Eur Spine J (2013) 22:977–984
DOI 10.1007/s00586-012-2479-5

ORIGINAL ARTICLE

Long-term health care utilisation and costs after spinal fusion in elderly patients

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Received: 30 January 2012 / Revised: 9 May 2012 / Accepted: 5 August 2012 / Published online: 21 August 2012

Abstract
Purpose Spinal fusion surgery rates in the elderly are increasing. Cost effectiveness analyses with relatively short-length follow-up have been performed. But the long-term effects in terms of health care use are largely unknown. The aim of the present study was to describe the long-term consequences of spinal fusion surgery in elderly patients on health care use and costs using a health care system perspective.
Methods 194 patients undergoing spinal fusion between 2001 and 2005 (70 men, 124 women) with a mean age of 70 years (range 59–88) at surgery were included. Average length of follow-up was 6.2 years (range 0.3–9.0 years). Data on resource utilisation and costs were obtained from national registers providing complete coverage of all reimbursed contacts with primary- and secondary health care providers. Data were available from 3 years prior fusion surgery until the end of 2009.
Results Use of hospital-based health care increased in the year prior to and the first year following surgery. Hereafter it normalised to the level of the background population and was mainly composed of diseases unrelated to the spine. In contrast, the use of primary health care appeared to increase immediately after surgery and continued to increase to a level that significantly exceeded that of the background population. It could be demonstrated that the increase was mainly due to an increasing number of general practitioner consultations.
Conclusion Spinal fusion surgery in older patients does not generate excess hospital-based health care use in the longer term as compared with the background population, but primary care use increases.

Keywords Spinal stenosis · Spinal fusion · Elderly · Costs · Health care utilisation

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Introduction

The estimated percentage of people above 60 years in developed countries is expected to increase steadily towards 2050 [28]. Thus an increased number of people will experience age-associated diseases. Within the field of spine surgery one of the most common diagnoses in the elderly is spinal stenosis. Several treatment options exist and although the choice of procedure is still debatable [5], there is evidence for the effect of decompression of neural structures with or without concomitant fusion [1, 19, 29]. Studies have shown the improvement in general health to be comparable with other well-established orthopaedic procedures such as hip and knee replacements [23].

Recent studies have shown an increase in spinal surgery procedures during the past decades [11, 22]. Furthermore there has been a shift towards a use of more complex and expensive procedures over less complex and less costly procedures [12]. This has raised concerns in health care managements about rising expenditures, not least in combination with the awareness of the demographic development. This calls for evaluation of the effect of surgery, not only in terms of quality of life of the patients, but also in terms of the economic consequences for health care systems [7].

Although cost-effectiveness studies of spinal surgery in elderly patients have been performed, they generally suffer from relatively short follow-up and an analytical perspective limited to hospital-based health care and/or spine-related morbidity [8, 21, 27]. Furthermore similar data from European studies are lacking. Long-term clinical studies have demonstrated that the full effects of spine surgery may not be manifest already after 2 years and that the provision of specialised treatment in the secondary health care sector may affect the resource use in other sectors, such as the primary care sector [24]. In fact, recent guidelines in, e.g. the UK seem to favour a modelling approach over evaluations conducted alongside clinical trials to inform priority-setting in the National Health Service [20]. The practicality of such modelling studies, however, relies on the availability of valid estimates of long-term consequences. Some evidence is available for the clinical efficacy but the literature on the consequences in terms of costs appears to be lacking. The aim of the present study was therefore to describe the long-term consequences of spinal fusion surgery on health care use and costs in the elderly patients.

Materials and methods

Patient population

A total of 194 patients were included in the present investigation. They all underwent lumbar spinal fusion surgery in the period from 2001 to 2005 at an age of 60 years or older. They were recruited from two previously reported cohorts. The first cohort consisted of 100 patients undergoing uninstrumented fusion with or without direct current-stimulation as part of a clinical trial [3]. Inclusion criteria were spinal stenosis surgery, where additional fusion was deemed necessary due to instability or the need for extensive decompression, or a significant degree of back pain indicating that additional fusion could be beneficial. The study had no upper age limit, grade 1–2 spondylolisthesis and minor degenerative scoliosis cases were allowed in the study, and manifest osteoporosis was not an exclusion criterion. Patients with major deformity or with spinal cord compression and back pain due to metastasis, infection or recent trauma were excluded. All patients underwent uninstrumented lumbar spinal fusion using fresh frozen allograft with or without direct-current stimulation. The second cohort was an observational cohort of 94 patients who underwent either uninstrumented spinal fusion (51 patients) or fusion using pedicle screw instrumentation (43 patients) [4]. Reasons for surgery in this cohort were the same as in the other group and all fusions were performed using fresh-frozen allograft. Patient demographics of the combined cohort are shown in Table 1. The average length of follow-up was 6.15 years, ranging from 0.29 to 8.96 years. Twenty-eight patients died during follow-up and one emigrated. Number of patients completing follow-up each year after surgery is seen in Fig. 1.

Preoperative and postoperative comorbidity was calculated using the index described by Charlson et al. [9]. It was calculated for each patient using the main diagnosis for all hospital contacts (in and outpatient) from the last 3 years prior to their fusion procedure and for the full follow-up period after surgery, respectively. As data on primary health care use do not provide disease codes the index has to be calculated using hospital contact data, patients with diseases successfully managed by the general practitioner, without hospital contacts, will receive a Charlson index of zero.

Costing

The study adapted a health care system perspective including all activity related to primary and hospital-based health care. Register data at the individual patient level were acquired from different registers to establish annual

Table 1 Patient characteristics

Patient demographics	Total
Gender (male/female)	70/124
Age at surgery (years)	69.9 (6.3/59–88)
Length of follow-up (years)	6.2 (1.7/0.3–9.0)
Diagnosis	
Degenerative	11
Spinal stenosis	119
Stenosis + deg. olisthesis	44
Stenosis + deg. scoliosis	20
Previous surgery	
Discectomy	25
Partial/total laminectomy	14
Other	2
Preoperative Charlson index	
0	137
1	42
2	11
3	2
4	2
Charlson index during follow-up	
0	83
1	43
2	27
3	14
4 or above (range 4–10)	27

Values are mean (SD/range) or number

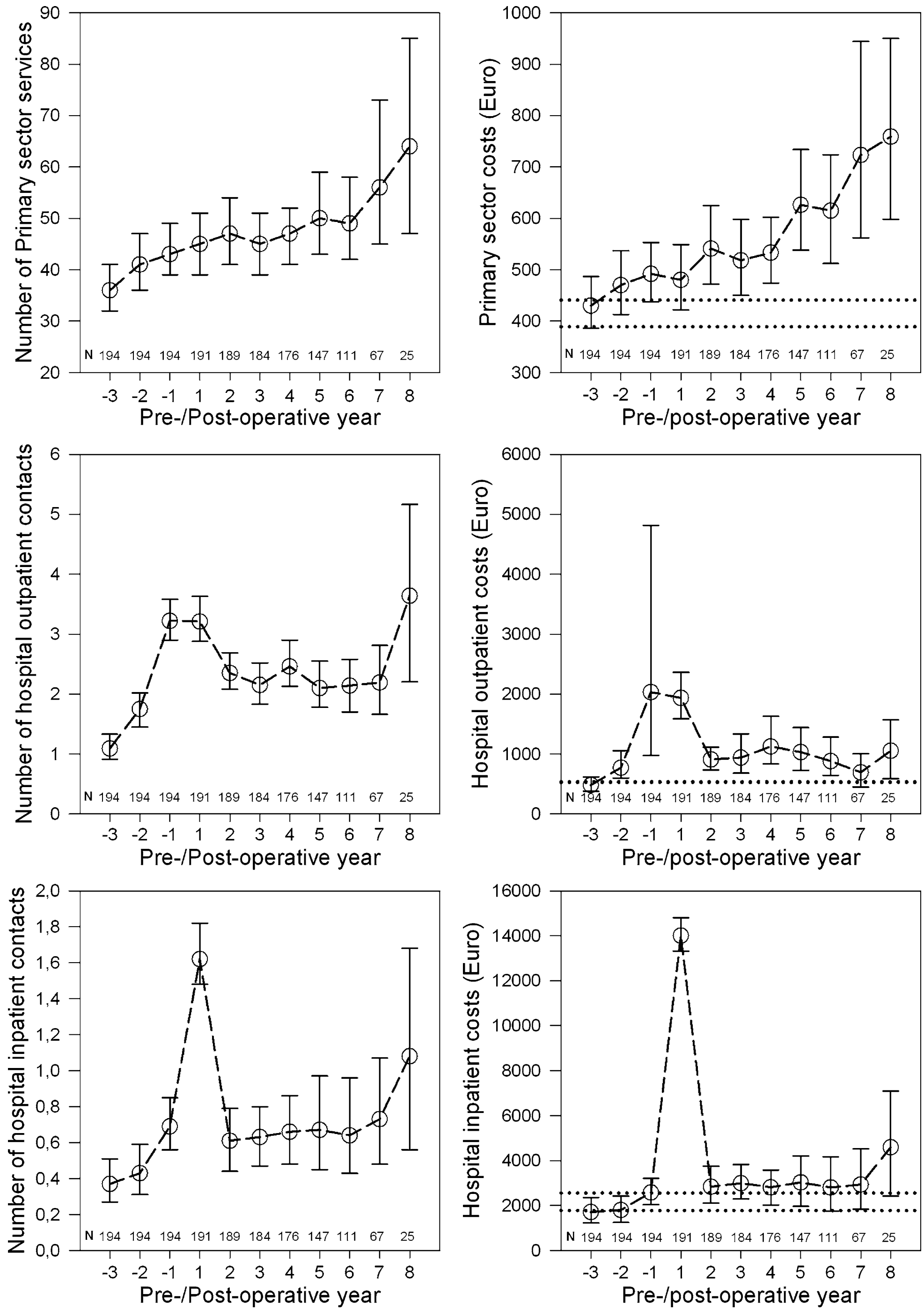

Fig. 1 Health care resource utilisation and costs prior to and after the spinal fusion procedure. Values are means with 95 % bias-corrected bootstrapped confidence intervals. *N* along the *x*-axis indicates number of patients completing follow-up for that respective year. Reference lines in cost graphs are average costs in the background population, with the *upper limit* representing the age group 75–84 years and the *lower limit* representing the age group 65–74 years (obtained from Sørensen and Søgaard [25])

rates of resource use (number of contacts/services) and costs (2010-€) for individual cost categories of primary and secondary health care use as well as for individual diagnostic entities. The only exception was use and cost of nursing homes, which is not available in national registries. All resource use and costs were collected from 3 years before surgery to the end of 2009. All costs were inflated to 2010-€ using the general consumer price index. As all registers are nationwide and covers all service providers, the only loss to follow-up is due to the patient dying or migrating. The following briefly describes the nature of the registries and the method used for valuing resource use.

Primary health care

All contacts to and services delivered by general practitioners, medical specialists, physiotherapists, psychologists, or chiropractors are recorded uniquely per patient in

The National Health Insurance Service Registry (run by the Danish National Health Service) [2]. These were valued using tariffs of the collective agreements between the Danish National Health Service and the societies of medical specialists or therapists.

Secondary health care

All hospital-based service utilisation is recorded uniquely per patient in The National Patient Registry (run by the Danish National Health Service) as well as information about the diagnosis-related-grouping (DRG) tariff used for reimbursement of the hospitals [18]. The variable with the DRG tariffs, however, suffered missing data for the years 2001–2004 and the available data for the years 2005–2009 was therefore used to generate an algorithm for valuing the resource use. Since the algorithm is restricted within this relatively homogeneous study population, it was considered to be more accurate in reflecting true costs than the national averages reflected in the DRG tariffs. Rather than imputing only the years 2001–2004 the algorithm was used to value all hospital-based service use. The item costs of the algorithm are shown in Table 2.

Statistical analysis

Actual values of the individual patient's resource use for each year are presented as means with 95 % bias-corrected confidence intervals obtained using a bootstrapping approach. In this case, patients who did not contribute with full follow-up in the relevant year were excluded. For comparison with the background population reference values were obtained from Sørensen and Søgaard [25], with the upper limit being the average cost in the age group 75–84 years (best comparison for the study cohort at the end of follow-up) and the lower limit the average cost in the age group 65–74 years (best comparison for the study cohort by time of study entry). In order to incorporate all available follow-up data, a population-based approach was used, in which incidence rates for utilisation and costs were calculated using poisson regression with 95 % bias-corrected confidence intervals obtained using bootstrapping. In this analysis all observations until death or censoring were included. Follow-up was calculated from time of surgery to time of death/study end; preoperatively it was full 3 years for all patients. All analyses were carried out using Stata Intercooled for Windows version 12.

Results

The overall use of primary and secondary care for elderly spinal fusion patients over the course of time is shown in Fig. 1. An increase in number of contacts to and services delivered by primary care providers is seen after surgery, with an increase over the years. This was reflected in the costs, which followed as expected. This finding was mainly due to an increased use of the general practitioner (Tables 3, 4). It was also evident that this increased usage resulted in higher costs as compared with the background population. The number of contacts with hospital-based health care appeared to slightly increase after surgery, but not for spinal conditions. Surgery had the largest impact on utilisation in the first 2 years after surgery, where after cardiovascular, respiratory and other diseases constituted a far larger part. Number of outpatient contacts was highest in the year before surgery and the year following surgery; after this it declined to a level with approximately two visits a year (Fig. 1). Importantly, we could not observe an increase in the rate of visits due to spinal or musculoskeletal disorders, but a wide variety of other diseases (Table 3). The associated costs were only marginally higher than the background population. The number of inpatient admissions was stable with a peak at the year of surgery reflecting that all patients were admitted for the fusion procedure (Fig. 1). No negative effect of surgery, with respect to an increase in number of admissions, was seen, and the associated costs, except for the fusion procedure, were at level with those observed in the background population.

Table 2 Item costs used for valuing the observed health care service utilisation (2010-€)

Procedure	Inpatient	Outpatient
Spine		
Decompression	5,642	NA
Uninstrumented fusion	10,002	NA
Instrumented fusion	15,332	NA
Other spine	7,493	5,486
Orthopaedic		
Upper extremity	6,749	1,250
Hip	9,286	NA
Knee (+lower extremity)	8,082	1,678
Surgery		
Abdominal	6,950	684
Heart/vascular	9,469	1,026
Other surgery	4,865	677
Various		
Endoscopy	3,215	592
Radiology	2,831	212
Other	5,818	285
None[a]	2,670	147

NA not applicable

[a] If no procedure is performed this is the cost for one outpatient visit and 1 day of admission to hospital, respectively

Table 3 Utilisation of health care before and after fusion

	3–0 years prior surgery	0–1 year after surgery	2–4 years after surgery	5–9 years after surgery
Primary health care				
General practitioner	23 (21–26)	28 (25–31)	28 (25–31)	31 (28–34)
Consultation	7.9 (7.1–9.1)	8.0 (7.1–9.0)	8.7 (7.7–9.9)	10 (8.7–11)
Telephone consultation	10 (9.0–12)	13 (12–15)	12 (11–14)	12 (10–14)
Blood sampling	1.2 (0.97–1.5)	1.3 (1.0–1.7)	1.7 (1.4–2.0)	1.9 (1.6–2.3)
Other	3.6 (3,1–4.2)	5.6 (4.7–6.7)	5.8 (5.0–6.49)	7.0 (6.2–8.1)
Physiotherapy	10 (7.5–13)	11 (7.5–16)	12 (8.5–18)	13 (8.0–19)
Practising specialist	2.4 (2.1–2.9)	2.2 (1.7–2.9)	2.5 (2.1–3.0)	2.9 (2.4–3.5)
Dentist	3.3 (2.9–3.7)	2.8 (2.3–3.2)	3.4 (3.0–3.9)	3.4 (2.9–4.0)
Other	1.2 (0.93–1.6)	0.72 (0.41–1.1)	0.78 (0.49–1.2)	0.73 (0.43–1.2)
Total	40 (36–45)	45 (39–50)	47 (42–53)	51 (44–58)
Hospital inpatient				
Spinal disorder	0.15 (0.12–0.19)	1.2 (1.1–1.3)	0.11 (0.079–0.14)	0.043 (0.021–0.074)
Other musculoskeletal disorder	0.084 (0.055–0.12)	0.068 (0.031–0.12)	0.070 (0.047–0.098)	0.083 (0.049–0.13)
Cardiovascular/respiratory disorder	0.13 (0.086–0.18)	0.20 (0.12–0.31)	0.23 (0.16–0.32)	0.29 (0.20–0.44)
Other	0.13 (0.089–0.17)	0.22 (0.14–0.33)	0.27 (0.21–0.34)	0.34 (0.27–0.43)
Total	0.50 (0.42–0.59)	1.7 (1.5–1.9)	0.68 (0.56–0.81)	0.76 (0.61–0.94)
Hospital outpatient				
Spinal disorder	0.68 (0.62–0.74)	1.1 (1.0–1.3)	0.21 (0.16–0.26)	0.14 (0.10–0.20)
Other musculoskeletal disorder	0.22 (0.17–0.28)	0.18 (0.11–0.24)	0.18 (0.14–0.24)	0.22 (0.15–0.28)
Cardiovascular/respiratory disorder	0.14 (0.10–0.19)	0.17 (0.099–0.24)	0.22 (0.17–0.29)	0.21 (0.16–0.28)
Other	0.98 (0.85–1.1)	1.8 (1.5–2.1)	1.8 (1.6–2.0)	1.8 (1.5–2.0)
Total	2.0 (1.8–2.3)	3.2 (2.9–3.7)	2.4 (2.2–2.7)	2.3 (2.1–2.6)
All health care use	43 (39–48)	50 (44–56)	50 (45–57)	54 (47–62)
Total observation time (person years)	582	192	559	443

Values are rates of service use per person year (95 % confidence intervals). All rates are number of services/1 person year (95 % CI)

In Tables 3 and 4, rates of service use and costs, respectively, are shown for detailed categories. In addition to the observed increase in the use of primary care, the rate of admissions to hospital-based health care due to cardiovascular, respiratory and other disorders rose, whereas it fell considerably when spinal disorders was the cause (Table 3). This was also reflected in associated costs, which were considerably higher in former categories (Table 4). Among patients with a history of previous spine surgery comorbidity was present in 29 %, which was no different from among those without a history of previous spine surgery, in which it was 32 % ($p = 0.713$). In general, neither previous spine surgery nor comorbidity was associated with increased cost produced from hospital utilisation. Primary health care costs, however, tended to be slightly higher in both groups, most pronounced in the group of patients with comorbidity (data not shown). Patients selected for surgery in the non-university spine centres had slightly lower rates of primary care use in the 3 years preceding surgery (36 services/year against 41 services/year, $p = 0.304$) and lower rates of hospital-based health care utilisation (Inpatient: 0.43 services/year against 0.51 services/year, $p = 0.422$. Outpatient: 1.56 services/year against 2.14 services/year, $p = 0.014$).

Discussion

This study has sought to fill a gap in the current literature by investigating long-term consequences of spinal fusion surgery on the general health care use in elderly patients. Two main results emerged: that the spine-related health care use in the longer term normalises to a level that is lower than before surgery and that the general health care use of these patients compares well to that of the general population in terms of specialised care, but not in terms of primary care, where the fused patients end up consuming relatively more care.

The observed increase in primary health care use could have several causes. As the cohort is selected on the fact that they underwent spinal surgery, mainly due to spinal stenosis, it might be speculated that they have higher prevalence of other musculoskeletal problems than the background population, leading to a higher usage of

Table 4 Cost of health care utilisation before and after fusion

	3–0 years prior surgery	0–1 year after surgery	2–4 years after surgery	5–9 years after surgery
Primary health care				
General practitioner	226 (201–255)	269 (239–302)	289 (259–324)	348 (306–393)
Consultation	137 (120–159)	148 (129–170)	157 (139–179)	184 (159–217)
Telephone consultation	42 (37–49)	55 (49–62)	48 (42–55)	47 (41–55)
Blood sampling	12 (10–15)	16 (12–20)	19 (16–23)	21 (18–24)
Other	36 (30–42)	53 (43–63)	66 (57–77)	96 (84–110)
Physiotherapy	71 (47–101)	71 (41–106)	70 (45–107)	95 (52–155)
Practising specialist	88 (73–107)	85 (60–125)	116 (91–147)	133 (104–166)
Dentist	45 (39–52)	39 (33–47)	49 (42–58)	47 (40–56)
Other	32 (26–40)	15 (9–23)	17 (11–23)	24 (16–34)
Total	463 (419–522)	479 (424–544)	541 (486–607)	647 (564–735)
Hospital inpatient				
Spinal disorder	524 (401–670)	12,314 (11,690–12,919)	680 (475–895)	300 (139–515)
Other musculoskeletal disorder	458 (303–665)	415 (182–751)	395 (250–566)	471 (282–710)
Cardiovascular/respiratory disorder	501 (330–724)	804 (440–1,293)	841 (605–1,156)	990 (679–1,409)
Other	540 (367–745)	933 (570–1,370)	1,108 (846–1,408)	1,546 (1,181–1,969)
Total	2,023 (1,683–2,411)	14,466 (13,603–15,415)	3,024 (2,535–3,578)	3,307 (2,665–4,067)
Hospital outpatient				
Spinal disorder	214 (185–261)	1,034 (766–1,446)	107 (69–164)	52 (23–123)
Other musculoskeletal disorder	438 (86–1,370)	135 (46–303)	70 (50–96)	78 (52–110)
Cardiovascular/respiratory disorder	92 (50–153)	77 (41–128)	122 (70–223)	167 (74–361)
Other	350 (293–427)	711 (560–908)	697 (571–892)	648 (530–778)
Total	1,095 (716–1,953)	1,957 (1,603–2,372)	998 (841–1,212)	945 (772–1,207)
All health care cost	3,581 (2,996–4,579)	16,902 (15,846–17,925)	4,563 (3,961–5,183)	4,899 (4,144–5,813)
Total observation time (person years)	582	192	559	443

Values are rates of total costs (2010-€) per person year (95 % confidence intervals). All rates are costs (2010-€)/1 person year (95 % CI)

primary care. This is supported by other studies. A recent Canadian survey found increased health care utilisation in people with back disorders [17], and using Medicare data, Chen et al. [10] found payment for spinal stenosis patients to be higher than the average. Another cause could be selection of relatively healthy patients for surgery as a large part participated in a clinical trial. The majority of the current study population (79 %) was included from a university spine centre and represented almost all patients above 60 years undergoing fusion for lumbar degenerative disease in the selected period. Also those not involved in the trial but fulfilling the same criteria were included. Furthermore, those patients tended to consume more care compared with patients included outside this centre; thus selection of healthy patients for the study is possible, but, we believe, not very influential. The process could, however, also work the other way round. Kim et al. [15] found patients, who underwent spinal stenosis surgery, to have lower mortality than the background population and also that fusion patients had lower mortality at long-term follow-up than non-fusion patients. They suggested that improved cardiovascular fitness from improved walking/physical performance could be a cause. This could also lead to a selection bias, with respect to the comparison with the background population, as fusion patients might be healthy enough to be treated by primary care providers and avoid use of hospital-based health care.

We did not observe any significant increase in need of secondary/revision surgery in this cohort of elderly patients, which has been the concern of several other papers [8, 12, 14]. This could have several explanations. One could be differences in patient selection, as this trend generally has been reported in papers based on data from the US. But as long as there are no data on this particular patient group from other European countries we do not know the extent to which observations from the current study is due to differences in patient selection and choice of type of surgery. Another explanation to our findings could be that, generally, the fusion procedure in these elderly patients is selected as a final treatment, with no more surgical offers existing beyond this procedure. This notion is supported by the substantial number of patients, who had a prior spine procedure performed (mainly discectomies or laminotomies). But it might also be that the result of fusion surgery is more stable over time, thereby offering less need for secondary surgeries. One study on decompressive surgery showed a significant 23 % rate of reoperation in a 7- to 10-year perspective [13]. We did not find pre-existing co-morbidity to severely increase use and costs of hospital based care. But as we rely on register data on hospital contacts there is a risk of underestimating co-morbidity managed by the general practitioner. Such unknown co-morbidity would tend to bias our results towards co-morbidity having no effect on utilisation of hospital based care.

One of the major strengths of the current study is the long-term follow-up, as the majority of cost-effectiveness studies on spinal surgery in this patient population have not gone beyond 2 years of follow-up [8, 21, 26]. Kuntz et al. [16] provided 10-year data, but this was done using a Markov-model, with input based on older data from different descriptive studies with varying follow-up time. Another strength in the current study is the completeness of the registered data, as the data cover all hospitals in the whole country. Even though misclassification might occur, data from the national registers have been shown to have good validity, and it seems reasonable that misclassification is negligible within the wide categories used in the current study [2, 18]. Although our valuation of hospital services was based on a small subsample due to register problems, the consumed units are not subject to change, and it is therefore very unlikely that smaller differences in costs for each procedure will significantly affect the general interpretation of the results.

Based on the data from this study it seems that surgery for spinal stenosis leads to a heavier use and increased costs during the first two years after surgery, where after other diseases seem to be cost drivers. It is not possible to determine whether this is due to unwanted side effects of fusion surgery, or due to other factors. One limitation of the current study is that tertiary health care resource use (nursing home, extra social services provided, etc.) was not included. Deyo et al. [12] found a twice as high rate of discharges to a nursing facility in older patients undergoing fusion for spinal stenosis as compared with those only undergoing decompression, but did not report the associated costs. Generally, very little is known about the costs of tertiary health care and we cannot draw conclusions on the effect of surgery on overall expenditure used on care. The most important message from this study is that spinal fusion surgery in the elderly patients is not necessarily associated with a subsequent need for additional treatment and reoperation and thus costly use of hospital-based health care in a long-term perspective. This is an important finding in relation to the critique of trial-based cost-effectiveness studies regarding limited follow-up time, which might not be justified. As ongoing costs are not an issue, this implicates that the result of any cost-effect analysis in this patient population will depend to a wide extent on the costs associated with the surgery and first-year follow-up. The next step then is to prove evidence of a consistent long-term effect of fusion surgery in the population of older patients. Several studies have done this and shown stable results, both at short term up to 2 years and at long-term follow-up [4, 6, 29]. So cost-effectiveness of fusion surgery in the older patients in a long-term perspective might be expected, but still needs to be documented.

Conflict of interest This study received support from the Danish Strategic Research Council (CESpine grant 2142-08-0017).

References

1. Amundsen T, Weber H, Nordal HJ et al (2000) Lumbar spinal stenosis: conservative or surgical management? A prospective 10-year study. Spine 25(11):1424–1435
2. Andersen JS, Olivarius NF, Krasnik A (2011) The Danish National Health Service register. Scand J Public Health 39(7 Suppl):34–37
3. Andersen T, Christensen FB, Ernst C et al (2009) The effect of electrical stimulation on lumbar spinal fusion in older patients: a randomized, controlled, multi-center trial: part 1: functional outcome. Spine 34(21):2241–2247
4. Andersen T, Christensen FB, Niedermann B et al (2009) Impact of instrumentation in lumbar spinal fusion in elderly patients. Acta Orthop 80(4):445–450
5. Ausman JI (2007) Spinal stenosis-what is the best treatment? Surg Neurol 68(5):486
6. Becker P, Bretschneider W, Tuschel A, Ogon M (2010) Life quality after instrumented lumbar fusion in the elderly. Spine 35(15):1478–1481
7. Boos N (2009) The impact of economic evaluation on quality management in spine surgery. Eur Spine J 18(Suppl 3):338–347
8. Carreon LY, Glassman SD, Djurasovic M et al (2009) RhBMP-2 versus iliac crest bone graft for lumbar spine fusion in patients over 60 years of age: a cost-utility study. Spine 34(3):238–243
9. Charlson ME, Pompei P, Ales KL, Mackenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40(5):373–383
10. Chen E, Tong KB, Laouri M (2010) Surgical treatment patterns among medicare beneficiaries newly diagnosed with lumbar spinal stenosis. Spine J 10(7):588–594
11. Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI (2005) United States trends in lumbar fusion surgery for degenerative conditions. Spine 30(12):1441–1445
12. Deyo RA, Mirza SK, Martin BI et al (2010) Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA 303(13):1259–1265
13. Katz JN, Lipson SJ, Chang LC et al (1996) Seven- to 10-year outcome of decompressive surgery for degenerative lumbar spinal stenosis. Spine 21(1):92–98
14. Katz JN, Lipson SJ, Lew RA et al (1997) Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis: patient selection, costs, and surgical outcomes. Spine 22(10):1123–1131
15. Kim HJ, Lee HM, Kim HS et al (2008) Life expectancy after lumbar spine surgery: one- to eleven-year follow-up of 1015 patients. Spine 33(19):2116–2121

16. Kuntz KM, Snider RK, Weinstein JN, Pope MH, Katz JN (2000) Cost-effectiveness of fusion with and without instrumentation for patients with degenerative spondylolisthesis and spinal stenosis. Spine 25(9):1132–1139
17. Lim KL, Jacobs P, Klarenbach S (2006) A population-based analysis of healthcare utilization of persons with back disorders: results from the Canadian Community Health Survey 2000–2001. Spine 31(2):212–218
18. Lynge E, Sandegaard JL, Rebolj M (2011) The Danish National Patient register. Scand J Public Health 39(7 Suppl):30–33
19. Malmivaara A, Slatis P, Heliovaara M et al (2007) Surgical or nonoperative treatment for lumbar spinal stenosis? A randomized controlled trial. Spine 32(1):1–8
20. National Institute for Health and Clinical Excellence (2008) Updated guide to the methods of technology appraisal, London
21. Parker SL, Fulchiero EC, Davis BJ et al (2011) Cost-effectiveness of multilevel hemilaminectomy for lumbar stenosis-associated radiculopathy. Spine J 11(8):705–711
22. Rajaee SS, Bae HW, Kanim LE, Delamarter RB (2012) Spinal fusion in the United States: analysis of trends from 1998 to 2008. Spine 37(1):67–76
23. Rampersaud YR, Ravi B, Lewis SJ et al (2008) Assessment of health-related quality of life after surgical treatment of focal symptomatic spinal stenosis compared with osteoarthritis of the hip or knee. Spine J 8(2):296–304
24. Soegaard R, Bunger CE, Christiansen T et al (2007) Circumferential fusion is dominant over posterolateral fusion in a long-term perspective: cost-utility evaluation of a randomized controlled trial in severe, chronic low back pain. Spine 32(22):2405–2414
25. Sørensen J, Søgaard R (2011) Modeling the lifetime health care cost distribution of the Danish general population. In: Paper presented at 32nd Nordic Health Economists' Study Group Meeting (NHESG)
26. Tosteson AN, Lurie JD, Tosteson TD et al (2008) Surgical treatment of spinal stenosis with and without degenerative spondylolisthesis: cost-effectiveness after 2 years. Ann Intern Med 149(12):845–853
27. Tosteson AN, Skinner JS, Tosteson TD et al (2008) The cost effectiveness of surgical versus nonoperative treatment for lumbar disc herniation over two years: evidence from the spine patient outcomes research trial (SPORT). Spine 33(19):2108–2115
28. United Nations DoEaSA (2007) World Economic and Social Survey 2007 Development in an Ageing World, New York pp 1–212
29. Weinstein JN, Lurie JD, Tosteson TD et al (2009) Surgical compared with nonoperative treatment for lumbar degenerative spondylolisthesis. Four-year results in the spine patient outcomes research trial (SPORT) randomized and observational cohorts. J Bone Joint Surg Am 91(6):1295–1304