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REVIEW ARTICLE

Evaluating the utility and quality of large administrative databases in pediatric spinal neurosurgery research

Sarah Nguyen[1] · Parker Cox[2] · Justin M. Campbell[2] · Douglas L. Brockmeyer[1] · Michael Karsy[1]

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Abstract

Purpose The purpose of this study was to assess the quality of articles utilizing large administrative databases to answer questions related to pediatric spinal neurosurgery by quantifying their adherence to standard reporting guidelines.

Methods A systematic literature search was conducted with search terms including "pediatric" and "neurosurgery," associated neurosurgical diagnoses, and the names of known databases. Study abstracts were reviewed to identify clinical studies involving pediatric populations, spine-related pathology or procedures, and large administrative databases. Included studies were graded using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria.

Results A total of 28 papers of the initial 1496 identified met inclusion criteria. These papers involved 10 databases and had a mean study period of 11.46 ± 12.27 years. The subjects of these research papers were undergoing treatment of scoliosis ($n = 5$), spinal cord injury ($n = 5$), spinal cord tumors ($n = 9$), and spine surgery in general ($n = 9$). The mean STROBE score was 19.41 ± 2.02 (out of 22).

Conclusion Large administrative databases are commonly used within pediatric spine-related neurosurgical research to cover a broad spectrum of research questions and study topics. The heterogeneity of research to this point encourages the continued use of large databases to better understand treatment and diagnostic trends, perioperative and long-term outcomes, and rare pathologies within pediatric spinal neurosurgery.

Keywords Pediatric neurosurgery · Scoliosis · Spine injury · Spine tumor · Administrative database · Spine surgery

Abbreviations

ACS	American College of Surgeons
AIS	Adolescent idiopathic scoliosis
EDS	Ehlers-Danlos syndrome
HCUP	Healthcare Cost and Utilization Project
KID	Kids' Inpatient Database
LOS	Length of stay
MVA	Motor vehicle accident
NCDB	National Cancer Database
NIS	National Inpatient Sample
NRD	Nationwide Readmissions Database
NSQIP-P	National Surgical Quality Improvement Program–Pediatric
PHIS	Pediatric Health Information System
SCI	Spinal cord injury
SEER	Surveillance, Epidemiology, and End Results
SID	State Inpatient Database
SRS M&M	Scoliosis Research Society Morbidity and Mortality Database

✉ Michael Karsy
neuropub@hsc.utah.edu

[1] Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, 175 N. Medical Drive East, Salt Lake City, UT 84132, USA

[2] School of Medicine, University of Utah, Salt Lake City, UT, USA

Introduction

Large administrative databases are commonly used in neurosurgical research, including pediatric neurosurgical spine research [1]. These large databases allow for "big data" research of relatively rare diseases, such as pediatric spine disease, that was previously impossible in single-institution or regionally based studies. However, despite their widespread use, the clinical utility of these databases remains unclear. One drawback is the variability in the quality of studies that use large administrative databases. The quality can be affected by the typical limitations of these types of studies, such as the fact that important data components may not be collected in the database and the problem of missing

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data. Because of the importance of administrative database studies to pediatric spinal neurosurgery, we performed a review to evaluate the adherence of papers to standard reporting guidelines that are intended to ensure quality by defining a minimum set of criteria to be used when planning the study that should be described in the paper.

Methods

Literature search and inclusion criteria

A PubMed literature search was conducted using the search string "(National Surgical Quality Improvement Program OR NSQIP OR NIS OR National Inpatient Sample OR HCUP-NIS OR HCUP-KID OR Kid's Inpatient Database OR PHIS OR Pediatric Health Information Systems OR MarketScan OR administrative database OR SEER OR SEER-Medicare OR NRD OR SID OR CMS OR Vizient OR Premier OR PearlDiver OR Optum) AND (pediatric) AND (neurosurgery OR hydrocephalus OR trauma OR epilepsy OR tumor)."

The resulting list of references was reviewed for inclusion based on the abstract and title (Fig. 1). The exclusion criteria were adult-only population, non-neurosurgical population, basic science, literature reviews, or meta-analyses. The list was further narrowed based on the title and abstract to include only spinal-related pathologies and procedures. The final inclusion criteria included a pediatric population, clinical articles, neurosurgical topic, spine-related pathology or procedure, and use of an administrative database.

Data collection and study evaluation

Study details were extracted and were then independently graded by two researchers using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria [2]. STROBE outlines 22 items that should be reported from observational studies including objectives, study design, biases, limitations, and funding (Table 1). Each study was given 0 (no) or 1 (yes) point for each of the 22 STROBE items. Scores were determined by adding up the total points and averaging the score between the two reviewers.

Statistical analysis

Continuous variables were reported as means and medians. Interrater reliability of STROBE criteria scores was assessed using Cohen's kappa statistic. Statistical analysis was performed using SPSS (V23).

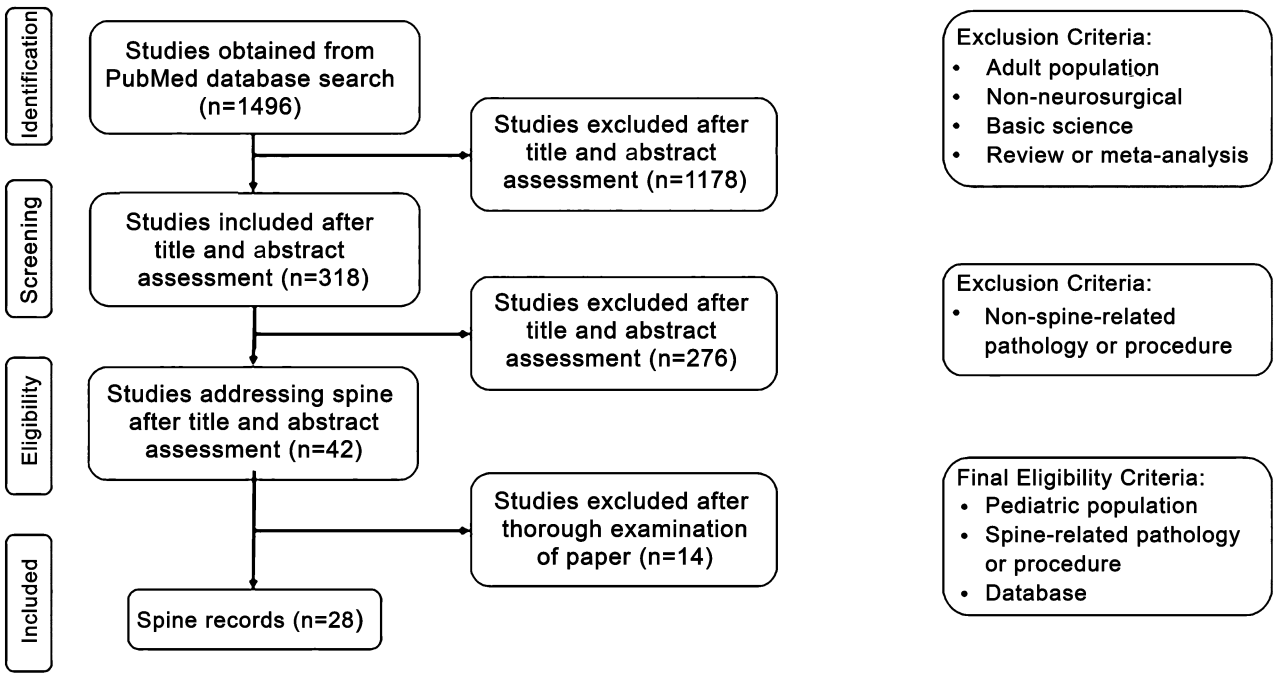

Fig. 1 STROBE outline demonstrating study selection

Table 1 The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: checklist of items that should be addressed in reports of observational studies

Item	Item emphasis	Recommendation
1	**Title and abstract**	(a) Study design described in title or the abstract (b) Informative abstract
	Introduction	
2	Background/rationale	Present scientific background and rationale for study
3	Objectives	Provide statement of objectives and hypotheses
	Methods	
4	Study design	Describe study design
5	Setting	Give setting, locations, and dates
6	Participants	Present eligibility criteria, patient selection methods, matching criteria
7	Variables	Define outcomes, exposures, and criteria
8*	Data sources/measurement	Present data sources and details of measurement
9	Bias	Describe efforts to address bias
10	Study size	Describe study size calculation
11	Quantitative variables	Explain quantitative variables
12	Statistical methods	Describe all statistical methods
	Results	
13*	Participants	Report numbers of participants at each stage of study and reasons for non-participation; consider a flow diagram
14*	Descriptive data	Report characteristics of study participants including missing data and follow-up time, if appropriate
15*	Outcome data	Report numbers of outcome events, exposures, or summary measures
16	Main results	Report unadjusted estimates and/or confounder-adjusted estimates and precision (e.g., 95% confidence interval)
17	Other analyses	Present other analyses performed
	Discussion	
18	Key results	Summarize key results in light of study objectives
19	Limitations	Discuss limitations of the study, including bias or imprecision
20	Interpretation	Give a cautious overall interpretation
21	Generalizability	Discuss the generalizability
	Other information	
22	Funding	List sources of funding and role of funders

*Present findings for cases/controls and exposed/unexposed groups

Results

The initial literature search resulted in 1496 papers (Fig. 1). An initial scan of the titles and abstracts excluded 1178 studies based on the preliminary exclusion criteria. This resulted in 318 papers that involved a pediatric neurosurgical patient population and used a database. These papers were further limited to those that addressed spinal pathologies or procedures (42 papers). Finally, papers were read in detail to ensure all papers met our inclusion criteria, resulting in 28 papers (Table 2).

Database and subtopic analysis

Ten different databases were used in the included studies, with ACS-NSQIP-P, KID, National Inpatient Sample (NIS), and Surveillance, Epidemiology, and End Results (SEER) tied as most common. Other databases included a statewide database (New York) and private databases (MarketScan, PearlDiver). Studies included data from 1973 to 2016, with an average study length of 11.46 ± 12.27 years. The longest studies (mean = 36.4 years) used data from the SEER database.

The most frequent study aims were patient outcomes ($n = 21$, 75%), including readmission, reoperation, complications, and survival. This was followed by specific operative, treatment, or hospital characteristics ($n = 17$, 60.7%). Finally, the study aims of describing epidemiology and identifying risk factors were equally common ($n = 9$, 32.1%). Individual studies often explored multiple study aims.

STROBE grading

The average score across studies was 19.41 ± 2.02 (median 20, range 13–22). The most consistent points missed was for items 9, 17, 21, and 22, corresponding

Table 2 Pertinent identifiers for each study under review

Author	Category	Database	Study years	Reviewer 1 score	Reviewer 2 score	Average score
Dallas et al. 2019 [7]	Scoliosis	NIS	2012–2015	21	20	20.5
De la Garza Ramos et al. 2017 [8]	Scoliosis	ACS-NSQIP-P	2013–2014	19	20	19.5
McLeod et al. 2015 [18]	Scoliosis	PHIS	2006–2009	20	20	20
Paul et al. 2018 [23]	Scoliosis	NY State Inpatient	2008–2011	14	18	16
Shaw et al. 2018 [28]	Scoliosis	ACS-NSQIP-P	2014–2015	20	18	19
Knox 2016 [14]	Spinal cord injury	KID	2012	15	17	16
Mendoza-Lattes et al. 2015 [19]	Spinal cord injury	KID	1997–2009	13	14	13.5
Nadarajah et al. 2018 [20]	Spinal cord injury	KID	2000–2012	19	20	19.5
Piatt 2018 [24]	Spinal cord injury	KID	1997–2012	20	20	20
Shin et al. 2016 [29]	Spinal cord injury	KID	2000–2012	21	22	21.5
Adams et al. 2012 [4]	Spinal cord tumor	SEER	1973–2007	19	19	19
Ambekar et al. 2014 [5]	Spinal cord tumor	NIS	2003–2010	18	21	19.5
Bhimani et al. 2019 [6]	Spinal cord tumor	ACS-NSQIP-P	2014–2015	19	20	19.5
Gephart et al. 2012 [10]	Spinal cord tumor	SEER	1975–2007	21	22	21.5
Janjua et al. 2019 [11]	Spinal cord tumor	NRD	2010–2015	22	21	21.5
Khalid et al. 2018 [13]	Spinal cord tumor	SEER	1973–2014	22	21	21.5
Lam et al. 2012 [15]	Spinal cord tumor	SEER	1973–2008	19	20	19.5
Luksik et al. 2017 [16]	Spinal cord tumor	SEER	1973–2013	20	21	20.5
Shweikeh et al. 2017 [30]	Spinal cord tumor	NIS, KID	2000–2009	20	21	20.5
Patil et al. 2008 [22]	Spinal surgery	NIS	1993–2002	17	20	18.5
Fu et al. 2011 [9]	Spinal surgery	SRS M&M	2004–2007	17	18	17.5
Smith et al. 2012 [31]	Spinal surgery	SRS M&M	2004–2007	19	22	20.5
Abu-Bonsrah et al. 2017 [3]	Spinal surgery	ACS-NSQIP-P	2012–2014	21	21	21
Matur et al. 2020 [17]	Spinal surgery	ACS-NSQIP-P	2012–2016	20	20	20
Patil et al. 2008 [21]	Spinal surgery	NIS	1993–2002	20	16	18
Purvis et al. 2018 [25]	Spinal surgery	NIS	2002–2011	20	20	20
Robinson et al. 2018 [26]	Spinal surgery	MarketScan	2003–2009	20	20	20
Rocque et al. 2014 [27]	Spinal surgery	PearlDiver	2005–2011	19	20	19.5

Overall kappa = 0.524 ($p = 0.0001$); overall agreement 96.4% of STROBE criteria

to addressing bias, reporting other analyses, discussing generalizability, and disclosing funding, respectively. All papers uniformly included items 1, 2, 4, 12, 18, and 20, corresponding to indicating study design in the title or abstract, explaining the scientific background and rationale, presenting key elements of study design, adequately describing statistical methods, summarizing key results, and giving a cautious overall interpretation, respectively (Table 2).

Overall interrater reliability showed a kappa of 0.524 ($p = 0.0001$) with agreement over 96.4% of potential STROBE criteria for all the studies. Interrater reliability showed the lowest correlation for items 3 (kappa = 0.1), 9 (kappa = 0.4), 13 (kappa = 0.2), and 16 (kappa = 0.3) signifying the areas with the greatest variability in identification by reviewers.

Discussion

Large administrative databases may be beneficial for tracking large-scale trends in diagnosis, treatment, incidence, and survival in pediatric spinal neurosurgery research. Our results showed that most studies demonstrated adequate reporting of study data as assessed by meeting STROBE criteria. We found that improved study methodology for administrative databases could be possible by encouraging the use of the most commonly missed STROBE factors, including predefined hypotheses to drive research questions, subgrouping of data to evaluate biases, removal of patients as part of sensitivity analyses, and interpretation of results in terms of clinical impact. These points may further improve clinical administrative studies.

This study also helped identify study components (as identified by STROBE criteria) that were either less commonly reported or inadequately reported (e.g., efforts to limit bias in study design). Better adherence to the STROBE guidelines may help to improve the quality of future database studies. The use of databases also enables confirmation of previous results and broader applicability across national cohorts. They also allow for more comprehensive study of rare disease, infrequent procedures, and unusual complications. The utility of these studies and analyses of the data presented in these large administrative databases is, however, reliant on the quality and rigor of reporting.

Several studies in neurosurgery have aimed to evaluate the strengths and limitations of databases in the neurosurgical literature [12, 32]. In their analysis of 74 articles that used big data for clinical pediatric neurosurgery research, Oravec et al. found that only 20% were of greatest clinical utility as demonstrated by study effect sizes, confidence interval precision, and strong *p* values [1]. This led to their conclusion that studies using large administrative databases may be best suited to research questions evaluating trends or cost analysis and may be less effective for answering questions related to clinical decision-making because of the prevalence of small effect sizes with large datasets. We agree that the use of large administrative databases may be best suited to research questions evaluating trends across time, geography, or large populations or focusing on less common pathologies or procedures. A failure to delineate specific patients or to adjust for study biases may cloud the research question and overall external validity. Nonetheless, databases may be helpful for evaluating rare pathologies that are not easily sampled in single-center studies.

Scoliosis

Five studies examined factors associated with outcomes after treatment for adolescent idiopathic scoliosis (AIS), including cost [7], body mass index [8], use of antifibrinolytics [18] or spinal growing implants [28], and complications/reoperations [23]. One study showed a median case cost of $68,815 between 2012 and 2015 for 1780 patients with large variability across hospital types [7]. Another study examined complication rates among 2712 patients treated for AIS in 2013–2014, noting higher complication rates in obese (4.2%) than in non-obese patients (0.9%) [8]. McLeod et al. [18] evaluated 2722 patients treated for AIS and 1547 treated for neuromuscular scoliosis, showing wide variation in antifibrinolytic use across hospitals. These data suggested that ε-aminocaproic acid decreased transfusion rates in AIS but no agent reduced transfusion rates in neuromuscular scoliosis. Shaw et al. [28] examined 796 patients treated by growing rods in 2014–2015; 73% underwent inpatient treatment, with a complication rate of 3.5%. Lastly, a study of 2356 patients from 2008 through 2011 provided descriptive analysis of reoperation rates [23].

Although these heterogenous studies do not provide a definitive view of scoliosis treatment, they do help answer some questions that would be otherwise impossible with single-institution data, such as comparisons of cost, readmission and complications analyses, and examinations of regional differences in practice. These studies help evaluate practice variation, such as the differences in cost or adjuvant treatments. Nonetheless, details as to the type and extent of correction for AIS were lacking in most studies. More thorough spine registries are needed, similar to those found for scoliosis in adults, with more granular data regarding pediatric scoliosis treatment and outcomes.

Spinal cord injury

Five studies used the KID database to examine spinal cord injury (SCI). Three epidemiological studies concurred that the risk of SCI increases with age and the most common mechanism of injury is motor vehicle accidents (MVAs) [19, 20, 29]. Among 9007 discharges, Mendoza-Lattes et al. [19] evaluated that the prevalence of SCI was 107.96 million in children/adolescents in 2009, an increase from 77.07 million in 1997. Neurological injury was present in 14.6% of cases, and MVAs accounted for 52.9% of all spine injuries. The length of stay (LOS) decreased over time, but hospital charges significantly increased. Nadarajah et al. [20] evaluated patients from 2000 through 2012 and found a prevalence of SCI of 0.8%, with greater risk in older children; they suggested that SCI due to sports was most prevalent in children aged 10–17 years. Shin et al. [29] showed that pediatric SCI occurred in 2.07% of 19,831 trauma patients between 2000 and 2012 which showed an overall mortality rate of 4.87%. Mortality was higher among younger patients. The cause and level of injury varied among age groups, with increased risk in older patients, non-Northeast regions, and MVAs [29]. Finally, Knox [14] evaluated 297 patients with SCI without radiographic abnormality. Additional injuries were found in 53% of patients, most often head trauma. The mean LOS was 13 days, but in-hospital mortality was low (2%).

One limitation of large multi-institutional administrative databases studying pediatric SCI, such as the National Pediatric Trauma Registry or National Trauma Data Bank, involves selection bias [29]. Often these registries require self-reporting of data and are not specific to pediatric neurological trauma. The use of multiple databases may be helpful in overcoming this limitation to better understand pediatric SCI and other pediatric spinal pathologies.

Penetrating spine injury

One study of patients with penetrating SCI from 1997 to 2012 evaluated 955 cases showing an annual incidence of 2.6–5.7 million, with overall decreasing incidence over time [24]. Piatt [24] found that penetrating SCI accounted for 2.3–5.7% of all SCI and resulted in a greater LOS compared with closed SCI (15.0 vs. 7.72 days, $p < 0.0001$). Mortality was greater for younger patients, but incidence was greater in older pediatric patients. When compared with patients with closed spinal injury, those with penetrating SCI were overwhelmingly male, older, and publicly insured, and their injuries were more often in the thoracic spine. There was no difference in mortality rates between closed and penetrating injuries, but SCI and adverse discharges were more common in patients with penetrating SCI [24]. Although our review identified only one study examining penetrating spine injury, it outlines the utility of large administrative databases on this specific research topic by allowing the evaluation of large patient cohorts for rare pathology over time, which is more challenging in single-institution studies.

Spinal cord tumor

Nine studies using large databases focused on spinal tumors, including astrocytoma [4, 15, 16], meningioma [5], ependymoma [13], and spinal tumors in general [6, 10, 11], and treatment patterns of spinal tumors [30]. All studies agreed that pediatric spinal tumors are a very rare entity, with spinal cord tumors accounting for 4–10% of all pediatric central nervous system tumors [6, 10]. The SEER database was used most frequently in these studies and was used exclusively for studies examining astrocytomas.

The three studies concerning astrocytomas found that survival is associated with a younger age and with a lower tumor grade [4, 15, 16]. Adams et al. [4] evaluated 135 patients diagnosed with astrocytomas of the spinal cord between 1973 and 2007 showing median length of survival and 5-year overall survival rates of 13 months and 18.7%, respectively. Overall survival was worse in pediatric patients compared with that in adults [4]. Lam et al. [15] had similar findings. Luksik et al. [16] evaluated 348 patients with primary spinal cord astrocytoma recorded in the SEER database between 1983 and 2013. Risk factors for poor survival included older age, non-white race, high-grade tumor status, distant extension of tumor, and radiation therapy. Patients receiving partial or gross total resection had better survival [16]. The SEER database used for these studies had more granular detail regarding patient treatment, such as doses of radiotherapy, genetic markers, tumor locations, and treatment with chemotherapy, but had less detail about risk factors. Nonetheless, the results are telling regarding patient outcomes nationally over a long period of time.

Pediatric spinal meningiomas [5] and spinal ependymomas [13] were evaluated. Spinal meningiomas demonstrated an increased incidence from 2003 to 2010 in a study of 13,792 patients. Pediatric patients accounted for 2% of patients and had a lower risk of adverse outcomes compared with adults and the elderly [5]. Khalid et al. [13] evaluated 2126 patients with spinal ependymoma between 1973 and 2014. Among 279 pediatric patients identified, gross total resection was the only factor that impacted survival after adjusting for age, sex, tumor size and extension, and the use of radiochemotherapy.

Three studies examined spine tumors as an aggregate [6, 10, 11]. Bhimani et al. [6] evaluated 139 patients with intramedullary spinal cord tumors between 2012 and 2016, finding low overall risks of patient morbidity along with no mortality. Readmission was seen in 8.6% of patients, and the most common causes of reoperation were management of respiration and hydrocephalus. Gephart et al. [10] evaluated 330 patients treated for spinal cord tumors between 1975 and 2007. The incidence of 0.09:100,000 person-years remained stable over the study period. Diagnosis of pilocytic astrocytoma and ependymoma increased over time while the use of external beam radiation decreased. Janjua et al. [11] evaluated 397 patients with spinal cord tumors between 2010 and 2015, showing a 10.8% overall 30-day readmission rate and 16.0% 90-day readmission rate. Readmission was most commonly due to chemotherapy and hematological (32.8%), neurological (23.0%), and pulmonary or infectious (24.6%) complications. Multivariate regression showed that only younger age was predictive of 30-day readmission, whereas mortality risk, complications, Medicaid payor, malignant tumor, and younger age were predictors of 90-day readmission [11].

Spinal surgery

Eight studies did not fit into the above criteria or examined spinal surgery more broadly [3, 9, 17, 21, 22, 25, 27, 31]. Two studies evaluated complications after spinal surgery [9, 31]. Smith et al. [31] included 108,419 pediatric and adult patients treated between 2004 and 2007 and found that, within the pediatric population, the rate of death after spinal surgery for scoliosis did not vary significantly among age subgroups. The most common causes of death for all patients in this study were respiratory or pulmonary complications, cardiac complications, and sepsis. Fu et al. [9] used the same database between 2004 and 2007 but examined the pediatric population only. A total of 23,918 patients with major spine pathologies including scoliosis (19,642 patients), kyphosis (1455 patients), spondylolisthesis (748 patients), trauma (478 patients), and others (1595 patients) were evaluated. The overall complication rate was 8.5%. More aggressive procedures for deformity increased the risk of complications,

especially within treatment of kyphosis or spondylolisthesis. Patil et al. [22] evaluated similar cohorts of patients in the NIS, finding an overall in-hospital complication of 14.9% and confirmed that most complications were due to pulmonary or cardiac complications. Abu-Bonsrah et al. [3] used data from 2012 and 2014 to study risk factors for complications after spinal arthrodesis. Among 4420 patients identified, there was a 3.6% rate of unplanned reoperation, a 3.96% rate of unplanned readmission, and a 9.0% complication rate. Pulmonary comorbidities and female sex represented significant risk factors for reoperation.

Five other studies used databases to examine more specific study populations. Matur et al. [17] compared 56 patients with Ehlers-Danlos syndrome (EDS) from 2012 through 2016 and 21,434 patients without EDS undergoing spine surgery. No differences in unplanned reoperation, wound infection, overall complications, transfusion, LOS, or operative time were seen between EDS and non-EDS patients. Purvis et al. [25] evaluated 2878 patients with cervical injury from 2002 and 2011 to compare external fixation vs. surgical fusion. For patients with atlantoaxial injuries, external fixation was associated with lower rates of complication and decreased cost. For subaxial injury, surgical fusion was more commonly used. Robinson et al. [26] evaluated 522 patients, including 103 pediatric patients, undergoing cervical arthrodesis for occipitocervical and atlantoaxial instability. Fusion failure was noted in 10.9% of patients in total and 18.9% of pediatric patients. No difference in fusion failure was seen depending on graft type, namely structural autograft, structural allograft, non-structural graft, or no graft. Rocque et al. [27] evaluated 4658 patients who underwent spinal fusion between 2005 and 2011, showing 37.6% of cases involved the use of bone morphogenic protein. No differences in complication or reoperation rates were seen. Patil et al. [21] evaluated patients between 1993 and 2002 to examine rates of visual loss (e.g., ischemic optic neuropathy, central retinal artery occlusion) after scoliosis correction and posterior lumbar fusion. An overall incidence of 0.094% of postoperative visual loss was seen, but pediatric patients were 5.8 times more likely than adult patients to develop vision loss. Hypotension, peripheral vascular disease, and anemia were the strongest risk factors.

Limitations

Database studies are inherently limited in evaluating detailed information about pediatric spine disease. No single database contains all the information necessary to fully investigate a specific topic, and adequate reporting of data is essential to accurately judge the presented data. A limitation of our study is in the subjective nature of STROBE criteria grading for each included study and the potential variability in defining when a study demonstrated the information appropriately. We aimed to improve the scoring of studies by using a training set and setting criteria prior to the evaluation of studies. Additionally, no perfect checklist may exist for evaluating administrative data, thereby resulting in different definitions of complete reporting. While these limitations exist, we believe our analysis and the findings we present not only highlight the utility of large administrative databases in pediatric spinal neurosurgery research, but also encourage the continued use of checklists, such as STROBE, to enhance the quality of the published data.

Conclusions

Large administrative databases are commonly used within pediatric spine-related neurosurgical research to cover a broad spectrum of research questions and study topics. The heterogeneity of research to this point encourages the continued use of large databases to better understand treatment and diagnostic trends, perioperative and long-term outcomes, and rare pathologies within pediatric spinal neurosurgery. Utilization of these findings can be improved by enhancing reporting of this data by better following the standards outlined in checklists such as the STROBE items.

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Availability of data and material All data are included in the paper.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest Michael Karsy — Thieme Medical Publishing (royalties).

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