillation Cardiac insufficiency Coronary artery disease Cerebrovascular disease Peripheral artery disease
Pulmonary	Chronic obstructive pulmonary disease asthma
Nervous system	Dementia Demyelinating or neurodegenerative disease (other than dementia) Polyradiculopathy Parkinson's disease Epilepsy
Psychiatric	Depression Other mental disorder Alcohol or drug addiction
Uremia or cancer	Uremia Cancer
Musculoskeletal degeneration	Arthrosis of the shoulder joint Arthrosis of the hip or knee joint Rotator cuff syndrome Fibromyalgia

data are given in Table 3 (see **Table, Supplemental Digital Content 3** for the granular comorbidity data).

Reoperation Data

During the follow-up, 2293 patients (11.8%) died. Altogether 2547 patients underwent a reoperation during the follow-up time of 0 to 19.4 yr; in 1777 patients (9.2%), the reoperation occurred over a year after the primary operation. The median follow-up times and the median time to reoperation varied between the diagnosis and the technique groups ($P < .001$) (Table 4, Figure 2). The mean age at reoperation was 54.6 ± 9.6 (range 25.6-85.2) yr and 59.8% of the patients were male. During the follow-up, 233 patients (1.2%) had 2, 41 (0.2%) had 3, and 8 patients (0.04%) had 4 reoperations.

The distribution of the reoperation diagnoses and the reoperation rate in each diagnosis group are depicted in Table 5. Approximately 75.5% of the reoperations were done for radiculopathy and 23.9% for spinal cord compression. Foraminal stenosis accounted for 54.2% of the reoperations. The distribution of the primary and reoperation techniques is detailed in Table 6. ACDF was used in 67.6% of the primary operations and 63.8% of the reoperations. Reoperations because of pseudoarthrosis were rare, only 0.1% of the reoperations.

The Kaplan-Meier estimates for the cumulative risk of reoperation are depicted in Figure 3A for all the reoperations, in

Figure 3B for reoperations after the first postoperative year, and in Table 7.

Risk Factors for Reoperation

Patients with radiculopathy underwent reoperations more frequently than those with myelopathy (10.1% vs 6.9%, $P < .001$). Figure 4 illustrates the reoperation rates within the diagnosis groups depending on the technique used. The rate of reoperations within the different groups is given in Table 8. Only 57 disc arthroplasty operations were identified (0.4% of the anterior operations); 14.0% of the arthroplasty patients and 9.8% of the ACDF patients underwent a reoperation ($P = .280$) during a mean follow-up time of 7.7 ± 2.2 and 7.2 ± 4.4 yr, respectively ($P = .134$). Of the foraminotomy patients, 10.3%, and 4.3% of the laminectomy patients underwent a reoperation.

In the multivariate analysis, operation for foraminal stenosis, ACDF technique, a younger age, male gender, pulmonary comorbidity, an operation in a public hospital, and the use of weak opiates or muscle relaxants were all independent risk factors for reoperation (Table 8, Figure 5A-5E). The risk of reoperation was approximately 50% higher when ACDF was utilized for foraminal or spinal canal stenosis compared with decompression (Figure 6A-6C). Within the ACDF group, the risk of reoperation was significantly higher in foraminal and spinal canal stenosis patients compared to disc protrusion patients (Figure 7A and 7B). The only risk factors affecting the time to reoperation were the diagnosis group, the patient age group, and operation years (Figure 8A-8C).

Trends in Reoperation Rates

The crude reoperation rate for each consecutive year of primary operations remained fairly stable at around 11.5% until 2008 (see **Table, Supplemental Digital Content 4** for details). In the multivariate analysis, the risk of reoperation was higher at 2005-2007 and 2013-2015, but there were no other significant differences (Table 8). The time to reoperation decreased statistically significantly over time.

DISCUSSION

Key Results

Nine-point 2% of the patients underwent a reoperation within a mean of 8.1 (range 0-19.4) yr follow-up. The estimated annual risk of reoperation increased up to 6 yr and decreased slightly thereafter; the estimated risk was 2.4% at 2 yr, 6.6% at 5 yr, 11.1% at 10 yr, and 14.2% at 15 yr. Seventy-five percent of the reoperations occurred within 1.0 to 6.5 yr after the primary operation. The median time to reoperation was 3.6 yr and varied depending on the diagnosis and the patient's age, the shortest being in the foraminal stenosis group and the oldest patients. The operative technique did not affect the time to reoperation. Only 1.4% of the patients had more than one reoperation. Most reoperations

TABLE 3. The Baseline Data on All the Patients Operated for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015

	Diagnosis groups				Technique groups		
	All patients	Disc protrusion	Foraminal stenosis	Spinal canal stenosis	Decompression	Anterior cervical decompression and fusion	Posterior decompression and fusion
Patients N, (%)	19 377	6925 (35.7%)	6874 (35.5%)	5578 (28.8%)	5998 (31.0%)	13 099 (67.6%)	280 (1.4%)
Male (%)	56.1	52.1	57.6	59.3	59.4	54.9	44.3
Mean age (SD)	53.2 (11.4)	47.5 (9.7)	53.3 (9.0)	60.0 (11.9)	57.1 (12.7)	51.1 (9.9)	62.8 (11.5)
Comorbidity group (%)							
Rheumatoid arthritis	4.1	2.7	4.0	6.0	4.5	3.6	21.1
Metabolic syndrome	40.5	29.9	41.3	52.8	44.3	38.4	61.4
Cardiovascular	14.8	8.7	13.5	23.9	20.1	12.0	28.2
Pulmonary	16.3	15.3	16.8	16.9	15.2	16.8	17.5
Nervous system	6.0	3.5	4.5	11.2	8.4	4.8	12.5
Uremia or cancer	5.1	3.3	4.3	8.4	7.0	4.1	11.4
Psychiatric ^a	23.5	21.1	25.3	24.4	21.0	24.7	21.8
Musculoskeletal	10.6	7.3	12.8	12.0	10.0	10.7	18.6
Preoperative pain medications (%)							
Antiepileptics	30.3	26.0	26.0	21.2	18.0	36.0	30.7
Duloxetine or amitriptyline	12.1	10.0	14.5	11.7	9.2	13.4	10.4
Weak opioid	4.2	2.5	3.2	2.8	1.9	3.2	11.4
Strong opioid	3.3	2.7	2.0	2.0	1.8	2.5	6.1
Muscle relaxants	63.1	68.1	67.4	51.7	49.3	69.5	61.8
Operations in a private hospital (%)	4.9	6.4	2.1	6.6	7.7	3.7	0.7

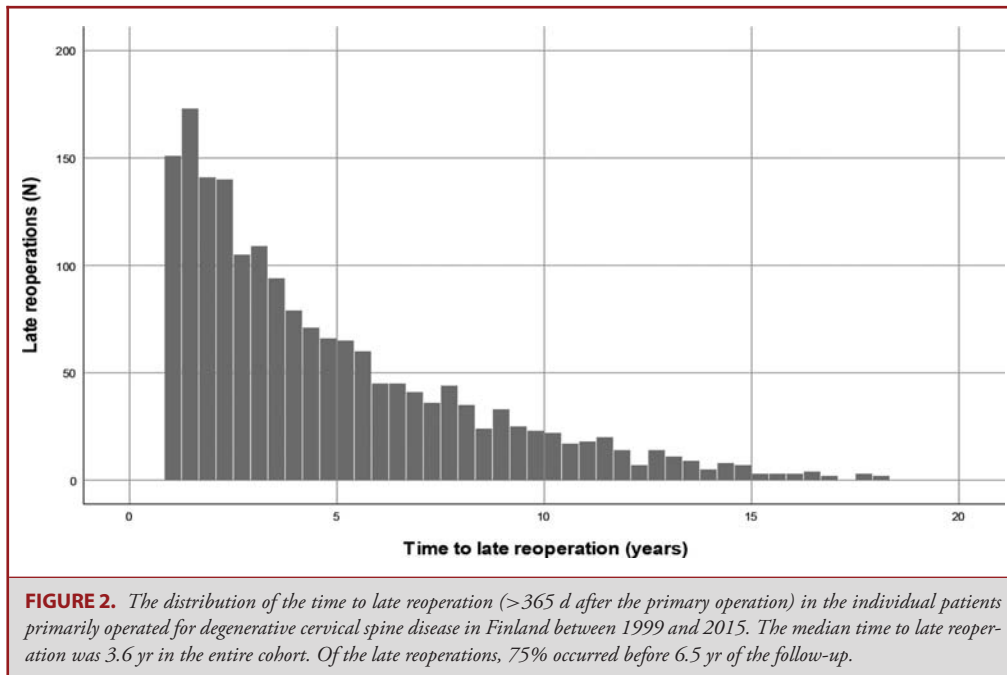
^aThe prevalence of psychiatric comorbidity is likely overestimated, as psychiatric comorbidity was recorded based on the International Classification of Diseases diagnosis codes from the Finnish Hospital Discharge Registry or the use of antidepressants. In this patient group, antidepressants can also be used for neuropathic pain.

TABLE 4. The Follow-Up Time, Rate, and Timing of Late Reoperations (>365 Days After the Primary Operation) for all the Patients Operated for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015 by Diagnosis and Technique Groups

	Diagnoses				Techniques		
	All	Disc protrusion	Foraminal stenosis	Spinal canal stenosis	Decompression	ACDF	PDF
Mean follow-up time (yr) (SD) ^a	8.1 (4.9)	9.0 (5.1)	7.6 (4.7)	7.5 (4.8)	10.1 (5.4)	7.1 (4.4)	6.1 (5.3)
Median follow-up time (yr) (IQR)	7.2 (4.0,11.7)	8.3 (4.6,13.2)	6.8 (3.8,10.8)	6.8 (3.7,10.9)	11.1 (5.3,14.7)	6.3 (3.8,9.8)	5.3 (2.8,8.2)
Late reoperations % (N)	9.1 (1777)	9.2 (634)	11.0 (756)	6.9 (387)	7.9 (476)	9.8 (1282)	6.8 (19)
Mean time to late reoperation (yr) (SD)	4.7 (3.5)	5.5 (3.9)	4.2 (3.0)	4.4 (3.3)	5.8 (4.2)	4.3 (3.0)	4.4 (3.0)
Median time to late reoperation years (IQR)	3.6 (2.0,6.5)	4.2 (2.4,7.8)	3.3 (1.8,5.8)	3.3 (2.0,6.0)	4.6 (2.3,8.4)	3.4 (2.0,5.8)	4.3 (1.5,7.0)

ACDF, anterior cervical decompression and fusion; PDF, posterior decompression and fusion; SD, standard deviation; IQR, interquartile range.

^aThe follow-up time was defined as time until the first reoperation or death.



were done for radiculopathy and specifically foraminal stenosis. In the multivariate analysis, foraminal stenosis patients had a 38% higher risk of reoperation compared with the disc protrusion group. The risk of reoperation was approximately 50% higher in the foraminal and spinal stenosis patients after ACDF compared to decompression; there was no difference in the disc protrusion group. Male gender, young age, pulmonary system comorbidity, and the use of weak opioids also emerged as risk factors for reoperation. The risk of reoperation did not increase over the years, while the time to late reoperation was reduced.

Strengths and Limitations of the Study

The analysis included every primary operation for DCSD performed in Finland between 1999 and 2015. The reliable administrative records and PICs enable individual tracking of every patient; no patients were lost to the follow-up. Patients were excluded if the diagnosis and operative codes could not be matched, which probably occurred in a random manner.

However, the administrative records lack data on the specifics of the diagnoses or techniques, such as the curvature and the extent of degeneration in the cervical spine, the number of

TABLE 5. The Rate and Indications for Late Reoperations (>365 Days After the Primary Operation) Within the Primary Diagnosis Groups on Patients Operated for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015

Reoperation indication	Primary diagnosis group, % (N) of patients within group undergoing reoperation for the specific indication			Proportion of all the reoperations % (N)
	Disc protrusion	Foraminal stenosis	Spinal canal stenosis	
Disc protrusion	3.3 (229)	1.5 (103)	0.9 (51)	21.6 (383)
Foraminal stenosis	4.2 (293)	7.9 (542)	2.3 (128)	54.2 (963)
Spinal canal stenosis	1.9 (110)	1.6 (107)	3.6 (203)	23.6 (420)
Mechanical problem	0.0 (2)	0	0	0.0 (2)
Hematoma ^a	0	0	2	0.0 (2)
Atlanto-axial subluxation	0	0.0 (4)	0.0 (3)	0.0 (7)
Reoperations in primary diagnosis group % (N)	9.2 (634)	11.0 (756)	6.9 (387)	1777

^aDiagnosis based solely on the diagnosis code.

TABLE 6. The Rate of Late Reoperations Within the Technique Groups and the Techniques Used in the Late Reoperations (>365 Days After the Primary Operation) on Patients Operated for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015

Reoperation technique	Primary technique groups, % (N) of patients within group undergoing reoperation using the specific technique			Proportion of reoperations % (N)
	Decompression	ACDF	PDF	
Decompression	3.3 (199)	2.9 (381)	0.01 (4)	32.9 (584)
ACDF	4.3 (259)	6.6 (868)	0.02 (6)	63.8 (1133)
PDF	0.2 (10)	0.2 (23)	0.03 (8)	2.3 (41)
Complication ^a	0.1 (8)	0.1 (10)	0.0 (1)	0.01 (19)
Reoperations in primary technique group % (N)	7.9 (476)	9.8 (1282)	0.07 (19)	1777

ACDF, anterior cervical decompression and fusion; PDF posterior decompression and fusion.

^aBased solely on the operative code. As per the operative codes, complications include 14 operations for hematoma, 2 operations for wound infection, 3 operations for "other postoperative complication" and 1 operation for "other wound complication."

TABLE 7. The Number of Reoperations and the Kaplan-Meier Estimates for the Rate of Reoperations for Adults Having Undergone a Primary Operation for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015

Follow-up (yr)	Patients at risk	Cumulative late reoperations	Estimated rate of late reoperations	SE of estimate
2	17 865	441	2.4	0.001
4	14 560	969	5.5	0.002
6	11 378	1277	7.7	0.002
8	8725	1473	9.5	0.002
10	6447	1605	11.1	0.003
12	4589	1695	12.5	0.003
14	2996	1740	13.6	0.003
16	1660	1765	14.6	0.004
18	501	1776	15.7	0.005

SE, standard error.

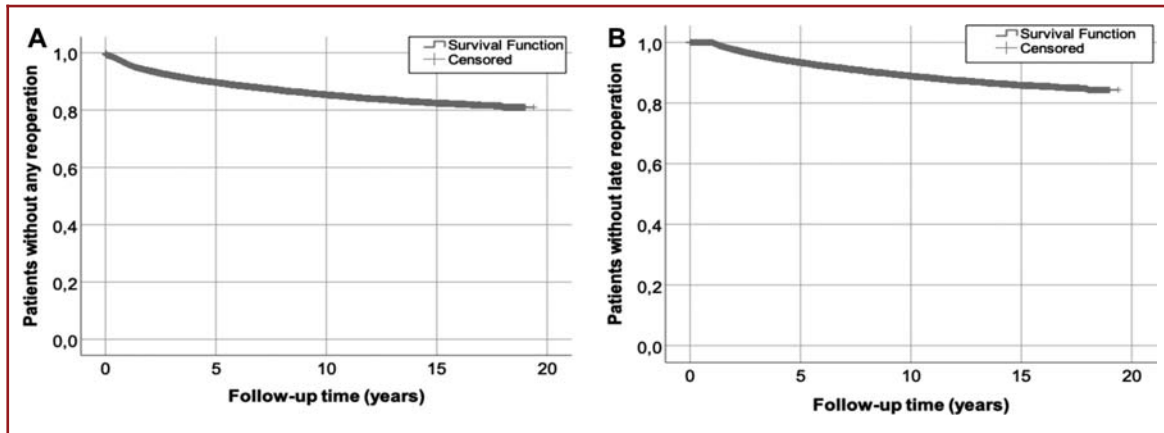


FIGURE 3. The unadjusted survival estimates (Kaplan-Meier analysis) of all the patients operated for degenerative cervical spine disease in Finland between 1999 and 2015 for any reoperation **A** and for reoperation after the first postoperative year **B**. The estimated risk of any reoperation was 4.0% (standard error [SE] 0.001) at 1 yr, 6.3% (SE 0.002) at 2 yr, 10.3% (SE 0.002) at 5 yr, 14.6% (SE 0.003) at 10 yr, and 17.6% (SE 0.004) at 15 yr. The estimated late reoperation risk was 2.4% (SE 0.001) at 2 yr, 6.6% (SE 0.002) at 5 yr, 11.1% (SE 0.003) at 10 yr, and 14.2% (SE 0.004) at 15 yr. The estimated late reoperation risk at 10 yr and at 15 yr was 12.6% (SE 0.006) and 17.1% (SE 0.008) in the 18- to 44-yr-olds, 11.7% (SE 0.004) and 14.3% in the 45- to 60 -yr-olds, 8.1% (SE 0.006) and 10.1% (SE 0.008) in the 61- to 75 -yr-olds, and 3.0% at both time points (SE 0.008) in the patients over the age of 75 yr.

vertebral levels involved or operated, or the type of instrumentation used.^{10,14-18} Therefore, we cannot assess the effect of these potential risk factors or the anatomical relationship of the reoperation with the primary operation. The number of vertebral levels operated may explain at least partially the differences in the reoperation rates between the ACDF and decompression groups, especially since the risk of reoperation did not increase between 1999 and 2015 despite the change in the operative techniques from predominantly decompressive to ACDF.¹⁹ Further limitations of the operative coding system have been discussed previously.^{7,19} Data on some potential confounding factors, especially smoking, are missing.^{13,17}

Interpretation

The reported reoperation rates have varied considerably (Table 9).^{9,15,20-29} In the 2 previous population-based studies, with short follow-up times, the reoperation rates were 5.6% in Washington state⁹ and 3.3% in Taiwan.²⁰ A recent meta-analysis reported reoperation rates between 0% and 16.9%, with a pooled prevalence of 5.8% and an annual addition of 0.24% in the risk of reoperation for any technique⁸; the reoperation rates after cervical fusion have varied between 1.6% and 4.2% annually.¹⁴ The long follow-up and the exclusion of the first postoperative year in our study may partly explain the differences in the reoperation rates, as the risk of reoperation declined after 6 yr. There may be differences in the operation indications, patient populations, diagnoses, and the techniques used.

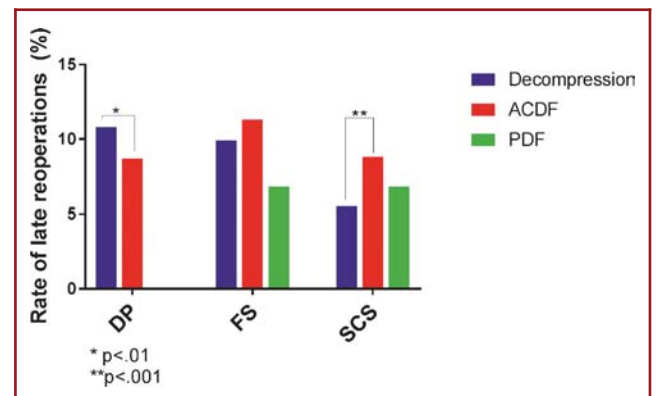


FIGURE 4. The reoperation rates in the diagnosis groups depending on the technique. The late (>365 d after the primary operation) reoperation rates (% of primary operations) for the patients primarily operated for degenerative cervical spine disease in Finland between 1999 and 2015 within the diagnosis groups depending on the operative technique. In disc protrusion (DP) patients, the rates of reoperation were statistically significantly higher in patients undergoing anterior cervical decompression and fusion (ACDF) compared to decompression patients ($P = .01$). In the spinal canal stenosis (SCS) group, the reoperation rates were also statistically significantly different depending on the technique used ($P < .001$). The patients having undergone ACDF had a significantly higher ($P < .05$) reoperation rate compared with decompression patients, while the differences in reoperation rates between posterior decompression and fusion (PDF) and decompression or ACDF were not statistically significant. In the foraminal stenosis (FS) group, the reoperation rates were not statistically significantly different between the technique groups.

TABLE 8. Risk Factors for Late (>365 Days After Primary Operation) Reoperation on all the Patients Operated for Degenerative Cervical Spine Disease in Finland Between 1999 and 2015 (Adjusted Cox Regression Analysis)

	Rate of reoperations, %	Hazard ratio of reoperations (CI)	Significance
Diagnosis group			
Disc protrusion	9.2	1.0	
Foraminal stenosis	11.0	1.38 (1.23-1.54)	<.001
Spinal canal stenosis	6.9	1.11 (0.96-1.27)	.436
Technique group			
Decompression	7.9	1.0	
Anterior decompression and fusion	9.8	1.33 (1.18-1.51)	<.001
Posterior decompression and fusion	6.8	1.31 (0.82-2.09)	.253
Gender			
Male	9.8	1.0	<.001
Female	8.4	0.79 (0.72-0.87)	
Age group			
18-44	11.5	1.0	
45-60	9.8	0.84 (0.75-0.94)	.002
61-75	6.2	0.68 (0.57-0.81)	<.001
Over 75	2.1	0.33 (0.20-0.55)	<.001
Comorbidity group			
Rheumatoid arthritis	8.3	1.10 (0.86-1.41)	.436
Metabolic syndrome	8.2	1.01 (0.91-1.13)	.801
Pulmonary	10.4	1.30 (1.15-1.47)	<.001
Nervous system	7.3	1.00 (0.80-1.25)	.979
Uremia or cancer	5.3	0.80 (0.61-1.06)	.125
Psychiatric	9.4	1.03 (0.91-1.16)	.609
Musculoskeletal degeneration	9.1	1.16 (0.99-1.36)	.060
Cardiovascular	6.3	0.84 (0.72-0.99)	.037
Hospital type			
Public	9.3	1.57 (1.19-2.07)	.001
Private	3.0	1.0	
Preoperative medication			
Antiepileptic drugs	8.9	1.10 (0.98-1.24)	.095
Amitriptyline or duloxetine	9.8	1.08 (0.92-1.27)	.332
Weak opiates	10.1	1.40 (1.11-1.77)	.005
Strong opiates	9.2	1.01 (0.77-1.32)	.959
Muscle relaxants	9.6	1.19 (1.07-1.32)	.001
Operation years			
1999-2001	10.6	1.0	.171
2002-2004	11.1	1.11 (0.94-1.32)	.227
2005-2007	11.8	1.26 (1.06-1.50)	.008
2008-2010	9.9	1.16 (0.96-1.39)	.125
2011-2012	8.1	1.20 (0.98-1.48)	.085
2013-2015	5.3	1.24 (1.00-1.54)	.046

CI, confidence interval.

Previous studies have discovered higher rates of reoperation for myelopathy compared with radiculopathy,^{9,23} which may reflect differences in the number of vertebral levels operated. The risk of reoperation has been found to be smaller in longer fusions.^{10,14,15} The degenerative changes are more diffuse at the spondylosis stage,³⁰ possibly predisposing foraminal stenosis patients to the development of sASD. Further, the progression of especially foraminal stenosis has been linked to radicular pain.³⁰ The longer follow-up time may also explain this difference, as 2 small series

of ACDF operations with an over 20-yr follow-up found reoperations in 23% of disc protrusion patients³¹ and 11% of spondylotic myelopathy patients.³² The operative indications in Finland may also favor foraminal stenosis: the incidence of primary surgery has increased most in this diagnosis group.⁷

Most previous series have found either no difference or a higher risk of reoperation for the posterior compared with the anterior techniques (Table 9)^{9,20,21,28}; the discrepancy may be due to the follow-up time, as the differences in the risk of reoperation

TABLE 9. Literature Review of Population-Based Series Describing Rates of Late Reoperations for Degenerative Cervical Spine Disease

Author	Patients and data source	Years, follow-up	Diagnoses and techniques	Reoperation rates	Risk factors for reoperation
All techniques King et al, 2009 ⁹	12 338 patients with degenerative cervical spine disease; from Washington SID ^a	1998–2002, median follow-up 2.3 yr (1–59 mo)	Degenerative cervical spine disease Any technique: 82% ventral, 14% dorsal, 4% combined, 0.1% unspecified Fusion in 87% of the surgeries; 100% of the ventral surgeries and 11% of the dorsal surgeries	5.6% reoperations; 2.5%/yr Ventral surgery: IRR ^b 0.71, fusion: IRR 0.65 Reoperation diagnoses: disc displacement 32%, spondylosis 20%, stenosis 12%, mechanical complication 11%	Higher risk: male gender (IRR 1.17), younger age, herniated disc with myelopathy (IRR 1.32) Lower risk: ventral surgery (IRR 0.82), fusion surgery (IRR 0.75)
Park et al, 2016 ²⁰	9071 patients with cervical radiculopathy or myelopathy; discectomy with anterior fusion, corpectomy, laminectomy with or without fusion or laminoplasty (LMP) as a primary procedure; from Korean HIRA ^c national database	Primary operation in 2009; followed until June 30, 2014; follow-up of 3.5 to 4.5 yr	Cervical radiculopathy or myelopathy ACDF ^d 89.77%; laminectomy with fusion 5.92%; laminoplasty 4.31%	Reoperation rate 3.31% Laminectomy with or without fusion: 12.48% Laminoplasty: 7.93% Discectomy or corpectomy with fusion: 2.48%	Higher risk: laminoplasty (HR ^e 2.4, CI 1.6–3.5), laminectomy with fusion (HR 4.7, CI 2.4–6.2), diabetes (HR 1.8, CI 1.4–2.3), comorbidity, hospital type Lower risk: female gender (HR 0.5, CI 0.34–0.61) Age not a significant risk factor
Puvanarajah et al, 2017 ²¹	55 346 patients undergoing ACDF, corpectomy (ACCF ^f) or PCF ^h for cervical spondylotic myelopathy; Medicare database from the PearlDiver Patient Records Database	2005–2012; follow-up up to 5 yr	1–2-level ACDF, 1–2-level ACCF, 1–2-level PCF, 3 or more levels PCF 63.0% ACDF, 7.8% ACCF, 11.0% 1–2-level PCF, 18.2% 3+ level PCF; the distribution was different between the patients aged 65 to 84 and younger than 65 yr	Younger age group: 1–2-level ACDF 13.8%, 1–2-level PCF 11.8%, 1–2-level ACCF 16.7%, 3+ level PCDF 11.3% Elderly (65 yr or older): ACDF 9.4%, 1–2-level PCF 9.5%, 1–2-level ACCF 10.0%, 3+ level PCDF 9.6%	Higher risk in the younger age group (< 65 yr): ACDF OR 1.56 or ACCF OR 1.75 Both age groups: ACCF No significant difference between ACDF and PCF in either age group
Anterior decompression Kelly et al, 2018 ²²	52 395 patients with single-level degenerative disc disease undergoing ACDF or TDR ⁱ from OSHPD ^k	2003–2010; follow-up up to 5 yr	ACDF or TDR 97.2% ACDF 2.8% TDR	Overall late reoperation rate 2.7/100 patient years No significant difference between ACDF and TDR (HR TDR versus ACDF) 0.86 (95% CI, 0.60–1.23)	Older age, HR 1.01; African-American, HR 1.27 Lower risk: female gender, HR 0.68 Worker's compensation, HR 0.78
Park et al, 2016 ²³	7948 patients operated by ACDF technique for cervical radiculopathy or myelopathy; identified from Korean HIRA national database	Primary operation in 2009, followed until June 30, 2014; minimum follow-up of 4.5 yr; mean follow-up period 4.92 yr	Cervical radiculopathy or myelopathy 82.28% radiculopathy, 17.72% myelopathy	Reoperation rate 2.45% 3.69% in patients with myelopathy; 2.19% in patients with radiculopathy	Higher risk: myelopathy, HR 1.43; diabetes, HR 1.54; hospital types, comorbidity, HR 1.39 Lower risk: female gender, HR 0.40 Age not a significant risk factor
Veeravagu et al, 2014 ²⁴	12 744 patients undergoing single- or multilevel ACDF for any indication, from the MarketScan research Database	2006–2010, minimum follow-up 2 yr, mean follow-up 3.2 (single-level) and 3.1 (multilevel) yr	Any indication	9.1% revisions in single-level and 10.7% revisions in multilevel ACDFs	Multilevel operation, OR 1.1 Greater than 2-level operation, OR 1.27 Hypertension, OR 1.1 Osteoporosis, OR 1.26 Age (10-yr groups), OR 0.90
Wu et al, 2012 ²⁵	19 385 ACDF surgeries; from the National Health Insurance Research Database (NHIRD) of Taiwan	1997–2007; minimum follow-up 1 yr	ACDF	2nd ACDF 2.9%, 3rd ACDF 0.15% Incidence of secondary ACDF 7.6/1000 patient-years (0.8%/yr)	Male gender, HR 1.27 Young age 15- to 39-yr-olds, HR 1.45 40- to 59-yr-olds, HR 1.41 compared to patients aged 60 yr or older

TABLE 9. Continued

Author	Patients and data source	Years, follow-up	Diagnoses and techniques	Reoperation rates	Risk factors for reoperation
Wu et al, 2019 ²⁹	38 149 ACDF surgeries; from the National Health Insurance Research Database (NHIRD) of Taiwan	1998-2013; follow-up until the end of 2013; mean follow-up 6.2 ± 3.9 yr	ACDF	2nd ACDF, 2.9% at the mean of 4.7 yr; incidence 4.64/1000 person-years	Male gender, HR 1.13 Younger age; risk diminishes by each progressively older age group Depression, HR 1.42 Psychoses, HR 1.45
Posterior decompression					
Sayari et al, 2017 ²⁶	6527 patients undergoing single-level posterior foraminotomy from the PearlDiver database	2007-2011; follow-up of 1, 2 or 4 yr	Posterior cervical foraminotomy	8.3% reoperations within 1 yr, 9.8% reoperations within 2 yr and 10.5% within 4 yr	Age under 65 yr; highest in the 50- to 54-yr age group No significant gender difference but a trend towards higher incidence of reoperations in females Regional differences in reoperation rates from 13.5% to 20.8% reoperations at 4 yr follow-up
Veeravagu et al, 2018 ²⁷	2613 patients undergoing cervical laminoplasty from the Thomson Reuters MarketScan Commercial Claims and Encounters and Medicare Supplemental and Coordination of Benefits databases	2007-2014; mean follow-up 2.2 yr	52.4% cervical spondylotic myelopathy, 19.3% cervical spinal stenosis, 10.6% disc disorder with myelopathy, 4.7% spondylosis without myelopathy, 1.9% disc displacement without myelopathy, 1.3% disc degeneration	10.9% reoperations; 4.2% after the first postoperative year Reoperations in 8.9% within first 2 yr 0.2% laminoplasty, 4.5% laminectomy, 4.5% fusion, 0.3% re-fusion	Not analyzed
Anterior versus posterior operation					
Lin et al, 2016 ²⁸	8183 patients undergoing multilevel ACDF or LMP ¹ for cervical degenerative disease; from Taiwan National Health Insurance Research Database	2001-2011; follow-up 1-10 yr	80.7% ACDF; 19.3% LMP	Incidence of reoperations after 1 yr in the LMP group 0.06/100 000 person months and in the ACDF group 0.04/100 000 person months Reoperation rate 0.48%/yr in the ACDF group ACDF group (HR 0.43, 95% CI 0.24-0.77), not in the LMP group	Higher risk: history of osteoarthritis, HR 2.07 in the ACDF group but not in the LMP group; diabetes in the LMP group, HR 3.27 Low risk: age 65 yr or older in the ACDF group (HR 0.43, 95% CI 0.24-0.77), not in the LMP group
Cervical fusion for any indication					
Derman et al, 2016 ⁵	87 042 patients undergoing isolated primary subaxial arthrodesis from New York Department of Health's Statewide Planning and Research Cooperative System database	1997-2012; median follow-up 70 mo, IQR 28-120 mo	All subaxial cervical arthrodeses	Revision rate 7.7%; probability of revision at 16 yr follow-up 12.6% (95% CI, 12.2-13.1%)	Risk factors for revision: age group 35-49 yr or under; Workers' Compensation or Medicare; white or black ethnicity; spinal stenosis HR 1.12, spondylosis HR 1.12, deformity HR 1.32, neoplasm HR 1.61 Anterior approach 13.4%, HR 1.0; posterior approach 7.4%, HR 0.76; circumferential approach 5.2%, HR 0.53 Higher revision risk in longer (3 or more vertebral levels) arthrodesis, HR 1.18; significant only in anterior arthrodesis, HR 1.25

^aSID, Washington State Inpatient Database.

^bIRR, incidence rate ratio.

^cHIRA, Korean Health Insurance Review and Assessment Service.

^dACDF, anterior cervical decompression and fusion.

^eHR, hazard ratio.

^fCI, confidence interval.

^gACCF, anterior cervical corpectomy and fusion.

^hPCF, posterior cervical foraminotomy.

ⁱOR, odds ratio.

^jTDR, total disc replacement.

^kOSHPD, California's Office of Statewide Health Planning and Development Database.

^lLMP, laminoplasty.

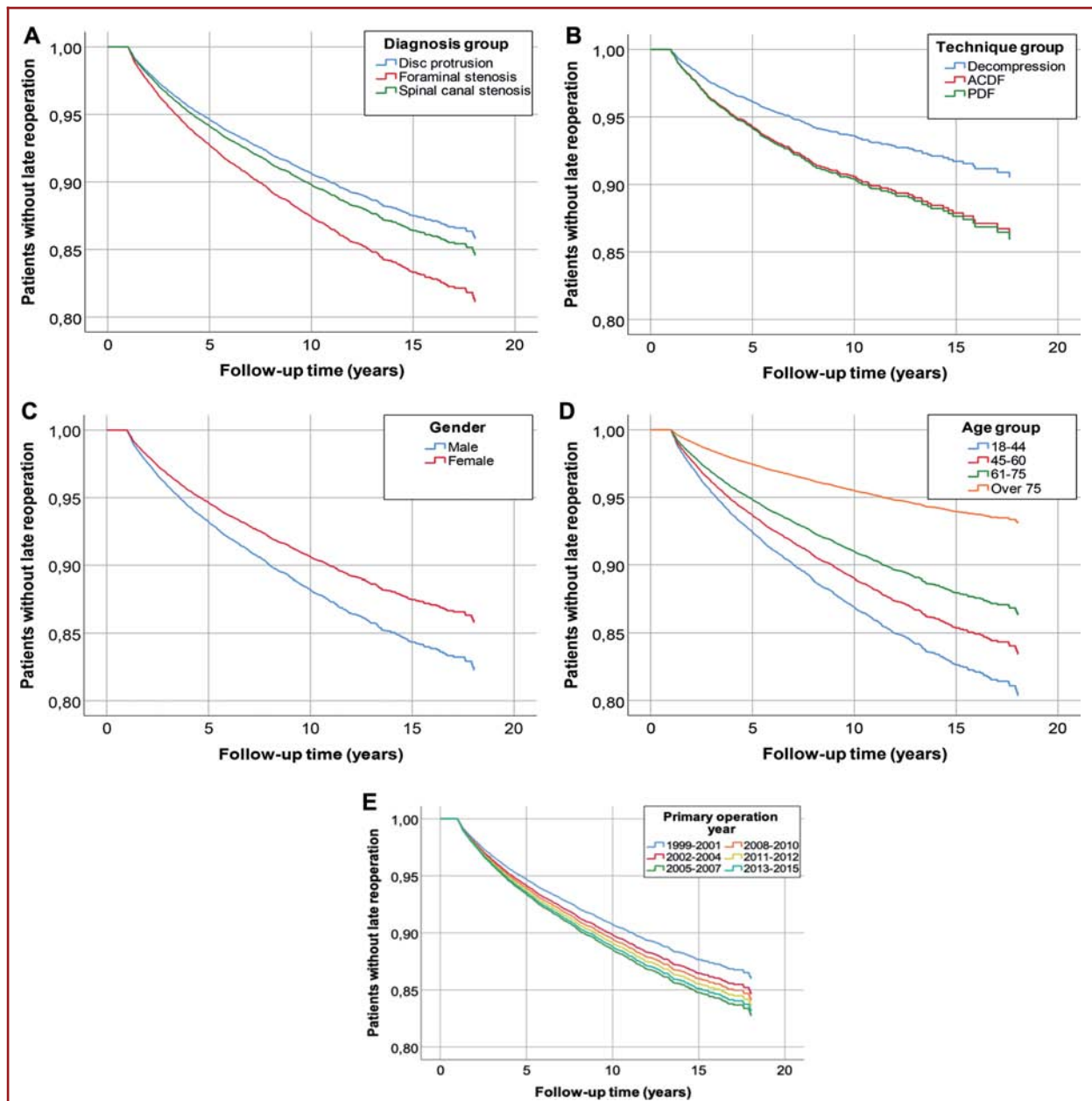
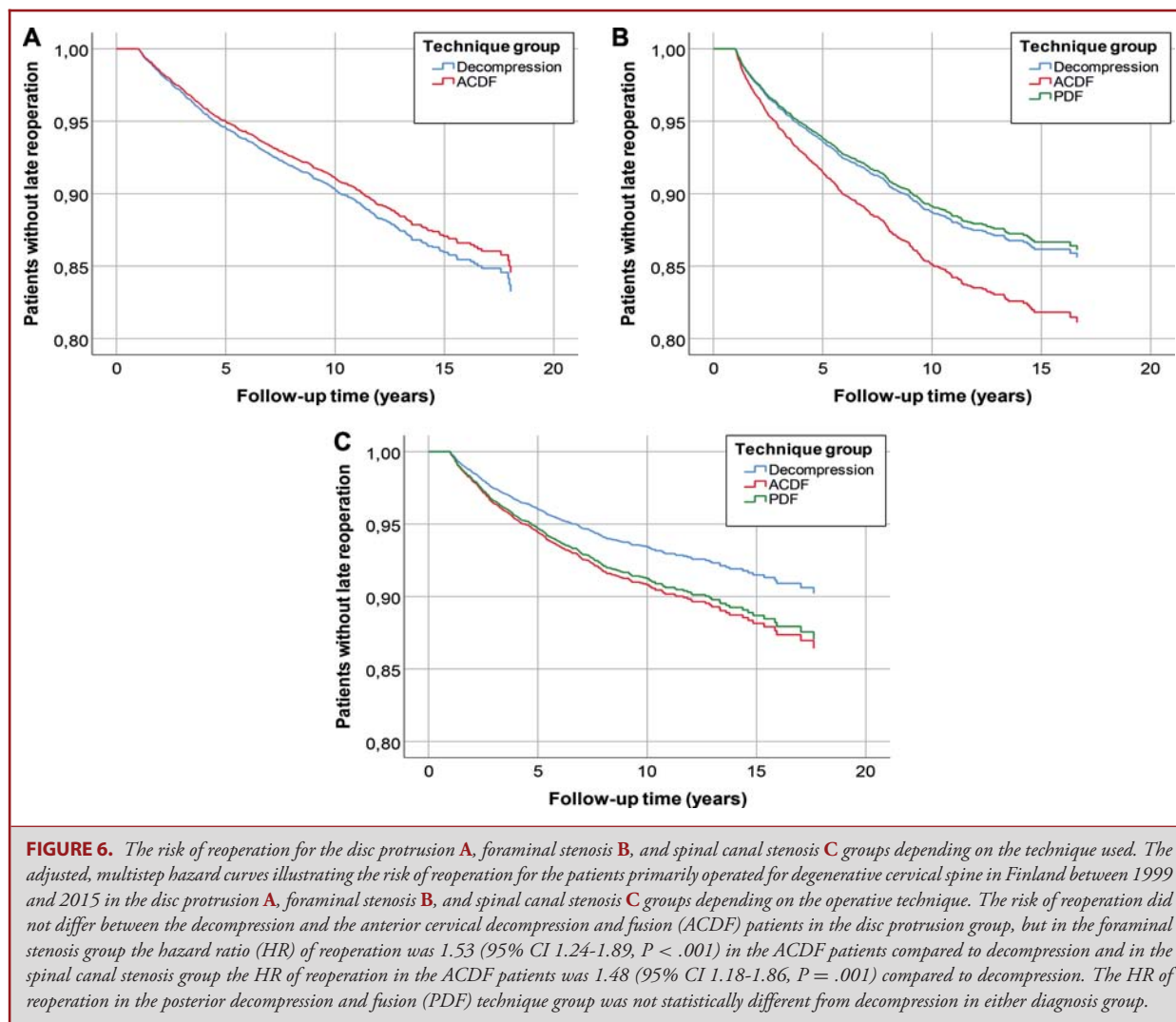


FIGURE 5. The risk of reoperation within the diagnosis **A**, technique **B**, gender **C**, age **D**, and primary operation year **E** groups. The adjusted multistep hazard curves illustrating the risk of reoperation for the patients primarily operated for degenerative cervical spine disease in Finland between 1999 and 2015 within the diagnosis groups **A**, within the technique groups **B**, between the genders **C**, within the age groups **D**, and within the primary operation year groups **E**. The risk of reoperation was 38% higher in the foraminal stenosis group compared with the disc protrusion group ($P < .001$), while the difference between the spinal canal stenosis and disc protrusion groups was not significant. The anterior cervical decompression and fusion patients (ACDF) had a 33% higher risk of reoperation compared with decompression patients ($P < .001$), while the difference between the posterior decompression and fusion (PDF) and decompression groups was not significant. Female patients had a 27% lower risk of reoperation compared with male patients ($P < .001$). The risk of reoperation was the highest in the youngest age group and lower with each consecutive age group. The risk of reoperation in the oldest age group was only 33% of the risk in the youngest age group. Compared to the years 1999-2001, the risk of reoperation was significantly higher between 2005-2007 and 2013-2015 only. The preoperative use of weak opioids (codeine or tramadol) increased the risk of reoperation by 40%, while the use of strong opioids (morphine, hydromorphone, oxycodone or fentanyl) did not influence the reoperation risk. Patients taking muscle relaxants preoperatively had a 19% higher risk of reoperation compared to those not taking muscle relaxants. Patients with pulmonary comorbidities had a higher and patient with cardiovascular comorbidities a lower risk of reoperation.



between the techniques appear to increase with time. A 16-yr follow-up of cervical fusion patients found a higher probability of revision in anterior versus posterior arthrodesis.¹⁵ The increased risk of reoperation after ACDF compared to decompression in foraminal and spinal stenosis, but not disc protrusion patients, may stem from differences in the extent of decompression, as the posterior approach may cover more segments than ACDF³³ or yield a better decompression of the foramen. There may also be differences in the patient populations that were not controlled for, eg, the curvature of the cervical spine, which would influence both the choice of technique and risk of reoperation.^{16,30} A recent meta-analysis, with relatively short follow-up times, found greater improvement of radicular symptoms after foraminotomy, yet no difference in the reoperation rates between foraminotomy and ACDF.³⁴

Most series have detected a higher risk of reoperation in males.^{9,20,22,25} The degenerative changes progress more in

asymptomatic men than in women³⁵ and become more prevalent in men compared to women with increasing age.³⁶ Younger age has consistently been identified as a risk factor,^{9,15,24,25,28} which probably represents differences in the stage of the degeneration³⁵ and possibly patient selection. The smoking data for our patients were unavailable; smoking might explain the increased reoperation risk in the patients with pulmonary comorbidities, as the group included chronic obstructive pulmonary disease.^{13,17,37} Higher complication risk and patient selection may explain the lower reoperation risk in the patients with cardiovascular comorbidities. Kalakoti et al³⁸ also found 21% higher odds of reoperation in patients with preoperative opioid use. The increased risk of reoperation in the patients taking muscle relaxants preoperatively is a novel finding.

The risk of reoperation did not increase between 1999 and 2015, even though the age- and sex-adjusted rate of primary operations for DCSD increased by 36% and the use of ACDF

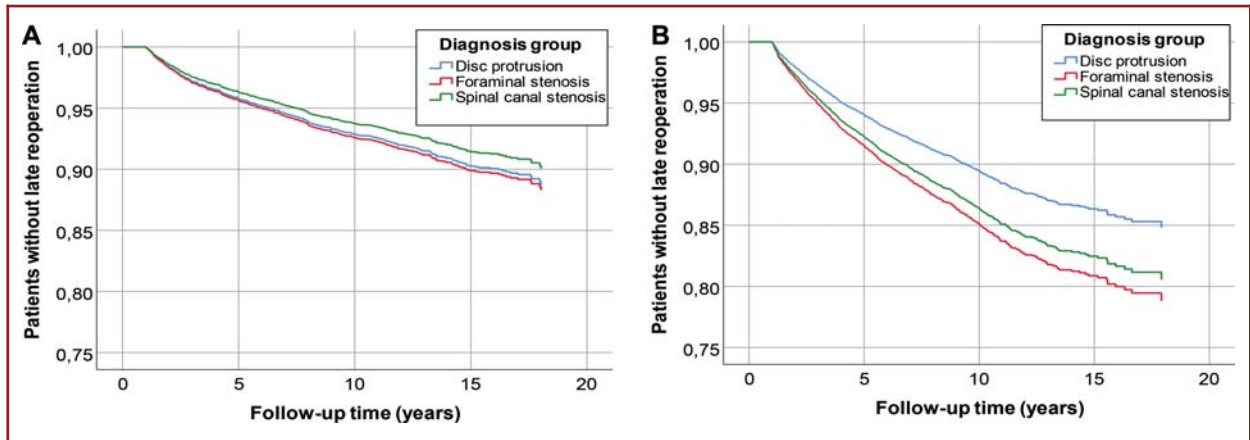


FIGURE 7. The risk of reoperation in the decompression **A** and anterior cervical decompression and fusion **B** and groups depending on the diagnosis. The adjusted, multi-step bazard curves illustrating the risk of reoperation for the patients primarily operated for degenerative cervical spine disease in Finland between 1999 and 2015 across the technique groups depending on the diagnosis: the decompression patients **A** and anterior cervical decompression and fusion (ACDF) patients **B**. In the ACDF group, the risk of reoperation was significantly higher in both the foraminal stenosis patients (HR 1.52, 95% CI 1.34-1.72, $P < .001$) and spinal canal stenosis patients (HR 1.23, 95% CI 1.03-1.45, $P = .019$) compared to disc protrusion patients. In the decompression and PDF groups, the risk of reoperation was not statistically significantly different between the diagnosis groups (there were only 19 reoperations in the PDF group, bazard curve not shown). Note the difference in scaling to Figures 5 and 6.

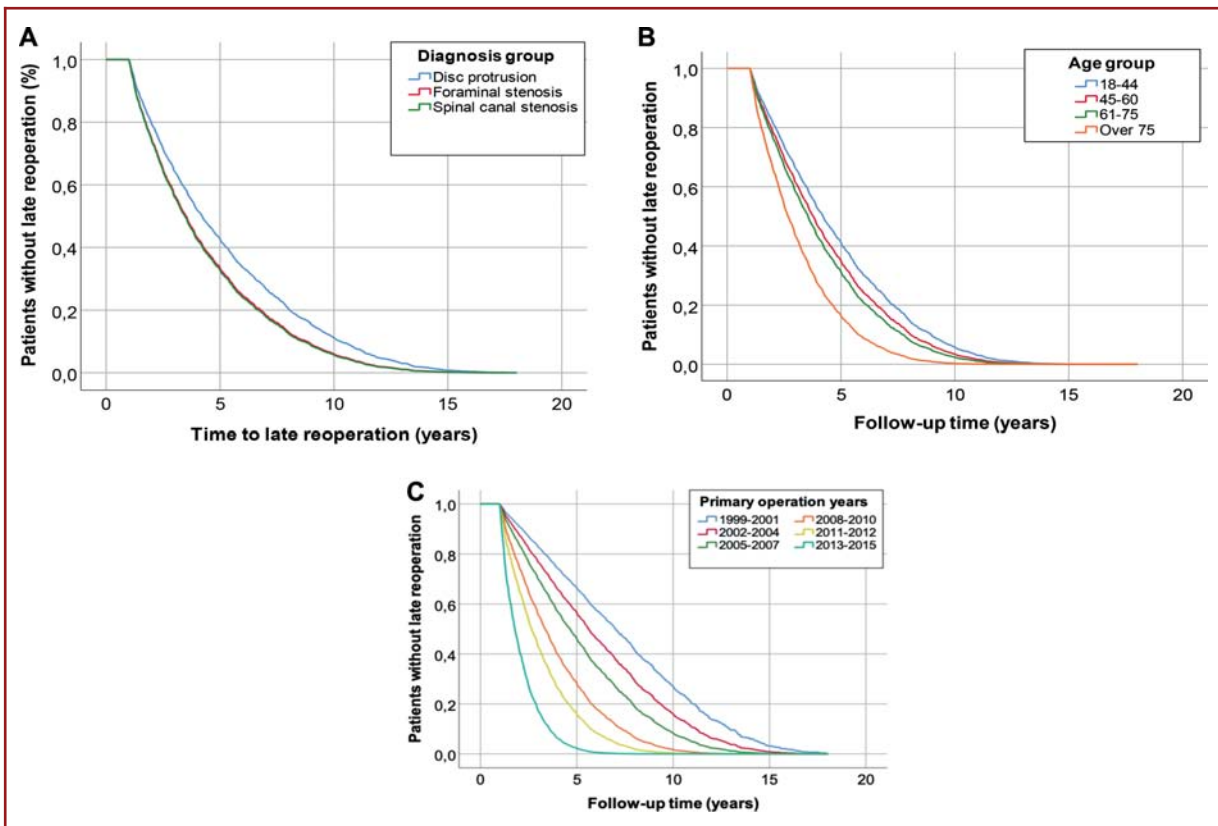


FIGURE 8. The factors affecting the time to reoperation: diagnosis **A**, age group **B**, and operation year **C**. The adjusted, multistep bazard curves illustrating the time to late reoperation for the patients primarily operated for degenerative cervical spine disease in Finland between 1999 and 2015 by diagnosis group **A**, patient age group **B**, and operation year range **C**. The time to late reoperation decreased from the youngest to the oldest age group and from the earlier to the later time periods. Foraminal stenosis patients and spinal canal stenosis patients underwent reoperations at an earlier time point compared to disc protrusion patients. The operative technique did not affect the time to late reoperation in the multivariate analysis.

increased to over 80% of the primary operations during the same period.^{7,19} As most of the reoperations occurred within the first 6 postoperative years, we presume that the follow-up was sufficiently long to analyze the trends in the reoperations. Such patient-level time trends in reoperations have not been assessed previously. In the US, the incidence of cervical spine fusion reoperations has increased more rapidly than the incidence of primary operations.¹³

Generalizability

The healthcare system in Finland is tax funded; the decision to operate and the technique are decided solely by the surgeon and the patient. The surgeons' salary is independent of the number or type of operations they perform. Over 90% of the operations occurred in teaching hospitals. These factors may influence the reoperation rates. There may be differences between populations in the prevalence of DCSD or the progression of the degenerative changes.

CONCLUSION

We assessed the occurrence, risk factors and the time trends of late reoperations in a longitudinal population-based survey of every patient operated for DCSD in Finland between 1999 and 2015. The principal findings were that the annual reoperation risk increased up to 6 yr and declined thereafter and that the patients operated for foraminal stenosis were especially likely to undergo a reoperation. ACDF technique increased the risk of reoperation by 50% compared with decompression in spondylosis patients, which may be explained by differences in the number of vertebral levels operated. The risk of reoperation developed differently depending on the technique with extending follow-up. These findings underline the importance of a long follow-up for a comparison between the techniques relative to ASD as well as for estimating the overall risk of reoperation. In spondylosis patients, with diffuse degeneration, the high rate of reoperations should be considered when deciding on the technique and the extent of decompression.

Funding

The Hospital district of Helsinki and Uusimaa has granted the study group and the responsible investigator Prof. Antti Malmivaara State research funding through the Orton Research Foundation (grant number 9310/403).

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article. The sponsors had no role in the design or conduct of this research.

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Acknowledgments

We would like to thank Mari Koivisto and Tero Vahlberg for their help with the statistical analyses, Elizabeth Nyman for the language editing, Seija Puro for editing Figure 1 and Emmi Kyytsönen for designing the icons for the visual abstract.

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Supplemental Digital Content 1. Table. The diagnosis (the 10th revision of the World Health Organization International Classification of Diseases) and operative (Nordic Medico-Statistical Committee classification of surgical procedures) codes used to identify complications from the Finnish Hospital Discharge Register.

Supplemental Digital Content 2. Table. The Social Insurance Institute special medication reimbursement codes and anatomical therapeutic chemical codes used to record the use of prescription medications.

Supplemental Digital Content 3. Table. The comorbidity data on all the patients operated for degenerative cervical spine disease in Finland between 1999 and 2015.

Supplemental Digital Content 4. Table. The rate of late reoperations among patients operated each consecutive year for degenerative cervical spine disease in Finland between 1999 and 2015.
