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REVIEW ARTICLE

Comorbidity data collection across different spine registries: an evidence map

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Abstract

Introduction Comorbidities are significant patient factors that contribute to outcomes after surgery. There is highly variable collection of this information across the literature. To help guide the systematic collection of best practice data, the Australian Spine Registry conducted an evidence map to investigate (i) what comorbidities are collected by spine registries, (ii) how they are collected and (iii) the compliance and completeness in collecting comorbidity data.

Method A literature search was performed to identify published studies of adult spine registry data reporting comorbidities. In addition, targeted questionnaires were sent to existing global spine registries to identify the maximum number of relevant results to build the evidence map.

Results Thirty-six full-text studies met the inclusion criteria. There was substantial variation in the reporting of comorbidity data; 55% of studies reported comorbidity collection, but only 25% reported the data collection method and 20% reported use of a comorbidity index. The variation in the literature was confirmed with responses from 50% of the invited registries (7/14). Of seven, three use a recognised comorbidity index and the extent and methods of comorbidity collection varied by registry.

Conclusion This evidence map identified variations in the methodology, data points and reporting of comorbidity collection in studies using spine registry data, with no consistent approach. A standardised set of comorbidities and data collection methods would encourage collaboration and data comparisons between patient cohorts and could facilitate improved patient outcomes following spine surgery by allowing data comparisons and predictive modelling of risk factors.

Keywords Humans · Registries · Spinal diseases · Spine · Comorbidities · Evidence map

Introduction

Many patients undergoing spine surgery have general health comorbidities. The most common age group for surgical interventions is people between 60 and 80 years of age [1], which is a rapidly increasing demographic in many First-World countries such as Australia. Within this cohort, there are a common range of comorbidities in patients undergoing spine procedures, which may contribute to outcomes following surgery. These comorbidities include cardiovascular disease, chronic pulmonary conditions, cerebrovascular disease, diabetes, renal disease, liver disease, dementia, cancer and depression [2, 3].

In an effort to monitor outcomes for spine surgery patients and drive quality improvement, clinical registries have been established in many countries that follow-up spine surgery patients. A purpose of clinical registries is usually to collect patient outcome data to help improve practice through a process of evaluating outcomes and providing feedback to participating surgeons and hospitals [4, 5]. Ideally, such data would be collected prior to surgery and then at regular follow-up time points, such as 12 months and 24 months post-surgery.

The Australian Spine Registry (ASR) was established in 2016 as a pilot project [6]. As at July 2022, the registry has 15 surgeons in 18 hospital sites across Australia and has recruited 3685 patients. This number is expected to increase as the registry matures and as more surgeons and their patients are recruited. The ASR collects demographic and diagnostic information and patient-reported outcomes (PROMS) including the

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Oswestry Disability Index (ODI), Neck disability Index (NDI) and the EuroQol Five Dimensions (EQ5D). These validated measures are well-accepted measures of functional disability and quality of life relevant to spine surgery [7–10]. As an evolving clinical registry, there is a valuable opportunity at this time to consider what comorbidity data are important to collect and what can help inform research and clinical outcomes.

A previous systematic review examined a number of spine registries globally and summarised their data collection [4]. This review highlighted the heterogeneity of the data collected and the high risk of bias in many published studies and potential selection bias due to the type of registry [4]. Spine registries may be national or institutional organisations. National registries may be voluntary or mandatory, secondary to government or insurer regulations surrounding quality control or audit. Multicentre institutional registries may carry a risk of selection bias as many are tertiary referral institutions with selected patients or are industry sponsored [4]. In addition, the previous review made several recommendations regarding optimal data collection in future spine registries. These recommendations included improvements to the organisation and methodological approach to spine registries, the use of patient-reported outcome measures (PROMS), improvements to analysis and reporting, and practical data management goals [11]. While a summary of the registries and data collected was presented in the previous review, information about the comorbidities collected by the respective registries was not detailed.

Comorbidities are significant patient factors that contribute to outcomes. Comorbidities in patients may be assessed using a comorbidity scale, such as the Charlson Comorbidity Index (CCI) or the Elixhauser Comorbidity Index [12]. Comorbidity scales can be used to estimate risk of mortality and post-operative complications in a systematic manner [13]. The majority of studies have shown that complications and hospital stay are associated with comorbidities. For example, higher CCI scores are associated with readmission after orthopaedic surgery [2]; a higher risk of mortality [14]; and predictive of post-operative outcome [15]. However, the relevance of individual comorbidities is unclear.

To help guide the systematic collection of best practice data in our registry and inform practice in other registries, this evidence mapping project aims to investigate (i) what comorbidities are collected in spine registries, (ii) how they are collected and (iii) the compliance and completeness of collected comorbidity data.

Methods

This evidence map reviewed the comorbidities collected by spine registries globally and identified where possible the measures and methods used for reporting comorbidities.

Inclusion criteria–data sources

In addition to published studies, we included grey literature, such as annual reports and conference proceedings.

The inclusion criteria for this evidence map were that the study (a) reported registry data, (b) reported comorbidity collection and data items, and (c) was limited to patients aged 18 and over.

We defined spine registry data as data collected in a multicentre activity which reports outcomes of spine surgery. This definition included national registries, registries collecting data from multiple hospital sites and surgical databases from multiple sources that include data for spine surgery outcomes. We defined compliance as the proportion of patients for whom data are entered. Completeness was defined as the extent of comorbidity data collected and reported.

Exclusion criteria

We did not include studies reporting data for people aged under 18 years due to a potential confounder with the consent process and disease spectrum. We also excluded studies from single disease-specific databases, data from single institutions, data related to spine trauma or emergency admission, non-English publications and those published before 2015. The rationale for limiting the search to results published since 2015 was that the previous systematic review by van Hoof and colleagues [4] had listed the registries and outcomes measured up to 2015. Since this time, new registries have been formed and we wanted to obtain a more contemporary view of the evidence about comorbidity measurement and inclusion within spine registries.

Healthcare settings

We included studies from all healthcare systems that contribute to spine registry data. Earlier work [4] has identified registries in numerous countries with differing healthcare systems. As such, we expected a range of healthcare settings and systems to be represented in the evidence map.

Outcomes–comorbidity measures

We included all studies that used the descriptor "comorbidity" or "comorbidities" with enough detail to determine what comorbidities had been collected and, if available, the method of collection. This pragmatic approach was taken as our knowledge of spine registry data suggested that there

would considerable variation of collection and measurement methods.

Search strategy

The search strategy was designed to capture all publications that showed the comorbidities collected by spine registries and was based on the search used by van Hoof et al. [4], with additional terms to capture comorbidities. We included terms related to the words "spine", "back pain", "registry", "comorbidity" and "surgery". The terms were searched separately and then combined with the Boolean operator AND to include all terms.

The search was designed to retrieve a broad range of results and included all published research articles based on spine registry data and included conference abstracts. In addition, we used the search engines Google and Google Scholar to search for available registry annual reports and presentations from professional conferences that would not be available through the databases. Where annual reports were available, we included the most recently published version.

Ovid Embase (including Medline) was searched on 15 September 2021. The search included the fields of: title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word and candidate term word. The search was limited to English language results from 1 January 2015, to 15 September 2021. In addition, we used the same search strategy to search Scopus for any additional papers or conference abstracts. The search strategy is shown in a supplementary file (S1).

Additional primary data collection from established registries

Our knowledge of the literature based on spine registry data suggested that there may be limited information available in published articles, conference abstracts or published reports to detail the collection of comorbidity outcomes by spine registries. As such, we decided to write to established registries to directly solicit information. We established a list of spine registries, based on previously published work [4] and updated to reflect more recent additions. We searched for publicly available contacts for the relevant registries and augmented this with contact details for registry leaders known to the authors. A list of questions was drafted by one author and reviewed by two other authors. This list of questions is included as a supplementary file (S2). This data collection was approved by the Human Research Ethics Committee (HREC) of the participating university, HREC approval number 30985. The questions were then emailed to the relevant contact person of the respective registries.

Results

Articles, conference abstracts, annual reports and presentations

As shown in the PRISMA 2020 flow diagram (Fig. 1) [16], the search identified 172 records from Ovid Embase (including Medline), with a further 20 unique entries identified from Scopus. Following removal of duplicate records ($n=4$), 188 records were screened on the abstract by one author (MQ). Ninety records were excluded based on the abstract. As such, 99 records were sought for retrieval. Twenty-two of these records were for conference abstracts, and as such, the full text was not available. Seventy-seven full-text articles were screened for inclusion by two authors (MQ and EA), with the data extraction spreadsheet reviewed by three authors (MQ, EA and MJ) until consensus was reached for inclusion. Following screening of the abstracts and full-text articles, 36 full-text articles and 4 conference abstracts were included in the evidence map. Reasons for exclusion included data from a single site ($n=22$), a specialist database ($n=3$), data from a registry other than spine ($n=7$), insufficient comorbidity data ($n=4$), paediatric data ($n=4$) and systematic reviews ($n=1$).

Five annual reports and 1 presentation were publicly available on the Internet. While 1 report (Australian Spine Registry) and 1 slide presentation (American Spine Registry) mentioned comorbidities, neither detailed the method of comorbidity collection.

Types of registries

Due to the inclusion criteria, studies represented different kinds of registries. There were 11 studies from national spine registries [17–27], 2 from combined registry data within a country [28, 29], 3 from an international spine registry [30–32], 4 from multicentre registries [11, 33–35], 15 from large surgical databases [36–50], 2 from a statewide registry [51, 52] and 3 where the type of registry was unclear [53–55]. Details of these registries are shown in Table 1.

Comorbidities collected and methods of collection

In the included published studies, the most commonly collected comorbidities were: neurological disease, cardiovascular disease, cancer, anxiety/depression, diabetes, smoking status, chronic obstructive pulmonary disease (COPD), cerebrovascular disease and obesity (Fig. 2).

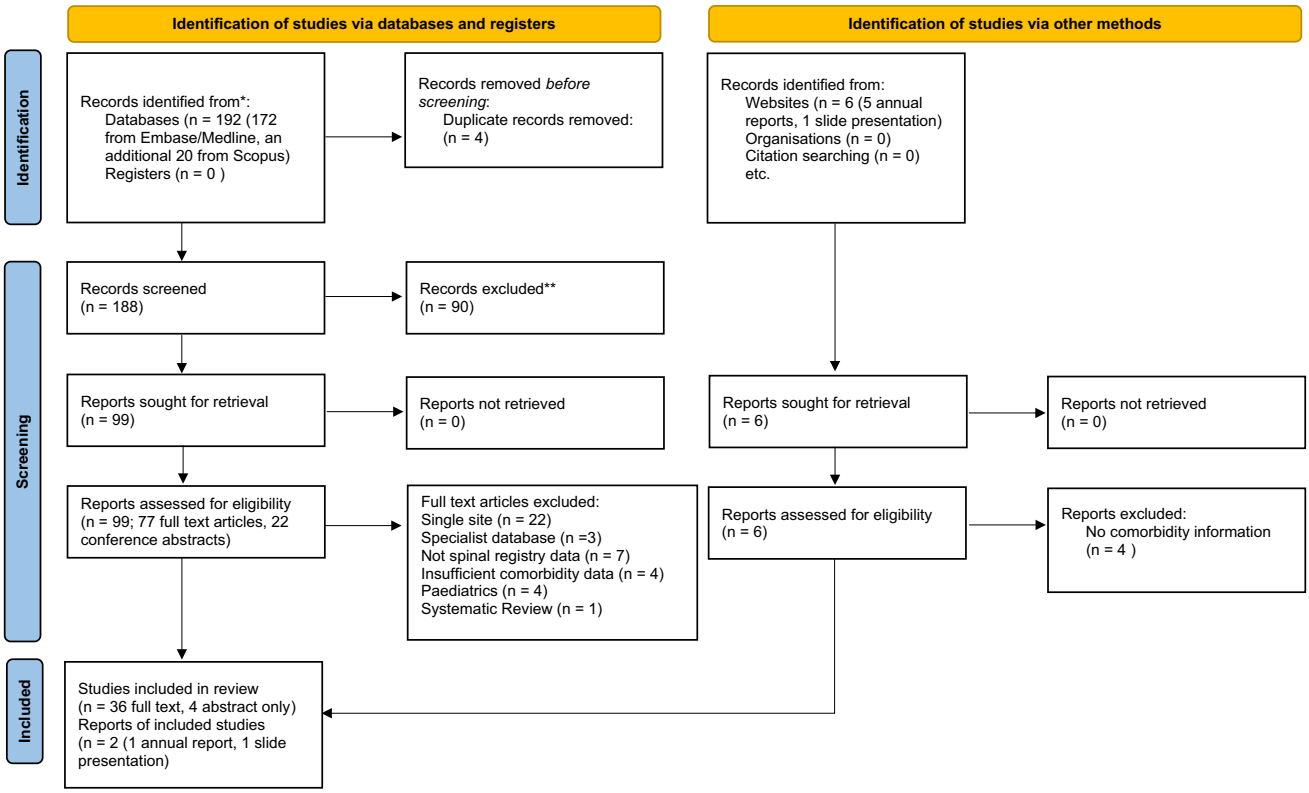

Fig. 1 Prisma 2020 flow diagram showing identification and screening of included studies

Table 1 Registries with included studies

Registry name	Type of registry	Country/region	Number of published studies included
Multicentre	Multicentre	USA	4
Canadian Spine Outcomes and Research Network (CSORN)	National	Canada	2
SWESpine	National	Sweden	4
NORSpine	National	Norway	1
DANESpine	National	Denmark	1
SWESpine, NORSpine and DANESpine combined	National	Sweden, Norway, Denmark	3
SWESpine and Swedish Hip Arthroplasty Register	Combined databases	Sweden	1
Finnish PERFECT	Combined databases	Finland	1
Spine Tango	International	Europe	3
Quality outcomes database lumbar registry	Surgical database	USA	5
Quality outcomes database	Surgical database	USA	2
Michigan Spine Surgery Improvement Collaborative (MSSIC)	Statewide registry	USA	2
American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)	Surgical database	USA	8
Japan Association of Spine surgeons with Ambition (JASA)	Unclear	Japan	1
“27 linked institutions”	Unclear	Japan	1
“Prospective web-based registry”	Unclear	USA	1
Total			40

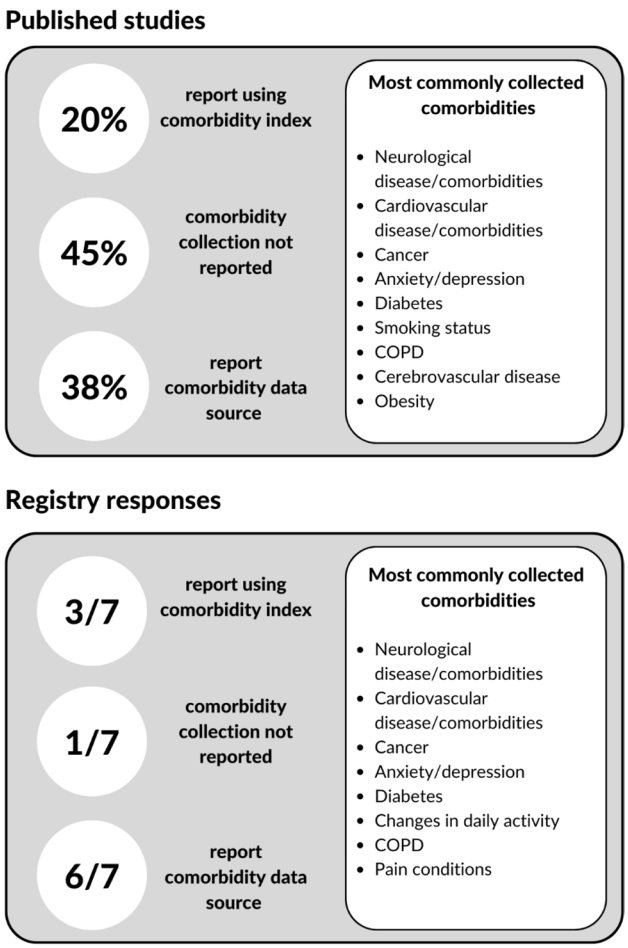

Fig. 2 Overview of the most commonly collected comorbidities, use of comorbidity indices and reporting of comorbidity collection and data source, from included studies and from registry responses

55% of studies reported comorbidity collection. 20% of studies reported using a comorbidity index. Only 25% of these studies (10/40) explicitly stated how the actual data were collected and 38% of studies reported the comorbidity source, i.e. patient, EMR, surgeon, etc. (Fig. 2).

The method of comorbidity collection differed by registry. Of the 11 studies from national spine registries, SWEspine and DANEspine report use of patient-reported comorbidity data collected at baseline or following surgery, while others (e.g. NORspine) report use of surgeon reported data for individual patients [17, 21, 22]. One SWEspine study reported use of a comorbidity index calculated on healthcare utilisation in the 12 months prior to surgery [19]. The Canadian Spine Outcomes and Research Network (CSORN) registry employs local research coordinators who enrol the patients at each site and collect demographic and comorbidity data [20]. The 3 conference abstracts from established national spine registries (2 SWEspine, 1 CSORN) did not explicitly report the method of comorbidity data collection [25, 27, 56].

There were 3 studies from an international registry, Spine Tango [30–32]. Studies using data from this registry report the use of standardised forms to collect the American Society of Anaesthesiologists (ASA) grade but suggest that this registry does not collect other comorbidity data [31].

The 15 studies from large surgical outcomes database registries report employment of dedicated personnel and specific forms, and commonly utilise extraction from hospital records to populate the data at each site. Examples of this can be found in studies from the Quality Outcomes Database [38, 45], the Quality Outcomes Database Lumbar Registry [36, 39, 44, 47, 50] and the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) [37, 40–43, 46, 48, 49].

The one included statewide registry (Michigan Spine Surgery Improvement Collaborative (MSSIC)) reports collection of demographic and comorbidity data, but the collection method is not clear. One study from MSSIC reports comorbidity collection at baseline [51], while another reports collection via patient self-report 30 days after surgery [52].

The studies identified from multicentre registries reported comorbidity collection using the CCI or extraction to include the comorbidities covered by the CCI [11, 33–35]. One of these studies also documented the ASA grade [35].

The studies where the registry type was unclear did not state how the comorbidity data were collected [53–55], though one study reported that data were recorded for the diseases and/or states covered by the CCI [53].

An overview of the included studies, the comorbidities collected and the method of collection is shown in Table 2.

The extent of compliance and completeness in collecting comorbidities data

None of the included studies reported the compliance and success of comorbidity data collection from any type of spine registry.

Results–data collection from other spine registries

Of the 14 spine registries approached, we received responses from 7 (50%). These were the British Spinal Registry, the Norwegian registry for spine surgery (NORspine), Eurospine (Spine Tango), the Canadian Spine Outcomes and Research Network (CSORN), SweSpine, DaneSpine and the American Spine Registry (AmSR).

Registries reported similar variation to published studies regarding comorbidity collection. The most commonly collected comorbidities were: neurological disease, cardiovascular disease, cancer, anxiety/depression, diabetes, changes in daily activities, COPD and pain conditions (Fig. 2,

Table 2 Included studies, comorbidities collected and the method of collection

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Surgical Treatment of Degenerative Disk Disease in Three Scandinavian Countries: An International Register Study Based on Three Merged National Spine Registers	Global Spine Journal. 9(8) (pp 850–858), 2019. Date of Publication: 01 Dec 2019	Andersen M.O. Fritzell P. Eiskjaer S.P. Lagerback T. Hagg O. Nordvall D., et al.	2019	At the time of admission for surgery (baseline), the patient self-reports data on demographics, life style matters, comorbidity, and PROMs with the use of questionnaires	Binary y/n classification: Any comorbidity Neurological comorbidities Heart comorbidities Cancer comorbidities	Swespine, NORspine, DANEspine
Article	Patient characteristics of smokers undergoing lumbar spine surgery: An analysis from the Quality Outcomes Database	Journal of Neurosurgery: Spine. 27(6) (pp 661–669), 2017. Date of Publication: December 2017	Asher A.L. Devin C.J. McCutcheon B. Chotai S. Archer K.R. Nian H., et al.	2017	None	Anxiety CAD Depression Diabetes Smoking status	Quality Outcomes Database Lumbar Registry
Article	Respiratory Compromise After Anterior Cervical Spine Surgery: Incidence, Subsequent Complications, and Independent Predictors	Global Spine Journal. (No pagination), 2021. Date of Publication: 2021	Boddapati V. Lee N.J. Mathew J. Held M.B. Peterson J.R. Vulapalli M.M., et al.	2021	Not stated	Bleeding disorder Congestive heart failure COPD Diabetes Dyspnoea Hypertension smoking history	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Women fare best following surgery for degenerative lumbar spondylolisthesis: a comparison of the most and least satisfied patients utilizing data from the Quality Outcomes Database	Neurosurgical focus. 44(1) (pp E3), 2018. Date of Publication: 01 Jan 2018	Chan A.K. Bisson E.F. Bydon M. Glassman S.D. Foley K.T. Potts E.A., et al.	2018	Not stated explicitly	Anxiety ASA classification Coronary artery disease [CAD] Depression Diabetes Osteoporosis Smoking	Quality Outcomes Database (QOD)
Article	The influence of unemployment and disability status on clinical outcomes in patients receiving surgery for low back-related disorders: An observational study	Spine Surgery and Related Research. 5(3) (pp 182–188), 2021. Date of Publication: 2021	Cook C.E. Garcia A.N. Shaffrey C. Gottfried O	2021	Through QOD, where presence of comorbidities was labelled as absent or present	Anxiety CAD COPD Depression Diabetes Multiple sclerosis Osteoarthritis Osteoporosis PVD Renal disease	Quality Outcomes Database Lumbar Registry

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	United States neurosurgery annual case type and complication trends between 2006 and 2013: An American College of Surgeons National Surgical Quality Improvement Program analysis	Journal of Clinical Neuroscience, 31. 2017	Cote D.J., Karhade A.V., Larsen A.M.G., Burke W.T., Castlen J.P., Smith T.R	2017	Not stated	Alcohol use CHF Coma > 24 h COPD Current dialysis Current smoker CVA with neurological Deficit Dependent health status Prior to surgery Diabetes Disseminated cancer Dyspnoea Hypertension requiring medication Impaired sensorium MI in previous 6 months Open wound/infection Quadriplegia Recent cancer treatment Recent operation Renal failure Steroid use for chronic condition Ventilator dependence	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Lumbar surgery prior to total hip arthroplasty is associated with worse patient reported outcomes	Bone and Joint Journal, 99B, 6. 2017	Eneqvist T., Nemes S., Brisby H., Fritzell P., Garellick G., Rolfson O	2017	Reported by patients as per CCI, for data from the Swedish Hip Arthroplasty Register	As per CCI	SweSpine and Swedish Hip Arthroplasty Register
Conference abstract	Patient reported value 1 year after surgery for lumbar disc herniation: Predictors of outcome using the Swedish national spine register; Swespine	European Spine Journal. Conference: EUROSPINE Meetings 2015. Copenhagen Denmark. Conference Publication: 24(6 SUPPL. 1) (pp S705), 2015. Date of Publication: September 2015	Fritzell P. Hagg O. Stromqvist B. Knutsson B	2015	None stated	Not stated	Swespine

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Conference abstract	179. Predictors of clinical outcome following surgery for lumbar spinal stenosis: a study of postoperative pain and disability trajectories	Spine Journal. Conference: Proceedings of the 34th Annual Meeting of the North American Spine Society. Chicago United States. 19(9 Supplement) (pp S86-S87), 2019. Date of Publication: September 2019	Hebert J. Bigney E. Wedderkopp N. Richardson E.A. Darling M.A. Manson N.A	2019	None stated	Depression	Canadian Spine Outcomes and Research Network (CSORN)
Article	Pain during sex before and after surgery for lumbar disc herniation: A multicenter observational study	Spine. 45(24) (pp 1751–1757), 2020. Date of Publication: 15 Dec 2020	Holmberg S.T. Salvesen O.O. Vangen-Lonne V. Hara S. Fredheim O.M. Solberg T.K., et al.	2020	Registration form with comorbidity fields	ASA grade Cancer Cardiovascular disease Cerebrovascular disease Depression or anxiety Endocrine disorders Hip or knee osteoarthritis Hypertension Lung disease Musculoskeletal pain Neurological disorder Osteoporosis Rheumatic diseases Vascular claudication	NORspine
Article	Predicting clinical outcome and length of sick leave after surgery for lumbar spinal stenosis in Sweden: a multiregister evaluation	European Spine Journal. 28(6) (pp 1423–1432), 2019. Date of Publication: 01 Jun 2019	Iderberg H. Willers C. Borgstrom F. Hedlund R. Hagg O. Moller H., et al.	2019	Comorbidity index calculated on healthcare utilisation in 12 months prior to surgery	Not specified	Swespine
Article	Factors associated with using an interbody fusion device for low-grade lumbar degenerative versus isthmic spondylolisthesis: A retrospective cohort study	Journal of Neurosurgery: Spine. 35(3) (pp 299–307), 2021. Date of Publication: September 2021	Inculet C. Urquhart J.C. Rasoulinejad P. Hall H. Fisher C. Attabib N., et al.	2021	Reported preoperatively by patients, classified by number of comorbidities	Cardiac disease Cerebrovascular disease Depression Diabetes Hypertension Osteoarthritis Peripheral vascular disease Systemic vascular disease	CSORN national registry

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Conference abstract	Surgical treatment outcome of lumbar disc herniation (LDH) in different ages	Value in Health. Conference: ISPOR 20th Annual European Congress. Glasgow United Kingdom. 20(9) (pp A538), 2017. Date of Publication: October November 2017	Jonsson E. Hansson-Hedblom A. Fritzell P. Hagg O. Borgstrom F	2017	None		Swedish national spine surgery register: Swespine

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Machine learning modeling for predicting hospital readmission following lumbar laminectomy	Journal of Neurosurgery: Spine, 30,3. 2019	Kalagara S., Eltorai A.E.M., Durand W.M., Mason DePasse J., Daniels A.H	2019	States that the ACS-NSQIP uses medical record data	Acute renal failure Angina (in the month prior to surgery) Ascites Bleeding disorder Chemotherapy (in the 30 days prior to surgery) CHF (in the 30 days prior to surgery) CNS tumour Current pneumonia Currently on dialysis Diabetes Disseminated cancer Oesophageal varices Hemiplegia High alcohol use History of revascularisation/amputation for peripheral vascular disease History of severe COPD History of transient ischaemic attacks, CVA or stroke w/or w/o neurological deficit Hypertension requiring medicine Impaired sensorium In coma for > 24 h MI (in the 6 months prior to surgery) Open wound infection prior to surgery Paraplegia Preop transfusion of RBCs Previous cardiac surgery Previous operation (in the 30 days prior to surgery) Previous percutaneous coronary intervention Quadriplegia Radiotherapy (in the 90 days prior to surgery) Rest pain/gangrene Smoking Steroid use for chronic condition Systemic sepsis Ventilator dependent Weight loss (> 10% loss in the 6 months prior to surgery)	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Preoperative and surgical factors associated with postoperative intensive care unit admission following operative treatment for degenerative lumbar spine disease	European Spine Journal, 25, 3. 2016	Kay H.F., Chotai S., Wick J.B., Stonko D.P., McGirt M.J., Devin C.J	2016	Not stated	Anxiety ASA grade CAD CHF Depression Diabetes Hypertension MI	"Prospective, web-based registry"
Article	Complications Associated With Spine Surgery in Patients Aged 80 Years or Older: Japan Association of Spine Surgeons with Ambition (JASA) Multicenter Study	Global Spine Journal. 7(7) (pp 636–641), 2017. Date of Publication: 01 Oct 2017	Kobayashi K. Imagama S. Ando K. Ishiguro N. Yamashita M. Eguchi Y., et al.	2017	Not stated	Cerebrovascular disease, Diabetes Hypertension Pre-existing neoplasm	JASA (Japan Association of Spine Surgeons with Ambition)
Article	Risk factors for in-hospital mortality after spine surgery: a matched case–control study using a multicenter database	Spine Journal, 20, 3. 2020	Kushioka J., Takenaka S., Makino T., Sakai Y., Kashii M., Iwasaki M., et al.	2020	Diseases for which a patient regularly sees a doctor. Data recorded for the diseases/states covered by the CCI	As per CCI	27 linked institutions in Japan
Article	Effectiveness of surgery for sciatica with disc herniation is not substantially affected by differences in surgical incidences among three countries: results from the Danish, Swedish and Norwegian spine registries	European Spine Journal. 28(11) (pp 2562–2571), 2019. Date of Publication: 01 Nov 2019	Lagerback T. Fritzell P. Hagg O. Nordvall D. Lonne G. Solberg T.K., et al.	2019	Comorbidity is physician-reported in the Norwegian register and patient-reported in the Swedish and Danish registers	Binary y/n classification: Any comorbidity Neurological comorbidities Heart comorbidities Cancer comorbidities	Swespine, NORspine, DANEspine

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Effects of preoperative obesity and psychiatric comorbidities on minimum clinically important differences for lumbar fusion in grade 1 degenerative spondylolisthesis: Analysis from the prospective Quality Outcomes Database registry	Journal of Neurosurgery: Spine. 33(5) (pp 635–642), 2020. Date of Publication: November 2020	Laratta J. Carreon L.Y. Buchholz A.L. Yew A.Y. Bisson E.F. Mummaneni P.V., et al.	2020	Obesity—demographic info in registry (BMI > 30) Depression and anxiety: self-report or note in medical record	Anxiety Depression Obesity	Quality Outcomes Database Lumbar Registry
Article	Increased rates of septic shock, cardiac arrest, and mortality associated with chronic steroid use following anterior cervical discectomy and fusion for cervical stenosis	International Journal of Spine Surgery. 14(5) (pp 649–656), 2020. Date of Publication: 01 Oct 2020	Lee R. Lee D. Gowda N.B. Iweala U. Weinreb J.H. Falk D.P., et al.	2020	Not stated	ASA grade Congestive heart failure COPD Diabetes Dialysis dependence Disseminated cancer Dyspnoea Functional dependence Haematologic disorders Hypertension acute renal Failure Open wound or wound infections Smoking history Systemic sepsis Weight loss of more than 10% in previous 6 months	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Lumbar spinal stenosis: comparison of surgical practice variation and clinical outcome in three national spine registries	Spine Journal. 19(1) (pp 41–49), 2019. Date of Publication: January 2019	Lonne G. Fritzell P. Hagg O. Nordvall D. Gerdhem P. Lagerback T., et al.	2019	At admission for surgery (baseline), the patient reports data on demographics, risk factors, and PROMs—method of comorbidity collection not stated	Binary y/n classification: Any comorbidity, Neurological comorbidities Heart comorbidities Cancer comorbidities	Swespine, NORspine, DANEspine

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Disparities in outcomes after spine surgery: A Michigan Spine Surgery Improvement Collaborative study	Journal of Neurosurgery: Spine. 35(1) (pp 91–99), 2021. Date of Publication: July 2021	Macki M. Hamilton T. Lim S. Telemi E. Bazydlo M. Nerenz D.R., et al.	2021	None stated	The associations between race/ethnicity and the pros were adjusted for: Age BMI Coronary artery disease Current smoking status Depression Diabetes Education (at least some college vs high school diploma or less) Preoperative ambulation status Sex	MSSIC
Article	Is There a "Sex Effect" in 30-Day Outcomes After Elective Posterior Lumbar Fusions?	World Neurosurgery, 120, 2018	Malik A.T., Jain N., Yu E., Kim J., Khan S.N	2018	None stated	Bleeding disorders CHF Chronic steroid use COPD Diabetes Dialysis dependent Dyspnoea Functional health status prior to surgery Hypertension Smoking	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	An analysis from the Quality Outcomes Database, Part 1. Disability, quality of life, and pain outcomes following lumbar spine surgery: Predicting likely individual patient outcomes for shared decision-making	Journal of Neurosurgery: Spine. 27(4) (pp 357–369), 2017. Date of Publication: October 2017	McGirt M.J. Bydon M. Archer K.R. Devin C.J. Chotai S. Parker S.L., et al.	2017	ASA grade	CAD Diabetes Osteoporosis Psychological distress Smoking	Quality Outcomes Database Lumbar Registry
Article	Minimally invasive versus open fusion for Grade I degenerative lumbar spondylolisthesis: analysis of the Quality Outcomes Database	Neurosurgical focus. 43(2) (pp E11), 2017. Date of Publication: 01 Aug 2017	Mummaneni P.V. Bisson E.F. Kerezoudis P. Glassman S. Foley K. Slotkin J.R., et al.	2017	None stated	Anxiety ASA grade Depression Diabetes Osteoporosis Smoking	Quality Outcomes Database

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Risk factors for dural tears: a study of elective spine surgery*	Neurological Research. 39(2) (pp 97–106), 2017. Date of Publication: 01 Feb 2017	Murphy M.E. Kerezoudis P. Alvi M.A. McCutcheon B.A. Maloney P.R. Rinaldo L., et al.	2017	ASA scores	Congestive heart failure COPD Corticosteroid use for a Chronic condition Diabetes Hypertension	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Discharge destination influences risks of readmission and complications after lumbar spine surgery in severely disabled patients	Clinical Neurology and Neurosurgery. 207 (no pagination), 2021. Article Number: 106801. Date of Publication: August 2021	Park C. Cook C.E. Garcia A.N. Gottfried O.N	2021	ASA scores, CCI	Anxiety BMI > 30 Depression Diabetes Multiple sclerosis Parkinson's disease	Quality Outcomes Database Lumbar Registry
Article	Prognostic factors for satisfaction after decompression surgery for lumbar spinal stenosis	Neurosurgery. 82(5) (pp 645–651), 2018. Date of Publication: 01 May 2018	Paulsen R.T. Bouknaitir J.B. Fruensgaard S. Carreon L. Andersen M	2018	Reported by patients at baseline	Comorbidities were registered by the patient at baseline and divided into 4 categories: No comorbidities Cardiac disease Neurological disease Cancerous disease	DaneSpine
Article	Impact of Obesity on Outcomes in Adults Undergoing Elective Posterior Cervical Fusion	Spine, 42, 4, 2017	Phan K., Kothari P., Lee N.J., Virk S., Kim J.S., Cho S.K	2017	Not stated	Cardiac comorbidities Pulmonary comorbidities	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Identifying thoracic compensation and predicting reciprocal thoracic kyphosis and proximal junctional kyphosis in adult spinal deformity surgery	Spine. 43(21) (pp 1479–1486), 2018. Date of Publication: 2018	Protopsaltis T.S. Diebo B.G. Lafage R. Henry J.K. Smith J.S. Scheer J.K., et al.	2018	CCI	As per CCI	Multicentre registry
Article	Association of patient-reported narcotic use with short- and long-term outcomes after adult spinal deformity surgery: Multicenter study of 425 patients with 2 year follow-up	Spine. 43(19) (pp 1340–1346), 2018. Date of Publication: 2018	Raad M. Jain A. Neuman B.J. Hassanzadeh H. Gupta M.C. Burton D.C., et al.	2018	CCI	As per CCI	Multicentre registry

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Mortality Caused by Surgery for Degenerative Lumbar Spine	Spine. 42(14) (pp 1080–1087), 2017. Date of Publication: 15 Jul 2017	Salmenkivi J. Sund R. Paavola M. Ruuth I. Malmivaara A	2017	None stated	Alcoholism/narcomania Atherosclerosis Atrial fibrillation COPD and asthma Dementia Depression Diabetes EPILEPSY Heart insufficiency Hypercholesterolemia Hypertension Ischaemic heart disease Malignancy Multiple sclerosis Parkinson disease Psychosis Uraemia	Finnish PERFECT back database
Article	Racial Disparities in Surgical Outcomes After Spine Surgery: An ACS-NSQIP Analysis	Global Spine Journal, 9, 6.2019	Sanford Z., Taylor H., Fiorentino A., Broda A., Zaidi A., Turcotte J., Patton C	2019	Not stated	Ascites CHF COPD Diabetes Dyspnoea Hypertension Inpatient status Renal failure, Smoking status Ventilator use	American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP)
Article	Development of a Preoperative Adult Spinal Deformity Comorbidity Score That Correlates With Common Quality and Value Metrics: Length of Stay, Major Complications, and Patient-Reported Outcomes	Global Spine Journal. 11(2) (pp 146–153), 2021. Date of Publication: March 2021	Sciubba D. Jain A. Kebaish K.M. Neuman B.J. Daniels A.H. Passias P.G., et al.	2021	CCI,	As per CCI	Unstated multicentre registry, USA

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Article	Outcome of decompression with and without fusion in spinal stenosis with degenerative spondylolisthesis in relation to preoperative pain pattern: A register study of 1624 patients	Spine Journal. 15(4) (pp 638–646), 2015. Date of Publication: 01 Apr 2015	Sigmundsson F.G. Jonsson B. Stromqvist B	2015	None identified	Not clear—binary yes/no measure	Swespine
Article	Complication rates associated with 3-column osteotomy in 82 adult spinal deformity patients: Retrospective review of a prospectively collected multicenter consecutive series with 2-year follow-up	Journal of Neurosurgery: Spine. 27(4) (pp 444–457), 2017. Date of Publication: October 2017	Smith J.S. Shaffrey C.I. Klineberg E. Lafage V. Schwab F. Lafage R., et al.	2017	ASA score, CCI	As per CCI	Multicentre registry
Article	Predictors of improvement in quality of life and pain relief in lumbar spinal stenosis relative to patient age: a study based on the Spine Tango registry	European Spine Journal. 26(2) (pp 462–472), 2017. Date of Publication: 01 Feb 2017	Sobottke R. Herren C. Siewe J. Mannion A.F. Roder C. Aghayev E	2017	Collected with Spine Tango forms	ASA grade	SpineTango
Article	The Preoperative Risks and Two-Year Sequelae of Postoperative Urinary Retention: Analysis of the Michigan Spine Surgery Improvement Collaborative (MSSIC)	World Neurosurgery, 133. 2020	Zakaria H.M., Lipphardt M., Bazydlo M., Xiao S., Schultz L., Chedid M., et al.	2020	Via patient self-report 30 days after surgery	Anxiety disorder ASA grade > 2 BMI CAD Depression Diabetes History of DVT Osteoporosis, Scoliosis	MSSIC Registry (Michigan Spine Surgery Improvement Collaborative) 27 hospitals across Michigan
Article	Influence of previous surgery on patient-rated outcome after surgery for degenerative disorders of the lumbar spine	European Spine Journal. 25(8) (pp 2553–2562), 2016. Date of Publication: 01 Aug 2016	Zehnder P. Aghayev E. Fekete T.F. Haschtmann D. Pigott T. Mannion A.F	2016	Collected with Spine Tango forms	ASA grade	SpineTango

Table 2 (continued)

Type	Title	Publication	Authors	Years	Comorbidity measure/method of collection	Comorbidities included	Registry
Conference abstract	The law of diminishing returns in surgery for degenerative spinal disorders: Quantification of the effect of previous surgery on patient rated outcomes	European Spine Journal. Conference: EUROSPINE Meeting 2016. Berlin Germany. 25(Supplement 3) (pp S303), 2016. Date of Publication: September 2016	Zehnder P. Aghayev E. Fekete T.F. Haschtmann D. Pigott T. Mannion A.F	2016	As per SpineTango	Not stated	Spine Tango

Table 3). Recognised comorbidity indices were only used by 2/7 registries: the British Spine Registry (CCI) and CSORN (Quan Comorbidity Index). The American Spine Registry reports using an expanded dataset including the CCI where relevant to specific studies or reports. A further 3/7 of registries reported use of ASA grade entered by the operating surgeon in lieu of a recognised comorbidity index (SweSpine, DaneSpine, NORSpine). The use of patient-reported comorbidity data at baseline is common (SweSpine, DaneSpine, British Spine Registry CSORN). The American Spine Registry uses electronic medical record (EMR) extraction to report comorbidities identified by International Classification of Disease (ICD) codes, which are submitted to the registry by staff at participating institutions.

Similarly, as indicated in Table 3, the compliance and completeness for those entering the comorbidity information varied by registry. The British Spine Registry reported 100% compliance for patients entered into the registry, as the data fields are mandatory for both patients and clinicians. The Scandinavian registries report differing levels of compliance. For patient-reported comorbidities SweSpine reports 80% compliance at baseline, while DaneSpine reports "almost 100%". NORspine reports difficulties in assessing compliance, as both patients and surgeons can choose a "no comorbidity" option. Difficulties in obtaining follow-up data were reported; Swespine reported 75% compliance at 1-year follow-up, while DaneSpine reported 80% compliance at 1 year and 45% compliance at 10 years. For ASA grade, there were also differences in compliance; NORspine reports 100% compliance, while DaneSpine reports approximately 50% compliance. The AMSR highlighted that it is difficult to ascertain whether "no reported comorbidities" represents patients with no comorbidities or the degree of missing data.

Discussion

Our findings have identified that there is variation in the methods of collection and the types of comorbidities collected in the published literature, with many studies not reporting these details. Our additional primary data collection from established registries was vital to our understanding regarding comorbidity collection in spine registries as many published studies provided scant detail about the methods of collection, the rationale for using a given method or the completeness and compliance associated with use.

Typically, the most complete comorbidity collection is done by large surgical databases, such as the American College of Surgeons NSQIP. These large multicentre databases or registries have dedicated staff who collect the comorbidity data directly from the patient at baseline or have access to patient medical records from either electronic hospital databases or national healthcare registers. In addition, for

countries that have a nationalised healthcare system, or where medical records are available on a single national database, consistent comorbidity data are easier to collect. Canada, for example, has a universal, publicly funded, decentralised healthcare system where patient data are available through hospital EMRs. In Sweden, the use of personal identification numbers facilitates the linkage of patient data making the collection of specific comorbidities easier [57].

Communication with the established registries also identified that there was limited consistency in the comorbidities collected, confirming the findings from published studies. In spine surgery, the typical comorbidity measure is the CCI [12]. However, the CCI is now used to predict a variety of outcomes and to adjust for comorbidities. Furthermore, the CCI has been adapted and modified by researchers in relation to included conditions and the weighting of conditions [58] making comparisons across studies using different versions of CCI difficult. Some registries use ASA grades as a proxy for comorbidity measurement. The ASA classification was developed in 1942 and has undergone various revisions [59] with the latest amendment in 2020 [60]. It currently serves two functions: (a) to quantify the physiological reserve of a patient at the time they are about to undergo a surgical procedure and (b) as a healthcare billing tool [61]. Although not a formal comorbidity instrument or a formal predictor of perioperative risks, ASA is used to stratify the preoperative health status and for assessing risk of intra- and post-operative complications of spine surgery patients [62]. Although the ASA is a simple rating process, it is based on multiple factors and requires the expertise of a trained anaesthetist or surgeon. However, due to the subjective nature of scoring, studies have shown variability between surgeons' and anaesthetists' ASA scores [63, 64]. The inter-reliability of the ASA score, when different anaesthetists were compared, has been reported to be only "fair" [65].

However, a recent study evaluated the discriminatory ability of the ASA, the CCI and the modified Frailty Index (mFI) to predict adverse outcomes after lumbar fusion in 17,000 patients, finding that the most predictive comorbidity index was the ASA and the demographic factor of age [58]. This raises an interesting point about the need for collecting extensive comorbidity data.

The importance of age should not be overlooked. In 2019, the number of people globally over the age of 65 was 703 million with this number predicted to double by 2050 [66]. The proportion of older people undergoing spine surgery is also increasing with the age group where spine surgery is most frequently performed being 60–79 years [67]. The collection of comorbidity or "multimorbidity" data (multimorbidity defined as the presence of two or more chronic diseases [68]) is important for the assessment of risk and personalised management of patients undergoing spine surgery. To analyse spinal surgery outcomes, patient-reported outcomes, and to translate these outcomes into perioperative risk and healthcare costs, accurate collection of comorbidities is essential [68]. However, the methods used for collecting comorbidities in spine surgery literature is rarely reported, and the reporting of comorbidities is very heterogeneous [68, 69].

The use of comorbidity indices in large registries or national datasets, like NSQIP or CSORN, can also be influenced by the type of data the registry collects, the method of collection and the data completeness [58, 70]. Comorbidities which are collected directly from electronic hospital records, and coded by medical administrators, rely on the accuracy and definition of the comorbidities in the International Classification of Disease (ICD) handbook. As a consequence of updates to the ICD (the latest being ICD-10), registries and large dataset comorbidity definitions can change, and the indices they use need to be adapted for continued accuracy making longitudinal analyses difficult [70].

Strengths of this evidence map are that the literature was extensively searched and we subsequently collected primary data from international spinal registries to address the gaps in the published literature. Limitations of this evidence map include the low response rate from the primary data collection; of the 14 spine registries contacted, only 50% responded. However, the registries that responded represent a range of registries within different countries and healthcare systems, similar to the published literature. Another limitation is that our search and primary data collection were limited to the English language, so it is possible that there may be relevant studies and/or registries from non-English-speaking countries that were not included. Although potentially clinically important, the collection and relevance of risk adjustment factors such as patient education level or insurance status are not comorbidities and were therefore beyond the scope of this study.

Conclusion

This evidence map identified that publication of spine surgery comorbidity data either by registries or by smaller research groups is varied, with less than half of published studies reporting the methods of data collection and a low proportion reporting use of a comorbidity index. The quantity, type and collection method of comorbidity data, along with who should collect or report the data to accurately determine prediction of surgical risks and outcomes remains unclear. Without disclosure on the data source and method, the ability to directly compare information from different registries is extremely difficult. Due to the variability in published data, we recommend that these details be included in the literature to inform researchers of the types of methodologies used. For spine registries, it would be beneficial to

Table 3 Spine registry responses to the comorbidity data questionnaire

Registry name	Year registry established	Number of comorbidities collected	Comorbidities collected by the registry	Time points of collection	Use of a comorbidity index	Method of collection (paper-based, software, EMR mining)?	Collected by whom (surgeon, junior staff, patient, medical records)?	Completion rate for those entering the information?
British Spinal Registry	2012	> 20	Anaemia or other blood disease (e.g. bleeding, blood clotting disorder) Aortic aneurysm Arrhythmia Back pain Blood-borne infectious diseases Cancer (within the last 5 years) Depression Diabetes Disease of the nervous system Epilepsy or seizures Fainting or blackouts Heart disease Hypercholesterolaemia Hypertension Kidney disease Leg pain when walking due to poor Circulation Liver disease Lung disease No medical problems On selection of some comorbidities, e.g. heart, lung, cancer, blood-borne diseases, PE or DVT the patient is asked further questions about this comorbidity Osteoarthritis or degenerative arthritis Other—on selecting this a patient can then free text any other information they wish Problems caused by stroke Rheumatoid arthritis Stomach disease (peptic ulcer) Thyroid or endocrine disease	Once, at baseline entry to the registry—the patient puts what they believe and then this is verified by the clinician in their clinical assessment, with the availability of the patient responses on screen at the same time	Charlson	Software—the BSR is an electronic input only registry	Patient, verified by clinician from available medical records	100% of patients who participate and go on the registry as this is a mandatory question both of patient and clinician

Table 3 (continued)

Registry name	Year registry established	Number of comorbidities collected	Comorbidities collected by the registry	Time points of collection	Use of a comorbidity index	Method of collection (paper-based, software, EMR mining)?	Collected by whom (surgeon, junior staff, patient, medical records)?	Completion rate for those entering the information?
The Norwegian registry for spine surgery (NORspine)	2006	> 20	At baseline, reported by the surgeon: any RELEVANT of the following (yes/no): ASA grade (I–V) Bechterew's disease Cancer Cardiovascular disease Cerebrovascular disease, Chronic neurological disease Chronic pulmonary disease Depression and/or anxiety Diabetes General musculoskeletal pain syndrome Hip and/or knee arthrosis Hypertension Osteoporosis Osteoporotic fracture(s) of the spine Other (specified in free text) Other endocrine disease Other rheumatic disease Polyneuropathy Prostatism Rheumatoid arthritis Vascular claudication At follow-ups, reported by patients: any NEW disease or injury occurring AFTER the operation of the following (yes/no) Any other significant disease Cancer Cardiovascular disease Joint pain (e.g. arthrosis) Neurological disease Traumatic injury with sequelae	At baseline (by the surgeon) and at 3 and 12 months follow-up (by the patients)	ASA grade	At baseline, by the surgeon: Either (optional) in a web-based electronic system or on paper questionnaires subsequently scanned by office staff (optional) At follow-ups, by patients: prior to 2022 on paper questionnaires distributed by post and returned to the central NORspine-office for scanning. Currently implementing an electronic online system, which is integrated in the general national ehealth system and available for all citizens. Non-responders after one electronic reminder will be reminded by post and receive a paper questionnaire	The surgeon is in this context the operator, who could be either a specialist or a physician in training in orthopaedic surgery or neurosurgery The patients must be able to consent and usually complete forms themselves, but they can use assistance from anyone if the wish	For the ASA grade, 100%. For all the other data, difficult to assess, because checking "No comorbidity" is an option for both surgeons and patients
Eurospine, Spine Tango	2002	0	Not collected	Unanswered	Unanswered	Unanswered	Unanswered	Unanswered

Table 3 (continued)

Registry name	Year registry established	Number of comorbidities collected	Comorbidities collected by the registry	Time points of collection	Use of a comorbidity index	Method of collection (paper-based, software, EMR mining)?	Collected by whom (surgeon, junior staff, patient, medical records)?	Completion rate for those entering the information?
Canadian Spine Outcomes and Research Network	2015	> 20	Anaemia or other blood disease Angina or previous heart surgery Asthma Back/neck pain that is present more often than not Cancer: any malignancy including leukaemia or lymphoma Changes in everyday activity (changes in any ONE of the following): Cooking food/preparing meals Bathing/showering Dressing (putting clothes on, taking clothes off) Grooming (brushing hair, brushing teeth, shaving, putting on make-up) Going out alone (leaving the house/apartment without any assistance Chronic pulmonary disease (Emphysema, chronic bronchitis, chronic obstructive lung disease) or current pneumonia Congestive heart failure (likely symptoms: fluid in lungs; foot, ankle or leg swelling; shortness of breath and fatigue) Connective tissue disease (Marfan Syndrome, Ehlers-Danlos Syndrome, rheumatoid disease, lupus) Dementia (Alzheimer's disease or other form of dementia associated with reduced memory) or delirium Depression Diabetes Diabetes with end organ damage (visual, kidney, peripheral problems) Frequent headaches (including migraines) Heart attack in the past 6 months (likely resulting from coronary artery disease) Hemiplegia High blood pressure (hypertension) that requires medication High cholesterol HIV positive (AIDS) Kidney disease: moderate to severe (a loss of kidney function, chronic kidney failure) Liver disease: mild Liver disease: moderate to severe Muscular Dystrophy, Polio, Cerebral Palsy) Nervous system disorders (Parkinson's, Osteoarthritis (chronic inflammation or degeneration of one or more joints) Peripheral vascular disease or rest pain/gangrene (requiring operation to unclog or bypass arteries in legs) Stroke (cerebrovascular accident) with neurological deficit Stroke (transient ischaemic attack) with no neurological deficit Tumour (metastatic solid) Ulcer disease (stomach ulcers or peptic ulcer disease)	Patients provide this information one time, at the initial assessment with the surgeon (baseline)	Quan comorbidity index. The questions on: angina, changes in everyday activity, pulmonary disease, congestive heart failure, dementia, diabetes, heart attack, hypertension, peripheral vascular disease and stroke are also used to calculate a modified Frailty index (mFI)	Mainly a "pen and paper" method of data collection; a small percentage of patients use the online portal to submit their information	These questions are located on the patient assessment form; the surgeon does not complete the comorbidity section	Unanswered

Table 3 (continued)

Registry name	Year registry established	Number of comorbidities collected	Comorbidities collected by the registry	Time points of collection	Use of a comorbidity index	Method of collection (paper-based, software, EMR mining)?	Collected by whom (surgeon, junior staff, patient, medical records)?	Completion rate for those entering the information?
SweSpine	1992	5	These comorbidity questions are used in Swespine and filled in by the patient: Do you suffer from any of the following diseases which strongly limits your quality of life? 0. None 1. Heart disease 2. Neurological disease 3. Cancer 4. Any other disease which affects your walking ability 5. Any other disease that gives you pain? If a patient answers a question with yes, the medical record is checked. Compliance is a crucial issue	Baseline +FU1 year +FU 2 years +FU 5 years +FU 10 years	ASA, as reported by the anaesthesiologist and recorded in the operating document by the surgeon at the time of Index surgery Follow-up is performed for index procedures. Follow-up is performed after 1–2-5–10 years	The register is filled in by patients; Baseline + FU1 year + FU 2 years + FU 5 years + FU 10 years. The only protocol filled in by the surgeon is the operating protocol. Primarily paper-based, with web-based information alternatives. Swespine has a coverage of > 95% (45/46 clinics),	Patient-reported + ASA reported by the anaesthesiologist	Compliance on a national basis of over 80% and FU after 1 year approximately 75%. These figures are somewhat different from year to year
DaneSpine	2011	5	DaneSpine is based on Swespine with very small alterations. Collects patient-reported information as yes/no on any of the following: Cancer Heart disease Neurological disease Other illness affecting your walking ability Other illness causing generalised pain	Preoperative, 1, 2, 5 and 10 years postoperative	ASA score as entered into the database by the operating surgeon	Data are collected electronically using Survey Exact	ASA: surgeon Other comorbidities: patients	Patient-reported comorbidities: preoperative: almost 100% dropping to 80% at one year and declining to 45% after 10 years The ASA score is reported in approximately 50% of patients
the American Joint Replacement Registry (AJRR)	2009	</= 20	The AJRR collects any/all comorbidities associated with the patient during the procedural encounter as identified by ICD diagnosis codes. Up to 20 codes may be submitted per record. Up to 10 diagnosis codes related to the cause of the arthroplasty are also collected	Unanswered	AJRR research efforts utilise Charlson Comorbidity Index (CCI) as a variable of interest or adjustment depending on the study/report design	Comorbidities are reported by institutions submitted to AJRR from an EMR export. Submissions can be sent by any level of staff participating in the registry	Via EMR export	It is unclear exactly how many cases have missing data versus those cases that truly do not have any comorbidities. Approximately 74% of AJRR cases have at least 1 comorbidity (per the 2021 AJRR Annual Report)

have a standardised set of comorbidities and data collection methods to facilitate collaboration and data comparisons between patient cohorts. The use of a standardised set would help to build best practice in spine registries and may also facilitate improved patient outcomes following spine surgery by allowing predictive modelling of risk factors.

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Author contributions MJ and EA conceived the study. MQ, EA and MJ contributed to the design of the study. MQ provided methodological input, and MJ provided clinical input during the protocol phase. MQ designed the search strategy for the literature search and EA and MJ developed the questionnaire. MQ, EA and MJ appraised the quality of the literature and performed the data extraction. They also analysed the data both for the evidence map and for the questionnaire responses. MQ and EA drafted the manuscript. MQ drafted the supplementary material. All the authors critically revised the manuscript, read and approved the final version.

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Data availability The datasets generated during and/or analysed during the current study are not publicly available due to the inclusion of contact information of participants but are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no conflict of interest to declare with respect to this work.

References

1. Epstein NE (2011) Spine surgery in geriatric patients: sometimes unnecessary, too much, or too little. Surg Neurol Int 2:188
2. Voskuijl T, Hageman M, Ring D (2014) Higher Charlson comorbidity index scores are associated with readmission after orthopaedic surgery. Clin Orthop Relat Res® 472(5):1638–1644
3. Cram P, Landon BE, Matelski J, Ling V, Perruccio AV, Paterson JM et al (2019) Utilization and outcomes for spine surgery in the United States and Canada. Spine 44(19):1371
4. van Hooff ML, Jacobs WC, Willems PC, Wouters MW, de Kleuver M, Peul WC et al (2015) Evidence and practice in spine registries. Acta Orthop 86(5):534–544
5. Hoque DM, Sampurno F, Ruseckaite R, Lorgelly P, Evans SM (2017) Study protocol of an equivalence randomized controlled trial to evaluate the effectiveness of three different approaches to collecting patient reported outcome measures (PROMs) data using the prostate cancer outcomes registry-Victoria (PCOR-VIC). BMC Health Serv Res 17(1):75
6. Ahern S, Apos E, McNeil JJ, Cunningham J, Johnson M (2018) Monitoring outcomes in spine surgery: rationale behind the Australian spine registry. ANZ J Surg 88(10):950–951
7. McCormick JD, Werner BC, Shimer AL (2013) Patient-reported outcome measures in spine surgery. J Am Acad Orthop Surg 21(2):99–107
8. Vernon H (2008) The neck disability index: state-of-the-art, 1991–2008. J Manip Physiol Ther 31(7):491–502
9. EuroQol G (1990) EuroQol–a new facility for the measurement of health-related quality of life. Health Policy 16(3):199–208
10. Solberg TK, Olsen JA, Ingebrigtsen T, Hofoss D, Nygaard OP (2005) Health-related quality of life assessment by the EuroQol-5D can provide cost-utility data in the field of low-back surgery. Eur Spine J 14(10):1000–1007
11. Sciubba D, Jain A, Kebaish KM, Neuman BJ, Daniels AH, Passias PG et al (2021) Development of a preoperative adult spinal deformity comorbidity score that correlates with common quality and value metrics: length of stay, major complications, and patient-reported outcomes. Glob Spine J 11(2):146–153
12. Charlson M, Szatrowski TP, Peterson J, Gold J (1994) Validation of a combined comorbidity index. J Clin Epidemiol 47(11):1245–1251
13. Austin SR, Wong Y-N, Uzzo RG, Beck JR, Egleston BL (2015) Why summary comorbidity measures such as the Charlson comorbidity index and Elixhauser score work. Med Care 53(9):e65
14. Harris MB, Reichmann WM, Bono CM, Bouchard K, Corbett KL, Warholic N et al (2010) Mortality in elderly patients after cervical spine fractures. J Bone Jt Surg Am 92(3):567
15. Shinonara K, Ugawa R, Arataki S, Nakahara S, Takeuchi K (2021) Charlson comorbidity index is predictive of postoperative clinical outcome after single-level posterior lumbar interbody fusion surgery. J Orthop Surg Res 16(1):1–6
16. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg 88:105906
17. Andersen MØ, Fritzell P, Eiskjaer SP, Lagerbäck T, Hägg O, Nordvall D et al (2019) Surgical treatment of degenerative disk disease in three Scandinavian countries: an international register

study based on three merged national spine registers. Glob Spine J 9(8):850–858
18. Holmberg ST, Salvesen ØO, Vangen-Lønne V, Hara S, Fredheim OM, Solberg TK et al (2020) Pain during sex before and after surgery for lumbar disc herniation: a multicenter observational study. Spine 45(24):1751–1757
19. Iderberg H, Willers C, Borgström F, Hedlund R, Hägg O, Möller H et al (2019) Predicting clinical outcome and length of sick leave after surgery for lumbar spinal stenosis in Sweden: a multi-register evaluation. Eur Spine J 28(6):1423–1432
20. Inculet C, Urquhart JC, Rasoulinejad P, Hall H, Fisher C, Attabib N et al (2021) Factors associated with using an interbody fusion device for low-grade lumbar degenerative versus isthmic spondylolisthesis: a retrospective cohort study. J Neurosurg Spine 35(3):299–307
21. Lagerbäck T, Fritzell P, Hägg O, Nordvall D, Lønne G, Solberg TK et al (2019) Effectiveness of surgery for sciatica with disc herniation is not substantially affected by differences in surgical incidences among three countries: results from the Danish, Swedish and Norwegian spine registries. Eur Spine J 28(11):2562–2571
22. Lønne G, Fritzell P, Hägg O, Nordvall D, Gerdhem P, Lagerbäck T et al (2019) Lumbar spinal stenosis: comparison of surgical practice variation and clinical outcome in three national spine registries. Spine J 19(1):41–49
23. Paulsen RT, Bouknaitir JB, Fruensgaard S, Carreon L, Andersen M (2018) Prognostic factors for satisfaction after decompression surgery for lumbar spinal stenosis. Neurosurgery 82(5):645–651
24. Sigmundsson FG, Jönsson B, Strömqvist B (2015) Outcome of decompression with and without fusion in spinal stenosis with degenerative spondylolisthesis in relation to preoperative pain pattern: a register study of 1624 patients. Spine J 15(4):638–646
25. Fritzell P, Hagg O, Strmqvist B, Knutsson B (2015) Patient reported value 1 year after surgery for lumbar disc herniation: predictors of outcome using the Swedish national spine register; SweSpine. Eurospine; Copenhagen, Denmark: European Spine Journal
26. Hebert J, Bigney E, Wedderkopp N, Richardson EA, Darling MA, Manson NA (2019) 179. Predictors of clinical outcome following surgery for lumbar spinal stenosis: a study of postoperative pain and disability trajectories. Spine J 19(9):S86–S87
27. Jonsson E, Hansson-Hedblom A, Fritzell P, Hägg O, Borgström F (2017) Surgical treatment outcome of lumbar disc herniation (LDH) in different ages. Value Health 20(9):A538
28. Eneqvist T, Nemes S, Brisby H, Fritzell P, Garellick G, Rolfson O (2017) Lumbar surgery prior to total hip arthroplasty is associated with worse patient-reported outcomes. Bone Jt J 99-B(6):759–765
29. Salmenkivi J, Sund R, Paavola M, Ruuth I, Malmivaara A (2017) Mortality caused by surgery for degenerative lumbar spine. Spine (Phila Pa 1976) 42(14):1080–1087
30. Sobottke R, Herren C, Siewe J, Mannion AF, Röder C, Aghayev E (2017) Predictors of improvement in quality of life and pain relief in lumbar spinal stenosis relative to patient age: a study based on the Spine Tango registry. Eur Spine J 26(2):462–472
31. Zehnder P, Aghayev E, Fekete TF, Haschtmann D, Pigott T, Mannion AF (2016) Influence of previous surgery on patient-rated outcome after surgery for degenerative disorders of the lumbar spine. Eur Spine J 25(8):2553–2562
32. Zehnder PAE, Fekete TF, Haschtmann D, Pigott T, Mannion AF 2016 The law of diminishing returns in surgery for degenerative spinal disorders: quantification of the effect of previous surgery on patient rated outcomes. Eurospine; Berlin, Germany: European Spine Journal
33. Protopsaltis TS, Diebo BG, Lafage R, Henry JK, Smith JS, Scheer JK et al (2018) Identifying thoracic compensation and predicting reciprocal thoracic kyphosis and proximal junctional kyphosis in adult spinal deformity surgery. Spine 43(21):1479–1486
34. Raad M, Jain A, Neuman BJ, Hassanzadeh H, Gupta MC, Burton DC et al (2018) Association of patient-reported narcotic use with short-and long-term outcomes after adult spinal deformity surgery: multicenter study of 425 patients with 2-year follow-up. Spine 43(19):1340–1346
35. Smith JS, Shaffrey CI, Klineberg E, Lafage V, Schwab F, Lafage R et al (2017) Complication rates associated with 3-column osteotomy in 82 adult spinal deformity patients: retrospective review of a prospectively collected multicenter consecutive series with 2-year follow-up. J Neurosurg Spine 27(4):444–457
36. Asher AL, Devin CJ, McCutcheon B, Chotai S, Archer KR, Nian H et al (2017) Patient characteristics of smokers undergoing lumbar spine surgery: an analysis from the quality outcomes database. J Neurosurg Spine 27(6):661–669
37. Boddapati V, Lee NJ, Mathew J, Held MB, Peterson JR, Vulapalli MM et al (2021) Respiratory compromise after anterior cervical spine surgery: incidence, subsequent complications, and independent predictors. Glob Spine J 12(8):1647–1654
38. Chan AK, Bisson EF, Bydon M, Glassman SD, Foley KT, Potts EA et al (2018) Women fare best following surgery for degenerative lumbar spondylolisthesis: a comparison of the most and least satisfied patients utilizing data from the quality outcomes database. Neurosurg Focus 44(1):E3
39. Cook CE, Garcia AN, Shaffrey C, Gottfried O (2020) The influence of unemployment and disability status on clinical outcomes in patients receiving surgery for low back-related disorders: an observational study. Spine Surg Relat Res 5(3):182–188
40. Cote DJ, Karhade AV, Larsen AM, Burke WT, Castlen JP, Smith TR (2016) United States neurosurgery annual case type and complication trends between 2006 and 2013: an American College of Surgeons National Surgical Quality Improvement Program analysis. J Clin Neurosci 31:106–111
41. Kalagara S, Eltorai AE, Durand WM, DePasse JM, Daniels AH (2018) Machine learning modeling for predicting hospital readmission following lumbar laminectomy. J Neurosurg Spine 30(3):344–352
42. Lee R, Lee D, Gowda NB, Iweala U, Weinreb JH, Falk DP et al (2020) Increased rates of septic shock, cardiac arrest, and mortality associated with chronic steroid use following anterior cervical discectomy and fusion for cervical stenosis. Int J Spine Surg 14(5):649–656
43. Malik AT, Jain N, Yu E, Kim J, Khan SN (2018) Is there a "sex effect" in 30-day outcomes after elective posterior lumbar fusions? World Neurosurg 120:e428–e433
44. McGirt MJ, Bydon M, Archer KR, Devin CJ, Chotai S, Parker SL et al (2017) An analysis from the quality outcomes database, part 1. Disability, quality of life, and pain outcomes following lumbar spine surgery: predicting likely individual patient outcomes for shared decision-making. J Neurosurg Spine 27(4):357–369
45. Mummaneni PV, Bisson EF, Kerezoudis P, Glassman S, Foley K, Slotkin JR et al (2017) Minimally invasive versus open fusion for grade I degenerative lumbar spondylolisthesis: analysis of the quality outcomes database. Neurosurg Focus 43(2):E11
46. Murphy ME, Kerezoudis P, Alvi MA, McCutcheon BA, Maloney PR, Rinaldo L et al (2017) Risk factors for dural tears: a study of elective spine surgery. Neurol Res 39(2):97–106
47. Park C, Cook CE, Garcia AN, Gottfried ON (2021) Discharge destination influences risks of readmission and complications after lumbar spine surgery in severely disabled patients. Clin Neurol Neurosurg 207:106801

48. Phan K, Kothari P, Lee NJ, Virk S, Kim JS, Cho SK (2017) Impact of obesity on outcomes in adults undergoing elective posterior cervical fusion. Spine 42(4):261–266
49. Sanford Z, Taylor H, Fiorentino A, Broda A, Zaidi A, Turcotte J et al (2019) Racial disparities in surgical outcomes after spine surgery: an ACS-NSQIP analysis. Glob Spine J 9(6):583–590
50. Laratta J, Carreon LY, Buchholz AL, Yew AY, Bisson EF, Mummaneni PV et al (2020) Effects of preoperative obesity and psychiatric comorbidities on minimum clinically important differences for lumbar fusion in grade 1 degenerative spondylolisthesis: analysis from the prospective quality outcomes database registry. J Neurosurg Spine 33(5):635–642
51. Macki M, Hamilton T, Lim S, Telemi E, Bazydlo M, Nerenz DR et al (2021) Disparities in outcomes after spine surgery: a Michigan spine surgery improvement collaborative study. J Neurosurg Spine 1(aop):1–9
52. Zakaria HM, Lipphardt M, Bazydlo M, Xiao S, Schultz L, Chedid M et al (2020) The preoperative risks and two-year sequelae of postoperative urinary retention: analysis of the Michigan spine surgery improvement collaborative (MSSIC). World Neurosurg 133:e619–e626
53. Kushioka J, Takenaka S, Makino T, Sakai Y, Kashii M, Iwasaki M et al (2020) Risk factors for in-hospital mortality after spine surgery: a matched case-control study using a multicenter database. Spine J 20(3):321–328
54. Kobayashi K, Imagama S, Ando K, Ishiguro N, Yamashita M, Eguchi Y et al (2017) Complications associated with spine surgery in patients aged 80 years or older: Japan Association of Spine Surgeons with Ambition (JASA) multicenter study. Glob Spine J 7(7):636–641
55. Kay HF, Chotai S, Wick JB, Stonko DP, McGirt MJ, Devin CJ (2016) Preoperative and surgical factors associated with postoperative intensive care unit admission following operative treatment for degenerative lumbar spine disease. Eur Spine J 25(3):843–849
56. Hebert JBE, Wedderkopp N, Richardson EA, Darling MA, Manson NA 2019 Predictors of clinical outcome following surgery for lumbar spinal stenosis: a study of postoperative pain and disability trajectories. In: 34th annual meeting of the North American Spine Society. Spine Journal, Chicago
57. Allin SMG, Peckham A (2020) University of Toronto. International health care system profiles. University of Toronto, Policies NAOoHSa, Canada
58. Ondeck NT, Bohl DD, Bovonratwet P, McLynn RP, Cui JJ, Shultz BN et al (2018) Discriminative ability of commonly used indices to predict adverse outcomes after poster lumbar fusion: a comparison of demographics, ASA, the modified Charlson Comorbidity Index, and the modified frailty index. Spine J 18(1):44–52
59. Knuf KA-O, Maani CV, Cummings AK. Clinical agreement in the American Society of Anesthesiologists physical status classification. (2047-0525 (Print))
60. ASA Physical Status Classification System. 2020. Accessed 13 Dec 2020
61. Schupper AJ, Shuman WH, Baron RB, Neifert SN, Chapman EK, Gilligan J et al (2021) Utilization of the American Society of Anesthesiologists (ASA) classification system in evaluating outcomes and costs following deformity spine procedures. Spine Deform 9(1):185–190
62. Mannion AF, Bianchi G, Mariaux F, Fekete TF, Reitmeir R, Moser B et al (2020) Can the Charlson comorbidity index be used to predict the ASA grade in patients undergoing spine surgery? Eur Spine J 29(12):2941–2952
63. Li G, Walco JP, Mueller DA, Wanderer JP, Freundlich RE (2021) Reliability of the ASA physical status classification system in predicting surgical morbidity: a retrospective analysis. J Med Syst 45(9):83
64. Kwa CXW, Cui J, Lim DYZ, Sim YE, Ke Y, Abdullah HR (2022) Discordant American Society of Anesthesiologists physical status classification between anesthesiologists and surgeons and its correlation with adverse patient outcomes. Sci Rep 12(1):7110
65. Sankar A, Johnson SR, Beattie WS, Tait G, Wijeysundera DN (2014) Reliability of the American Society of Anesthesiologists physical status scale in clinical practice. Br J Anaesth 113(3):424–432
66. Nations U (2019) World population ageing 2019: highlights. In: Department of Economic and Social Affairs PD
67. Mannion AF, Fekete TF, Porchet F, Haschtmann D, Jeszenszky D, Kleinstuck FS (2014) The influence of comorbidity on the risks and benefits of spine surgery for degenerative lumbar disorders. Eur Spine J 23(Suppl 1):S66-71
68. Cavalli L, Angehrn L, Schindler C, Orsini N, Grob C, Kaufmann M et al (2022) Number of comorbidities and their impact on perioperative outcome and costs—a single centre cohort study. Swiss Med Wkly 152:w30135
69. Bays A, Stieger A, Held U, Hofer LJ, Rasmussen-Barr E, Brunner F et al (2021) The influence of comorbidities on the treatment outcome in symptomatic lumbar spinal stenosis: a systematic review and meta-analysis. N Am Spine Soc J 6:100072
70. Ludvigsson JF, Appelros P, Askling J, Byberg L, Carrero JJ, Ekstrom AM et al (2021) Adaptation of the Charlson comorbidity index for register-based research in Sweden. Clin Epidemiol 13:21–41