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# Lumbar spine surgery across 15-years: trends, complications and reoperations in a time-series study

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## ABSTRACT

Studies from different Western countries have reported a rapid increase in spinal surgery rates, an increase that exceeds by far the growing incidence rates of spinal disorders in the general population. There are few studies covering all lumbar spine surgery and no previous studies from Norway.

### *Objectives*

The purpose of this study was to investigate trends in all lumbar spine surgery in Norway over 15 years, including length of hospital stay, and rates of complications and reoperations.

### *Design*

A time-series study over 15 year using hospital patient administrative data and sociodemographic data from the National Registry in Norway.

### *Setting and participants*

Patients aged ≥ 18 years discharged from Norwegian public hospitals between 1999 and 2013.

### *Outcome measures*

Annual rates of simple (microsurgical discectomy, decompression) and complex surgical procedures (fusion, disc prosthesis) in the lumbar spine.

### *Results*

The rate of lumbar spine surgery increased by 54%, from 78 (95%CI [75-80]) to 120 [107-113] per 100,000, from 1999 to 2013. More men had simple surgery whereas more women had complex surgery. Among elderly people over 75 years, lumbar surgery increased by a factor of five during the 15-year period. The rates of complications were low, but increased from 0.7% in 1999 to 2.4% in 2013.

***Conclusions***

There was a substantial increase in lumbar spine surgery in Norway from 1999 to 2013, similar to trends in other Western world countries. The rise in lumbar surgery among elderly people represents a significant workload and challenge for health services, given our aging population.

**Key Words**

neurosurgery, orthopaedic & trauma surgery, epidemiology

**Strengths and limitations of this study**

1. From 1999 to 2013 the annual rates of all lumbar spine surgery, including both simple procedures like microdiscectomy and decompression and complex procedures like fusion and disc prosthesis, in Norwegian public hospitals more than doubled.
2. The median length of hospital stay decreased from 7 days in 1999 to 4 days in 2013, but patients who received complex surgery the median length of stay was nearly double that of those who underwent a simple procedure (8 versus 4 days).
3. More men underwent simple surgical procedures, whereas more women underwent complex surgical procedures over the 15 years.
4. Most surgeries were performed on patients aged 40–59, but a substantial shift towards operations performed on the older age groups was apparent for both simple and complex surgery.
5. The complication rates were low, and were significantly associated with younger and middle-aged groups, receiving complex surgery, and having an extended hospital stay.

## INTRODUCTION

Low back pain is the leading cause of years lost to disability worldwide, and this burden is increasing as our population ages [1]. Low back pain was responsible for 60.1 million disability-adjusted life years in 2015, an increase of 54% since 1990, with the largest increase seen in low- and middle-income countries [1]. The economic burden is extensive, mostly due to sickness absence costs, but also due to the high cost of diagnostic tests and, in particular, spinal surgery [1]. The use of spinal surgery has increased considerably in many Western countries over the past 20 years [2-11]. This increase cannot be explained by higher incidence or prevalence rates of spinal disorders [2-7], and there are marked variations in spinal surgery rates between and within countries [7, 11].

National administrative databases provide important information regarding health services, which is crucial for planning and allocating healthcare resources. Many previous studies on the rates of all types of lumbar surgery come from the USA [2, 4, 7, 9]. There are also studies from Germany [6], United Kingdom [10], Sweden [3], and Denmark [5], but none from Norway. Moreover, none of the published studies provide an overview of *all* types of spinal surgery including simple surgical procedures such as microsurgical discectomy and/or decompression, and complex surgical procedures like fusions and disc prosthesis. An overview of all spinal surgery, including complication and reoperation rates, will provide important information for the evaluation of current public health services, as well as the planning of future services.

Hence, the primary aim of this study was to investigate the longitudinal trends in hospital discharges of *all* surgical procedures for lumbar spine disorders in Norway from 1999 to the end of 2013. Further, length of hospital stay, and rates of complications and reoperations over the 15-year period were investigated.

## MATERIAL AND METHODS

### *Design*

This was a retrospective observational study comprising all discharges from Norwegian public hospitals over a 15-year period (1999–2013). Norway (population of 4.46 million in 1999 and 5.05 million in 2013) [12] has a national healthcare system divided into four health regions (South-East, West, Middle, and North). Private surgery, primarily day surgery, became available after 2007. It is estimated that currently approximately 7% of all elective spinal surgeries take place in the private sector [13].

### *Data source*

Hospital patient administrative data were retrieved from a national database located at the Norwegian Knowledge Centre for the Health Services. The database was initially established as a part of the project "*Post-hospitalization survival rates in Norway as indicators of hospital* quality". A detailed description of the methods employed in data collection is published elsewhere [14]. Patient administrative data for the period 1999–2009 were extracted directly from all Norwegian public hospitals, and, for the period 2010–2013, from the Norwegian Patient Registry (NPR). Norwegian hospitals were mandated to submit data to the NPR since 2010. Each hospitalization record contains a personal identifier, codes for diagnoses, medical procedures, and date and time of admission and discharge. Data from the National Registry provided by Statistics Norway made it possible to link the NPR data to patients' age, sex, and municipality of residence. Each entry in the database represents a single hospitalization record including diagnoses based on ICD-10 and surgical procedure codes based on the NOMESCO Classification of Surgical Procedures (NCSP) [15].

### ***Patient and Public Involvement***

Due to the use of administrative data in this study patients or public were not involved in this project.

### ***Selection of sample and classification of outcome***

Inclusion criteria were: age ≥18 years and a lumbar spine diagnosis code (ICD-codes from M40 to M54). Exclusion criteria were: diagnoses related to the cervical, thoracic, or an unspecified region of the spine, as well as diagnoses indicating cancer, trauma, spinal fractures, pregnancy, spinal infections, and inflammatory diseases.

For identifying discharges with s*imple* surgical procedures defined as discectomy and/or decompression, the following NCSP ABC codes were used [15]: ABC07, ABC16, ABC26, ABC28, ABC36, ABC40, ABC56, ABC66, and ABC99. The *complex* surgical procedures included procedure codes for fusion surgery (NAG and NAN), disc prosthesis (NAB and NAC), and revision surgery (NAT and NAU) [15]. Further, NAE, NAF, NAH, NAM, NAT, and NAU procedure codes were included if coexisting with NCSP codes indicating a complex procedure. This is similar to the classification used in the Norwegian Registry for Spine Surgery (NORspine) [16]. A list of all included procedure codes can be delivered by contacting the corresponding author.

*Complications* were identified by the following ICD-10 codes occurring within 30 days after a discharge: postoperative hematoma (T81.0), post-procedural shock (T81.1), unintentional puncture/laceration (T81.2), disruption of wound/wound dehiscence (T81.3), infection following a procedure (T81.4), foreign body accidentally left in body following procedure (T81.5), acute reaction to foreign body accidentally left during a procedure (T81.6), vascular complications following a procedure (T81.7), unspecified or other complications of procedure, either upon initial surgical admission or upon readmission (T81.8-9), and complications during anesthesia (T88.4-5). NAW (reoperation) and AW (reoperations of the nervous system) procedure codes that occurred within 30 days after the initial surgery were also classified as *complications.* NAW and AW procedure codes occurring later than 30 days after an initial procedure were classified as *reoperations*.

***Background characteristics***

Patient age, gender, length of hospital stay, and number of operations were included. Age was categorized as 18–39 years, 40–59 years, 60–75 years, or >75 years.

***Statistical analyses***

Annual surgical incidence rates were calculated per 100,000 inhabitants based on the size of the total Norwegian population on Jan 1st of each analyzed year, retrieved from Statistics Norway [12]. Surgical incidence rates across age groups, gender, and type of surgery (simple/complex) were compared with $\chi 2$- and z-tests. Length of hospital stay over the time period and in relation to background characteristics was compared using a non-parametric Kruskal-Wallis test. Possible associations between complications and background characteristics were analyzed using a multivariate logistic regression. All tests were two-sided and p-values <0.05 were considered statistically significant. Data analyses were performed using SPSS version 25.0 (IBM, Armonk, NY, USA) and STATA version MP15.

## RESULTS

A total of *67,855* discharges for *57,081* individual patients were identified. A total of 56,764 (83.7%) discharges were for simple surgical procedures and 11,091 (16.3%) discharges were for complex surgical procedures. Most of the complex surgical procedures were fusion surgeries (94%). Further, 48,495 individual patients (71.5%) had only one discharge due to spinal surgery. The mean age of the patients was 52.3 (SD 15.9), and 51.4% were men. Background characteristics of all included discharges are presented in Table 1.

The median length of hospital stay for all patients undergoing spinal surgery decreased from 7.1 [IQR 6.0] days in 1999 to 3.8 [IQR 4.1] in 2013 (Table 1). For those undergoing a complex procedure the median length was nearly double that of those who underwent a simple procedure [8.2 (IQR) days versus 4.3 (IQR)]. In the simple surgery group, the length of hospital stay was reduced from a median of 6.2 [IQR 5.0] days in 1999 to 3.1 [IQR 3.1] in 2013, and in the complex surgery group there was a reduction from a median of 11.0 [IQR 6.1] in 1999 to 7.0 [IQR 4.0] in 2013.

**Insert Table 1 here**

The annual surgical rate including both simple and complex procedures increased from 77.8 (95%CI [75.2-80.4]) per 100,000 in 1999 to 119.9 (95%CI [107.0-112.8] in 2013 (Fig1). The rate of simple procedures increased by 138% (from 64.3 to 88.9 per 100,000 inhabitants for 1999 and 2013, respectively), and the rate of complex procedures increased by 154% (from 13.6 to 21.0 per 100,000). During the 15-year study period, significantly more males underwent simple surgical procedures, whereas more females underwent complex surgical procedures (Fig2).

**Insert Fig1 and Fig2 here**

Most surgeries were performed on patients aged 40–59 (Fig3). A substantial shift towards operations performed on the older age groups is apparent for both simple and complex surgery. Among those aged 75 years and above, the rate of simple surgery increased by more than a factor of five by 2013, reaching 167.8 [154.3-181.3]. A similar shift was also apparent for the complex procedures. In 1999 only 7.8 [30.3-42.9] operated patients per 100,000 inhabitants were in the oldest age group, whereas in 2013 this rate had increased to 36.6 [30.3-42.9]. In the younger age groups, the complex surgery rate remained stable over the 15-year period.

**Insert Fig3 here**

The occurrence of complications was generally low. During the 15-year period a total of 977 (1.4%, 95% [CI 1.38 – 1.56]) discharges were coded with diagnoses or procedures indicating complications. Of these, 42% occurred during the index stay and 68% underwent reoperation within 30 days. Over the 15-year period, the complication rate more than tripled, from 0.7% in 1999 to 2.4% in 2013. The multivariate analysis showed that complications were significantly associated with younger and middle-aged groups, receiving complex surgery, and having an extended hospital stay (Table 2). There was no statistically significant interaction between type of surgery (simple vs complex) and length of hospital stay (p=0.296), or between age groups and type of surgery (p=0.678).

A total of 10,015 (14.8%, 95% CI [14.5 – 15.0]) discharges were reoperations; 517 (0.8%, 95%CI [[0.8 – 0.9]) occurred between 30 and 90 days after the index discharge, 2611 (3.8%, 95%CI [3.7 – 4.0]) between 91 days and 12 months, and 2429 (3.6%, 95%CI [3.5 – 3.7]) between the first and second year. There was a large decrease in the proportion of patients who received reoperations during the 15-year period: from 21.6% in 1999 to 2.3% in 2013.

**Insert Table 2 here**

## DISCUSSION

This national study identified a significant increase in lumbar spine surgery in Norway from 1999 to 2013. This increase was most marked in the use of simple surgical procedures like microsurgical discectomy and/or decompression surgery, in particular among elderly patients above 75 years of age. The increase in complex surgery, for the most part fusion surgery, was also most prevalent in the oldest age group.

The main strength of the current study is that it covers all spinal surgery procedures carried out in public hospitals in Norway during a 15-year period, except for surgery due to red flag diagnosis (like cancer, spinal infections, inflammatory diseases) or trauma. A potential weakness is the risk of misclassification of diagnoses or procedures [23]. The lack of accuracy of diagnosis in such registries has been reported and a systematic review on this field has showed that procedure coding might be more accurate than coding based upon diagnosis [24]. Therefore, in order to reduce misclassification in the current study, we used the surgical procedure coding in combination with diagnoses when classifying the types of surgery provided. Further, we argue that the risk of misclassification is minor in this study as we assessed two large and different types of spinal surgery (simple versus complex spinal surgery procedures). As expected, the two groups differ with respect to length of hospital stay, complications, and reoperations. We considered classifying spinal surgery into simple and complex procedures, useful when reporting trends in spinal surgery within a large and heterogeneous dataset such as hospital administrative data used in this study. Finally, another weakness is that the present material did not include surgery conducted in private clinics/hospitals. Private for-profit hospitals in Norway perform currently approximately 7% of the total number of elective surgical procedures [13], usually as day surgeries. This might have contributed to the increase in complications in public hospitals after private surgery became common in 2007. Private surgery would leave the public hospitals to deal with the more complex cases and procedures during this portion of the study period (2007–2013). A previous study comparing surgery due to disc herniation in public and private hospitals in Norway, showed that patients operated by simple procedures due to lumbar disc herniation in public hospitals were older, and had more comorbidity and other risk factors associated with unfavorable outcomes compared to those operated in the private clinics [25].

There are very few published papers that provide an overview of *all* types of spinal surgery for degenerative disorders over an extended time period. There is one study by Davis [17], that presents trends in both cervical and lumbar spine surgery in the USA from 1979 to 1990. It states that hospitalization rates for all types of lumbar spinal surgery (including fusion, disc and exploration/decompression) increased markedly among both sexes. In line with Davis et al, our results demonstrate that more men than women receive lumbar spine surgery. Several studies on different types of spinal surgery, such as disc herniation and spinal fusion surgery, have been published [2-11]. In general, the findings in the present paper are in accordance with the other studies from Scandinavian countries [3, 5] and Germany [6], which show increased rates for lumbar disc herniation and spinal stenosis surgery. The increase reported in most of the western-European countries is not as large as that found in the United States [2, 4, 7, 9, 11] and United Kingdom [10]. Furthermore, these results also fit with the overall national healthcare expenditure across countries; in Norway it is 10.4% of the GDP, which is similar to other western-European countries such as Germany and Sweden, as compared to 17.1% in the United States [18].

The increase in public lumbar spine surgery in Norway is difficult to understand, because only minor increases in the incidence and severity of low back pain have been reported in the Norwegian population [19]. However, parts of the increase may be explained by the growing number of elderly patients and the increase of hospital surgeons in general [20]. In addition, there has been a substantial rise in the use of radiographic examinations such as MRI, which might have led to more surgery [21]. The large variations in spinal surgery rates may also be explained by a lack of uniform and consensus-based criteria for surgery, financial incentives for surgical interventions, and new technology [7-10, 22].

The mean complication rate during the study period was low, but it increased to 2.4% at the end of the period. This increase may be explained by the increase in reoperations within 30 days at the end of the 15-year period. Hence, there seems to be a trend towards a shorter timeframe for reoperations by the end of this 15-year time period, a trend which is also reported in the Swedish study of lumbar disc herniation surgery between 1987 and 1999 [3]. Our finding that older patients were less likely to experience complications and receive reoperations compared with the younger and middle-aged groups is hard to explain. It may be that surgeons are more hesitant to reoperate older people, and are more selective with respect to other potential risk factors for complications after surgery.

## CONCUSION

There was a substantial increase in spinal surgery in Norway from 1999 to 2013. The rise in number of surgeries, in particular among elderly people, represents a significant workload for hospitals in Norway, and a challenge to the public healthcare system in terms of meeting the increased burden associated with low back pain in an aging population.

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**Contributors**; MG, JH and JAZ designed the study. MG and MCS analysed the data, and JAZ, OF, LG, and TKS contributed in discussion of analyses and results presentation. MG wrote the manuscript with all authors contributing in reading, commenting and approving the final manuscript.

**The original protocol for the study** can be delivered upon request to the corresponding author.

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**Any checklist and flow diagram for the appropriate reporting statement**: not relevant

**Patient consent:** not required

**Ethics approval:** The study was approved by the Norwegian Data Inspectorate (2014/14413) and the Norwegian Regional Ethics Committee (2013/1662, REC south-east D).

**Data sharing statement**: It is not possible to participate in data sharing due to ethical reasons and strict data protection regulation in Norway.

**Figure legends**:

Fig 1. Annual surgery rates per 100,000 population of simple and complex lumbar surgical procedures in Norway from 1999 to 2013.

Fig 2. Annual incidence per 100,000 population of simple and complex lumbar surgery in Norway from 1999 to 2013, according to gender.

Fig 3. Annual incidence per 100,000 inhabitants of simple (upper figure) and complex (lower figure) surgery in Norway from 1999 to 2013, according to age groups.

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**Table 1.** Characteristics of *67,855* lumbar spine operations in *57,081* patients in Norway, 1999 to 2013

| | No. of operations (%) | Length of stay, median days [range, IQR] |
|---|---|---|
| Age (years) | | |
| 18-39 | 16396 (24.2) | 4.2 [724, 4.4] |
| 40-59 | 28237 (41.7) | 6.3 [618, 4.7] |
| 60-75 | 16160 (23.9) | 5.9 [250, 5.8] |
| > 75 | 6910 (10.2) | 7.2 [226, 6.7] |
| Missing | 152 | |
| Gender | | |
| Male | 34902 (51.4) | 4.7 [239, 4.4] |
| Female | 32801 (48.3) | 6.0 [724, 5.8] |
| Missing | 152 | |
| Year of operation | | |
| 1999 | 3460 (5.1) | 7.1 [149.9, 6.0] |
| 2000 | 3996 (5.9) | 7.0 [420, 6.0] |
| 2001 | 4200 (6.2) | 7.0 [138, 6.0] |
| 2002 | 3865 (5.7) | 6.2 [202, 6.0] |
| 2003 | 4557 (6.7) | 6.1 [238, 5.4] |
| 2004 | 4396 (6.5) | 6.1 [250, 5.8] |
| 2005 | 4572 (6.7) | 6.0 [724, 5.3] |
| 2006 | 4422 (6.5) | 5.8 [138, 5.5] |
| 2007 | 4255 (6.3) | 5.1 [618, 5.0] |
| 2008 | 4164 (6.1) | 4.9 [179, 4.3] |

| | | |
|---|---|---|
| 2009 | 4449 (6.6) | 4.2 [142, 4.9] |
| 2010 | 5130 (7.6) | 4.1 [183, 4.8] |
| 2011 | 5241 (7.7) | 4.0 [210, 4.2] |
| 2012 | 5597 (8.2) | 4.1 [165, 4.2] |
| 2013 | 5551 (8.2) | 3.8 [219, 4.1] |
| Missing | 0 | 0 |
| Type of surgery | | |
| Simple | 56764 (83.7) | 4.3 [724, 4.3] |
| Complex | 11091 (16.3) | 8.2 [420, 5.7] |
| No. of operations | | |
| One | 57029 (84.0) | 5.1 [724, 5.0] |
| Two | 8623 (12.7) | 5.2 [618, 5.1] |
| Three | 1602 (2.4) | 6.2 [205, 6.0] |
| ≥ Four | 467 (0.7) | 6.9 [115, 4.4] |
| Missing | 134 | 134 |

**Table 2.** Multivariate logistic regression model analysis of factors associated with complications (including reoperation within 30 days) due to lumbar spine surgery in Norway from 1999 to 2013 (N=*67,855*)

| | Complications (n=977) | OR | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| Age (years) | | | | |
| 18-39 | 250 | Ref | | |
| 40-59 | 460 | 0.97 | 0.83 | 1.13 |
| 60-75 | 198 | 0.61 | 0.50 | 0.74 |
| > 75 | 69 | 0.51 | 0.39 | 0.67 |
| Missing | 152 | | | |
| Gender | | | | |
| Male | 510 | Ref | | |
| Female | 467 | 0.90 | 0.79 | 1.02 |
| Missing | 152 | | | |
| Length of stay (cont.) | | 1.02 | 1.01 | 1.02 |
| Type of surgery | | | | |
| Simple | 659 | Ref | | |
| Complex | 318 | 2.34 | 2.04 | 2.69 |
| Year of operation | | | | |
| 1999 | 24 | Ref | | |
| 2000 | 29 | 0.98 | 0.57 | 1.71 |
| 2001 | 29 | 1.03 | 0.60 | 1.77 |
| 2002 | 33 | 1.31 | 0.77 | 2.22 |

| | | | | |
|---|---|---|---|---|
| 2003 | 44 | 1.52 | 0.92 | 2.50 |
| 2004 | 41 | 1.46 | 0.88 | 2.43 |
| 2005 | 67 | 2.23 | 1.39 | 3.57 |
| 2006 | 60 | 2.25 | 1.40 | 3.63 |
| 2007 | 58 | 2.25 | 1.39 | 3.64 |
| 2008 | 56 | 2.29 | 1.42 | 3.71 |
| 2009 | 80 | 3.12 | 1.97 | 4.94 |
| 2010 | 89 | 3.03 | 1.93 | 4.78 |
| 2011 | 93 | 3.03 | 1.93 | 4.77 |
| 2012 | 140 | 4.31 | 2.79 | 4.67 |
| 2013 | 134 | 4.16 | 2.68 | 6.44 |
| Missing | 134 | | | |

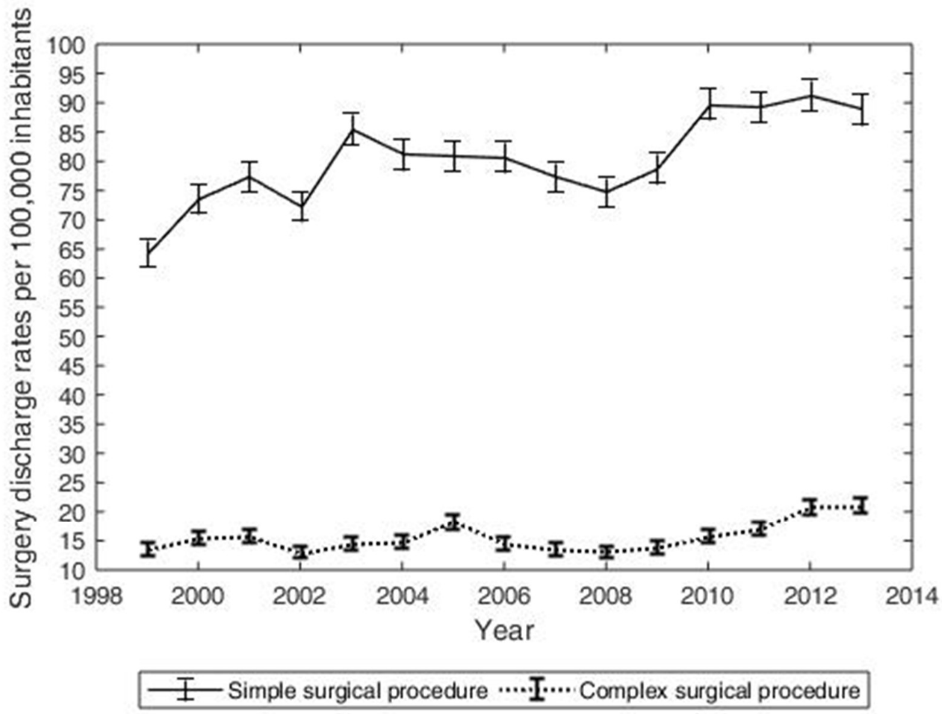



Fig 1. Annual surgery rates per 100,000 population of simple and complex lumbar surgical procedures in Norway from 1999 to 2013.

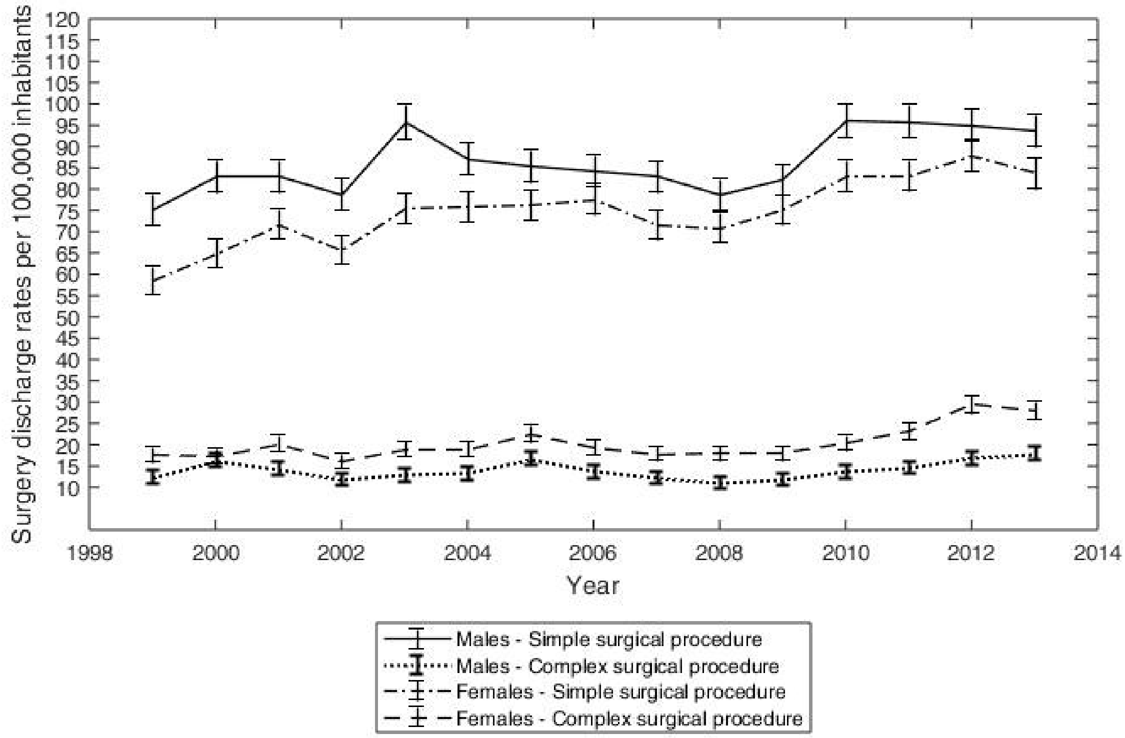
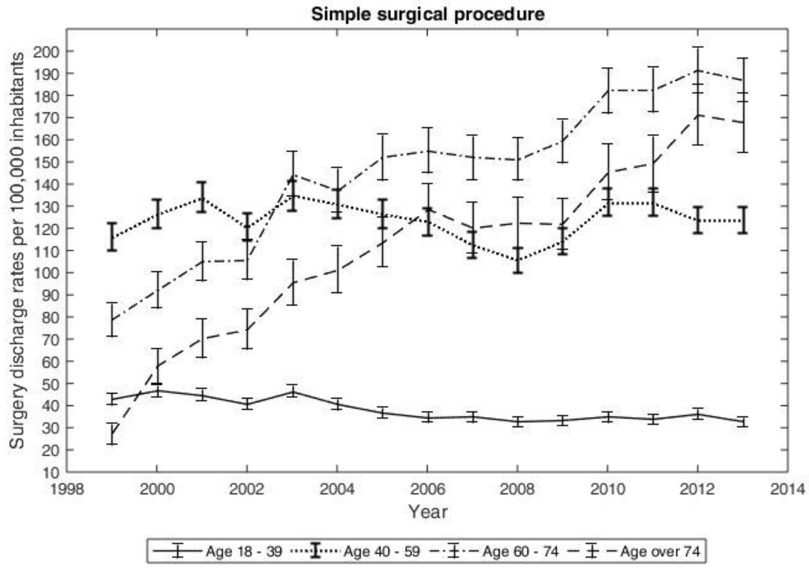



Fig 2. Annual incidence per 100,000 population of simple and complex lumbar surgery in Norway from 1999 to 2013, according to gender.



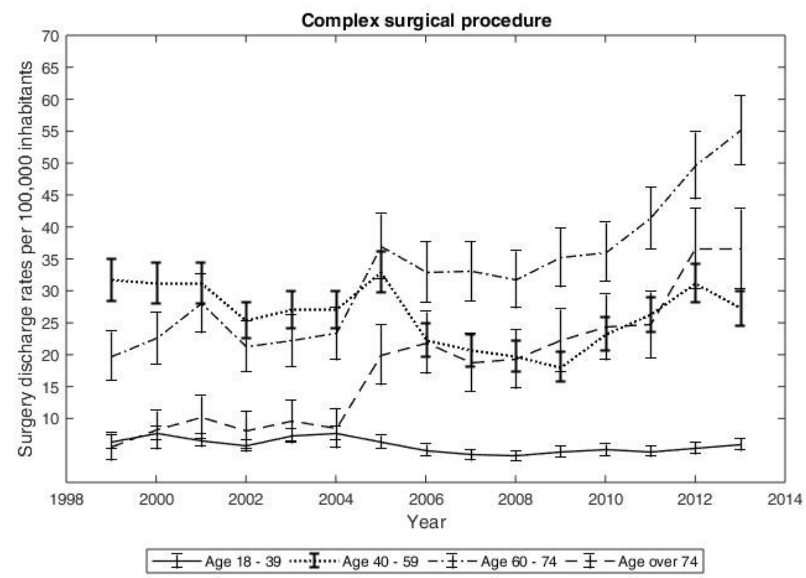




Fig 3. Annual incidence per 100,000 inhabitants of simple (upper figure) and complex (lower figure) surgery in Norway from 1999 to 2013, according to age groups.

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# Lumbar spine surgery across 15-years: trends, complications and reoperations in a longitudinal observational study from Norway

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# Lumbar spine surgery across 15-years: trends, complications and reoperations in a longitudinal observational study from Norway

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## ABSTRACT

Studies from different Western countries have reported a rapid increase in spinal surgery rates, an increase that exceeds by far the growing incidence rates of spinal disorders in the general population. There are few studies covering all lumbar spine surgery and no previous studies from Norway.

### *Objectives*

The purpose of this study was to investigate trends in all lumbar spine surgery in Norway over 15 years, including length of hospital stay, and rates of complications and reoperations.

### *Design*

A longitudinal observational study over 15 year using hospital patient administrative data and sociodemographic data from the National Registry in Norway.

### *Setting and participants*

Patients aged ≥ 18 years discharged from Norwegian public hospitals between 1999 and 2013.

### *Outcome measures*

Annual rates of simple (microsurgical discectomy, decompression) and complex surgical procedures (fusion, disc prosthesis) in the lumbar spine.

### *Results*

The rate of lumbar spine surgery increased by 54%, from 78 (95%CI [75-80]) to 120 [107-113] per 100,000, from 1999 to 2013. More men had simple surgery whereas more women had complex surgery. Among elderly people over 75 years, lumbar surgery increased by a factor

of five during the 15-year period. The rates of complications were low, but increased from 0.7% in 1999 to 2.4% in 2013.

***Conclusions***

There was a substantial increase in lumbar spine surgery in Norway from 1999 to 2013, similar to trends in other Western world countries. The rise in lumbar surgery among elderly people represents a significant workload and challenge for health services, given our aging population.

**Key Words**

neurosurgery, orthopaedic & trauma surgery, epidemiology

**Strengths and limitations of this study**

1. This study covers all lumbar spine surgery in Norwegian public hospitals across 15 years, and all annual rates during the time period were adjusted for age and gender.
2. In order to minimize the risk of misclassification, surgical procedure codings were used in combination with diagnoses to group all surgery into two main categories; simple surgery such as microdiscectomy and decompression, and complex surgery such as fusion and disc prosthesis .
3. This study did not include data from private clinics, which currently cover approximately 7% of the elective surgery in Norway.
4. Cases for non-lumbar indications, cancer, trauma, infection, pregnancy and inflammation were excluded.
5. The design and material of this study did not allow us to adjust for all potential confounding factors, that might have influenced the multivariate analyses of complications due to surgery .

## INTRODUCTION

Low back pain is the leading cause of years lost to disability worldwide, and this burden is increasing as our population ages [1]. Low back pain was responsible for 60.1 million disability-adjusted life years in 2015, an increase of 54% since 1990, with the largest increase seen in low- and middle-income countries [1]. The economic burden is extensive, mostly due to sickness absence costs, but also due to the high cost of diagnostic tests and, in particular, spinal surgery [1]. The use of spinal surgery has increased considerably in many Western countries over the past 20 years [2-11]. This increase cannot be explained by higher incidence or prevalence rates of spinal disorders [2-7], and there are marked variations in spinal surgery rates between and within countries [7, 11].

National administrative databases provide important information regarding health services, which is crucial for planning and allocating healthcare resources. Many previous studies on the rates of all types of lumbar surgery come from the USA [2, 4, 7, 9]. There are also studies from Germany [6], United Kingdom [10], Sweden [3], and Denmark [5], but none from Norway. Moreover, none of the published studies provide an overview of *all* types of lumbar spinal surgery including simple surgical procedures such as microsurgical discectomy and/or decompression, and complex procedures such as fusions and disc prosthesis. An overview of all spinal surgery, including complication and reoperation rates, will provide important information for the evaluation of current public health services, as well as the planning of future services.

Hence, the primary aim of this study was to investigate the longitudinal trends in hospital discharges of *all* surgical procedures for lumbar spine disorders in Norway from 1999 to the end of 2013. Further, length of hospital stay, and rates of complications and reoperations over the 15-year period were investigated.

## MATERIAL AND METHODS

### *Design*

This was a retrospective, longitudinal, observational study comprising all discharges from Norwegian public hospitals over a 15-year period (1999–2013). Norway (population of 4.46 million in 1999 and 5.05 million in 2013) [12] has a national healthcare system divided into four health regions (South-East, West, Middle, and North). Private surgery, primarily day surgery, became available after 2007. It is estimated that currently approximately 7% of all elective spinal surgeries take place in the private sector [13].

***Data source***

Hospital patient administrative data was retrieved from a national database located at the Norwegian Knowledge Centre for the Health Services. The database was initially established as a part of the project "*Post-hospitalization survival rates in Norway as indicators of hospital quality*". A detailed description of the methods employed in data collection is published elsewhere [14]. Patient administrative data for the period 1999–2009 were extracted directly from all Norwegian public hospitals, and, for the period 2010–2013, from the Norwegian Patient Registry (NPR). Norwegian hospitals were mandated to submit data to the NPR since 2010. Each hospitalization record contains a personal identifier, codes for diagnoses, medical procedures, and date and time of admission and discharge. Data from the National Registry provided by Statistics Norway made it possible to link the NPR data to patients' age, sex, and municipality of residence. Each entry in the database represents a single hospitalization record including diagnoses based on ICD-10 and surgical procedure codes based on the NOMESCO Classification of Surgical Procedures (NCSP) [15]. The NOMESCO Classification has been used in Norway, Sweden, Denmark, Finland, Iceland and Estonia since 1999. The NSCP algorithm used in this study has been validated by the Norwegian registry for spine surgery (NORspine) [16] and the Norwegian patient registry under the Norwegian Directorate of Health [17].

***Patient and Public Involvement***

Due to the use of administrative data in this study patients or public were not involved in this project.

***Selection of sample and classification of outcome***

Inclusion criteria were: age ≥18 years and a lumbar spine diagnosis code (ICD-codes from M40 to M54). Exclusion criteria were: diagnoses related to the cervical, thoracic, or an unspecified region of the spine, as well as diagnoses indicating cancer, trauma, spinal fractures, pregnancy, spinal infections, and inflammatory diseases.

For identifying discharges with s*imple* surgical procedures defined as discectomy and/or decompression, the following NCSP ABC codes were used [15]: ABC07, ABC16, ABC26, ABC28, ABC36, ABC40, ABC56, ABC66, and ABC99. The *complex* surgical procedures included procedure codes for fusion surgery (NAG and NAN), disc prosthesis (NAB and NAC), and revision surgery (NAT and NAU) [15]. Further, NAE, NAF, NAH, NAM, NAT, and NAU procedure codes were included if coexisting with NCSP codes indicating a complex procedure. This is similar to the algorithm  used in the NORspine [16] and the Norwegian patient registry [17].A list of all included procedure codes can be delivered by contacting the corresponding author.

C*omplications* were identified by the following ICD-10 codes occurring within 30 days after a discharge: postoperative hematoma (T81.0), post-procedural shock (T81.1), unintentional puncture/laceration (T81.2), disruption of wound/wound dehiscence (T81.3), infection following a procedure (T81.4), foreign body accidentally left in body following procedure (T81.5), acute reaction to foreign body accidentally left during a procedure (T81.6), vascular complications following a procedure (T81.7), unspecified or other complications of procedure, either upon initial surgical admission or upon readmission (T81.8-9), and complications during anesthesia (T88.4-5). NAW (reoperation) and AW (reoperations of the nervous system) procedure codes that occurred within 30 days after the initial surgery were also classified as *complications.* NAW and AW procedure codes occurring later than 30 days after an initial procedure were classified as *reoperations*.

***Background characteristics***

Patient age, gender, length of hospital stay, and number of operations were included. Age was categorized as 18–39 years, 40–59 years, 60–75 years, or >75 years.

***Statistical analyses***

Annual surgical incidence rates were calculated per 100,000 inhabitants based on the size of the total Norwegian population on Jan 1st of each analyzed year, retrieved from Statistics

Norway [12]. Surgical incidence rates across age groups, gender, and type of surgery (simple/complex) were compared with χ2- and z-tests. Length of hospital stay over the time period and in relation to background characteristics was compared using a non-parametric Kruskal-Wallis test. Possible associations between complications and background characteristics were analyzed using a multivariate logistic regression. All tests were two-sided and p-values <0.05 were considered statistically significant. Data analyses were performed using SPSS version 25.0 (IBM, Armonk, NY, USA) and STATA version MP15.

## RESULTS

A total of *67,855* discharges for *57,081* individual patients were identified. A total of 56,764 (83.7%) discharges were for simple surgical procedures and 11,091 (16.3%) discharges were for complex surgical procedures. Most of the complex surgical procedures were fusion surgeries (94.0%). Further, 48,495 individual patients (71.5%) had only one discharge due to spinal surgery. The mean age of the patients was 52.3 (SD 15.9), and 51.4% were men. Background characteristics of all included discharges are presented in Table 1.

The median length of hospital stay for all patients undergoing spinal surgery decreased from 7.1 [Inter quartil range (IQR) 6.0] days in 1999 to 3.8 [IQR 4.1] in 2013 (Table 1). For those undergoing a complex procedure the median length was nearly double that of those who underwent a simple procedure [8.2 (IQR 4.3) days versus 4.3 (IQR 5.7)]. In the simple surgery group, the length of hospital stay was reduced from a median of 6.2 [IQR 5.0] days in 1999 to 3.1 [IQR 3.1] in 2013, and in the complex surgery group there was a reduction from a median of 11.0 [IQR 6.1] in 1999 to 7.0 [IQR 4.0] in 2013.

**Insert Table 1 here**

The annual surgical rate including both simple and complex procedures increased from 77.8 [95%CI (75.2-80.4)] per 100,000 in 1999 to 119.9 [95%CI (107.0-112.8)] in 2013 (Fig1). The rate of simple procedures increased by 138% (from 64.3 to 88.9 per 100,000 inhabitants for 1999 and 2013, respectively), and the rate of complex procedures increased by 154% (from 13.6 to 21.0 per 100,000). During the 15-year study period, significantly more males underwent simple surgical procedures, whereas more females underwent complex surgical procedures (Fig2).

**Insert Fig1 and Fig2 here**

Most surgeries were performed on patients aged 40–59 (Fig3). A substantial shift towards operations performed on the older age groups is apparent for both simple and complex surgery. Among those aged 75 years and above, the rate of simple surgery increased by more than a factor of five by 2013, reaching 167.8 [154.3-181.3]. A similar shift was also apparent for the complex procedures. In 1999 only 7.8 [30.3-42.9] operated patients per 100,000 inhabitants were in the oldest age group, whereas in 2013 this rate had increased to 36.6 [30.3-42.9]. In the younger age groups, the complex surgery rate remained stable over the 15-year period.

**Insert Fig3 here**

The occurrence of complications was generally low. During the 15-year period a total of 977 [1.4%, 95% (CI 1.38 – 1.56)] discharges were coded with diagnoses or procedures indicating complications. Of these, 42% occurred during the index stay and 68% underwent reoperation within 30 days. During the 15-year period, there was an increase in reoperations within 30 days, leading to a large increase in the complication rate, from 0.7% in 1999 to 2.4% in 2013. The multivariate analysis showed that complications were significantly associated with younger and middle-aged groups, receiving complex surgery, and having an extended hospital stay (Table 2). There was no statistically significant interaction between type of surgery (simple vs complex) and length of hospital stay (p=0.296), or between age groups and type of surgery (p=0.678).

A total of 10,015 [14.8%, 95% CI (14.5 – 15.0)]) discharges were reoperations; 517 [0.8%, 95%CI (0.8 – 0.9)] occurred between 30 and 90 days after the index discharge, 2611 [3.8%, 95%CI (3.7 – 4.0)] between 91 days and 12 months, and 2429 [3.6%, 95%CI (3.5 – 3.7)] between the first and second year. There was a large decrease in the proportion of patients who received reoperations during the 15-year period: from 21.6% in 1999 to 2.3% in 2013.

**Insert Table 2 here**

## DISCUSSION

This national study identified a significant increase in lumbar spine surgery in Norway from 1999 to 2013. This increase was most marked in the use of simple surgical procedures like microsurgical discectomy and/or decompression surgery, in particular among elderly patients above 75 years of age. The increase in complex surgery, for the most part fusion surgery, was also most prevalent in the oldest age group.

The main strength of the current study is that it covers all spinal surgery procedures carried out in public hospitals in Norway during a 15-year period, except for surgery due to red flag diagnoses (cancer, spinal infections, inflammatory diseases, etc) or trauma. A potential weakness is the risk of misclassification of diagnoses or procedures [18]. The lack of accuracy of diagnosis in such registries has been reported and a systematic review on this field has showed that procedure coding might be more accurate than coding based upon diagnosis [19]. In order to reduce misclassification in the current study, we used the surgical procedure coding in combination with diagnoses when classifying the types of surgery provided. Further, we argue that the risk of misclassification is minor in this study as we assessed two large and different types of spinal surgery (simple versus complex spinal surgery procedures). As expected, the two groups differ with respect to length of hospital stay, complications, and reoperations. We considered classifying spinal surgery into simple and complex procedures useful when reporting trends in spinal surgery within a large and heterogeneous dataset such as hospital administrative data used in this study. Finally, the present material did not include surgery conducted in private clinics/hospitals. Private for-profit hospitals in Norway perform currently approximately 7% of the total number of elective surgical procedures [13], usually as day surgeries. This might have contributed to the increase in complications in public hospitals after private surgery became common in 2007. Private surgery would leave the public hospitals to deal with the more complex cases and procedures during this portion of the study period (2007–2013). A previous study comparing surgery due to disc herniation in public and private hospitals in Norway, showed that patients operated by simple procedures due to lumbar disc herniation in public hospitals were older, and had more comorbidity and other risk factors associated with unfavorable outcomes compared to those operated in the private clinics [20].

There are very few published papers that provide an overview of *all* types of spinal surgery for lumbar degenerative disorders over an extended time period. Davis [21] reported that hospitalization rates for all types of lumbar surgery (including fusion and decompression) increased markedly in the USA from 1979 to 1990 . In line with Davis, our results demonstrate that more men than women received lumbar spine surgery. Several studies on the rates of different types of spinal surgery, such as disc herniation and spinal fusion surgery, have been published [2-11, 22]. In general, the findings in the present paper are in accordance with the other studies from Scandinavian countries [3, 5] and Germany [6], which show increased rates for lumbar disc herniation and spinal stenosis surgery. The increase reported in most of the western-European countries is not as large as that found in the United States [2, 4, 7, 9, 11] and United Kingdom [10]. Furthermore, these results also fit with the overall national healthcare expenditure across countries; in Norway it is 10.4% of the GDP, which is similar to other western-European countries such as Germany and Sweden, as compared to 17.1% in the United States [23].

The increase in public lumbar spine surgery in Norway is difficult to understand, because only minor increases in the incidence and severity of low back pain have been reported in the Norwegian population [24]. However, parts of the increase may be explained by the growing number of elderly patients and the increase of hospital surgeons in general [25]. In addition, there has been a substantial rise in the use of radiographic examinations such as MRI, which might have led to more surgery [26]. The large variations in spinal surgery rates may also be explained by a lack of uniform and consensus-based criteria for surgery, financial incentives for surgical interventions, and new technology [7-10, 27]. There is a large need for high-quality scientific evidence as well as clinical consensus regarding an optimal use of resource-demanding investigations and treatments connected to spinal disorders. Many of the new technologies and more complex procedures have questionable clinical or cost-benefit efficacy. Furthermore, we need stronger scientific evidence with respect to the selection of patients to surgical treatment. Both in a clinical and societal perspective, non-surgical management might be an appropriate option for patients who wish to defer or avoid surgery [28]. The mean complication rate during the study period was low, but it increased to 2.4% at the end of the period. This increase may be explained by the increase in reoperations within 30 days at the end of the 15-year period. Hence, there seems to be a trend towards a shorter timeframe for reoperations by the end of this 15-year time period, a trend which is also reported in the Swedish study of lumbar disc herniation surgery between 1987 and 1999 [3]. Our finding that older patients were less likely to experience complications and receive reoperations compared with the younger and middle-aged groups is hard to explain. It may be that surgeons are more hesitant to re-operate older people, and are more selective with respect to other potential risk factors for complications after surgery.

## CONCUSION

There was a substantial increase in spinal surgery in Norway from 1999 to 2013. The rise in number of surgeries, in particular among elderly people, represents a significant workload for hospitals in Norway, and a challenge to the public healthcare system in terms of meeting the increased burden associated with low back pain in an aging population.

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**Contributors**; MG, JH and JAZ designed the study. MG and MCS analysed the data, and JAZ, OF, LG, KS, and TKS contributed in discussion of analyses and results presentation. MG wrote the manuscript with all authors contributing in reading, commenting and approving the final manuscript.

**The original protocol for the study** can be delivered upon request to the corresponding author.

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**Any checklist and flow diagram for the appropriate reporting statement**: not relevant

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**Data sharing statement**: It is not possible to participate in data sharing due to ethical reasons and strict data protection regulation in Norway.

**Figure legends**:

Fig 1. Annual surgery rates per 100,000 population of simple and complex lumbar surgical procedures in Norway from 1999 to 2013.

Fig 2. Annual incidence per 100,000 population of simple and complex lumbar surgery in Norway from 1999 to 2013, according to gender.

Fig 3. Annual incidence per 100,000 inhabitants of simple (upper figure) and complex (lower figure) surgery in Norway from 1999 to 2013, according to age groups.

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**Table 1.** Characteristics of *67,855* lumbar spine operations in *57,081* patients in Norway, 1999 to 2013

| | No. of operations (%) | Length of stay, days, median [range, IQR] |
|---|---|---|
| Age (years) | | |
| 18-39 | 16396 (24.2) | 4.2 [724, 4.4] |
| 40-59 | 28237 (41.7) | 6.3 [618, 4.7] |
| 60-75 | 16160 (23.9) | 5.9 [250, 5.8] |
| > 75 | 6910 (10.2) | 7.2 [226, 6.7] |
| Missing | 152 | |
| Gender | | |
| Male | 34902 (51.4) | 4.7 [239, 4.4] |
| Female | 32801 (48.3) | 6.0 [724, 5.8] |
| Missing | 152 | |
| Year of operation | | |
| 1999 | 3460 (5.1) | 7.1 [149.9, 6.0] |
| 2000 | 3996 (5.9) | 7.0 [420, 6.0] |
| 2001 | 4200 (6.2) | 7.0 [138, 6.0] |
| 2002 | 3865 (5.7) | 6.2 [202, 6.0] |
| 2003 | 4557 (6.7) | 6.1 [238, 5.4] |
| 2004 | 4396 (6.5) | 6.1 [250, 5.8] |
| 2005 | 4572 (6.7) | 6.0 [724, 5.3] |
| 2006 | 4422 (6.5) | 5.8 [138, 5.5] |
| 2007 | 4255 (6.3) | 5.1 [618, 5.0] |
| 2008 | 4164 (6.1) | 4.9 [179, 4.3] |

| | | |
|---|---|---|
| 2009 | 4449 (6.6) | 4.2 [142, 4.9] |
| 2010 | 5130 (7.6) | 4.1 [183, 4.8] |
| 2011 | 5241 (7.7) | 4.0 [210, 4.2] |
| 2012 | 5597 (8.2) | 4.1 [165, 4.2] |
| 2013 | 5551 (8.2) | 3.8 [219, 4.1] |
| Missing | 0 | 0 |
| Type of surgery | | |
| Simple | 56764 (83.7) | 4.3 [724, 4.3] |
| Complex | 11091 (16.3) | 8.2 [420, 5.7] |
| No. of operations | | |
| One | 57029 (84.0) | 5.1 [724, 5.0] |
| Two | 8623 (12.7) | 5.2 [618, 5.1] |
| Three | 1602 (2.4) | 6.2 [205, 6.0] |
| ≥ Four | 467 (0.7) | 6.9 [115, 4.4] |
| Missing | 134 | 134 |

**Table 2.** Multivariate logistic regression model of factors associated with complications (including reoperation within 30 days) due to lumbar spine surgery in Norway from 1999 to 2013 (N=*67,855*)

| | Complications (n=977) | OR | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| Age (years) | | | | |
| 18-39 | 250 | Ref | | |
| 40-59 | 460 | 0.97 | 0.83 | 1.13 |
| 60-75 | 198 | 0.61 | 0.50 | 0.74 |
| > 75 | 69 | 0.51 | 0.39 | 0.67 |
| Missing | 152 | | | |
| Gender | | | | |
| Male | 510 | Ref | | |
| Female | 467 | 0.90 | 0.79 | 1.02 |
| Missing | 152 | | | |
| Length of stay (days) | | 1.02 | 1.01 | 1.02 |
| Type of surgery | | | | |
| Simple | 659 | Ref | | |
| Complex | 318 | 2.34 | 2.04 | 2.69 |
| Year of operation | | | | |
| 1999 | 24 | Ref | | |
| 2000 | 29 | 0.98 | 0.57 | 1.71 |
| 2001 | 29 | 1.03 | 0.60 | 1.77 |
| 2002 | 33 | 1.31 | 0.77 | 2.22 |

| | | | | |
|---|---|---|---|---|
| 2003 | 44 | 1.52 | 0.92 | 2.50 |
| 2004 | 41 | 1.46 | 0.88 | 2.43 |
| 2005 | 67 | 2.23 | 1.39 | 3.57 |
| 2006 | 60 | 2.25 | 1.40 | 3.63 |
| 2007 | 58 | 2.25 | 1.39 | 3.64 |
| 2008 | 56 | 2.29 | 1.42 | 3.71 |
| 2009 | 80 | 3.12 | 1.97 | 4.94 |
| 2010 | 89 | 3.03 | 1.93 | 4.78 |
| 2011 | 93 | 3.03 | 1.93 | 4.77 |
| 2012 | 140 | 4.31 | 2.79 | 4.67 |
| 2013 | 134 | 4.16 | 2.68 | 6.44 |
| Missing | 134 | | | |

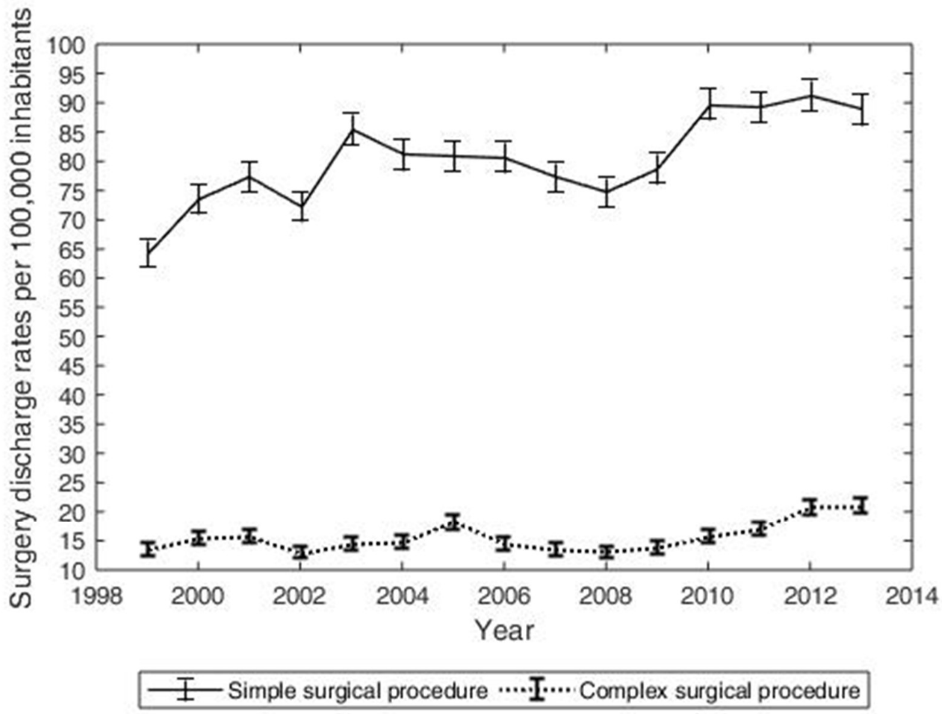


Fig 1. Annual surgery rates per 100,000 population of simple and complex lumbar surgical procedures in Norway from 1999 to 2013.

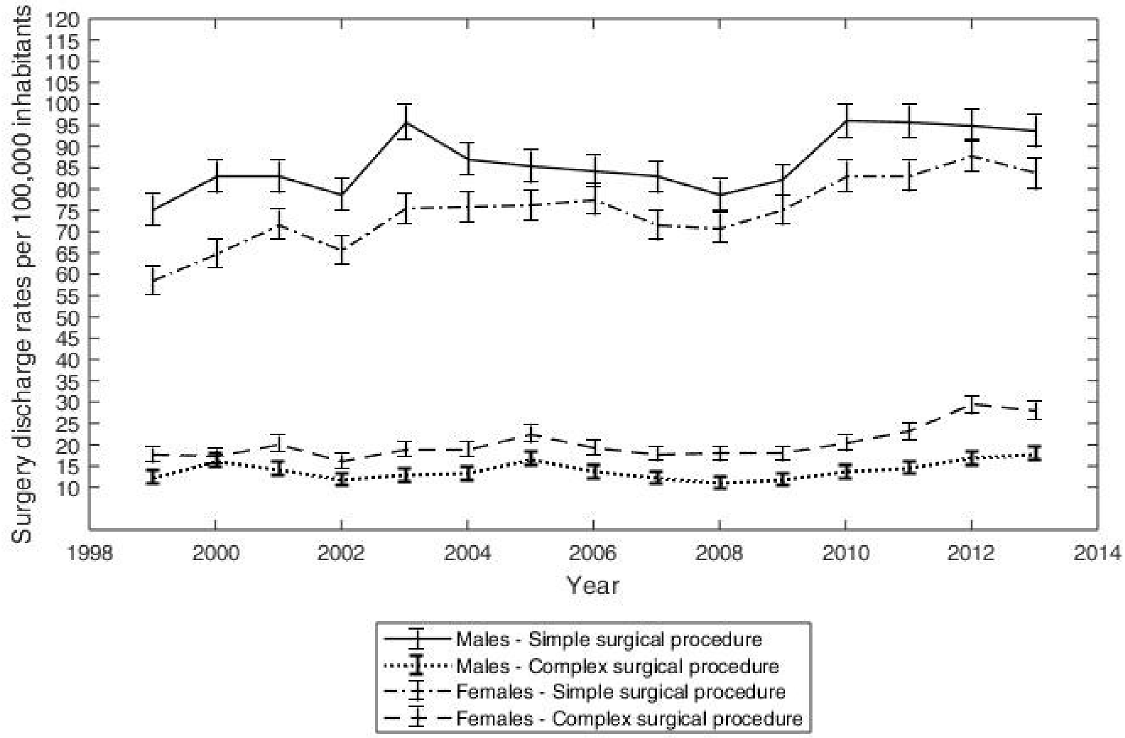


Fig 2. Annual incidence per 100,000 population of simple and complex lumbar surgery in Norway from 1999 to 2013, according to gender.

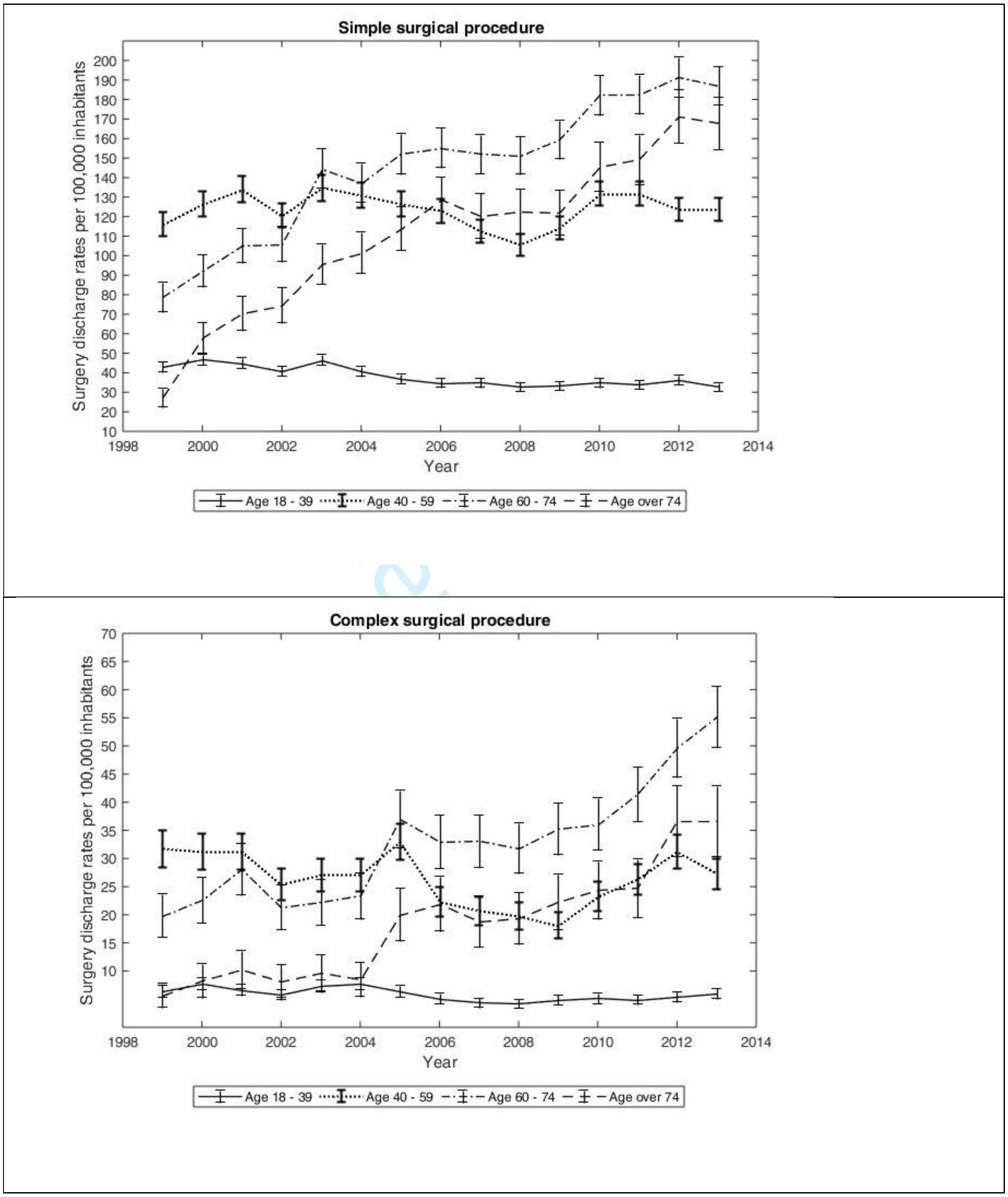


Fig 3. Annual incidence per 100,000 inhabitants of simple (upper figure) and complex (lower figure) surgery in Norway from 1999 to 2013, according to age groups.

STROBE Statement—Checklist of items that should be included in reports of *cohort studies*

| | Item No | Recommendation | |
|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | title |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | abstract |
| **Introduction** | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | Introduct p.3 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | –"– |
| **Methods** | | | |
| Study design | 4 | Present key elements of study design early in the paper | p.4 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | p.4-5 |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | p.4 l.10-22 |
| | | (*b*) For matched studies, give matching criteria and number of exposed and unexposed | + p.5 l.1-4 |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | p.5 l.5-24 |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | p.4 l.10-22 + p.5 l.5-24 |
| Bias | 9 | Describe any efforts to address potential sources of bias | p.6 l.1-10 |
| Study size | 10 | Explain how the study size was arrived at | not relevant, all cases included |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | p.6 l.1-10 |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | |
| | | (*b*) Describe any methods used to examine subgroups and interactions | |
| | | (*c*) Explain how missing data were addressed | –"– |
| | | (*d*) If applicable, explain how loss to follow-up was addressed | |
| | | (*e*) Describe any sensitivity analyses | |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | p.6 l.12-15 |
| | | (b) Give reasons for non-participation at each stage | not relevant |
| | | (c) Consider use of a flow diagram | –"– |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | p.6 l.12-17 + Table 1 |
| | | (b) Indicate number of participants with missing data for each variable of interest | not relevant |
| | | (c) Summarise follow-up time (eg, average and total amount) | p.6 + Table 1 |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time | + Fig 1+2 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | p.7 l.13-26 + Table 2 |
| | | (*b*) Report category boundaries when continuous variables were categorized | |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | not relevant |

| | | | |
|---|---|---|---|
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | |
| **Discussion** | | | |
| Key results | 18 | Summarise key results with reference to study objectives | p. 8 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | p. 8 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | p. 8-9 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | p. 8 |
| **Other information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | p. 10 |

*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.