North American Spine Society Journal (NASSJ) 20 (2024) 100555

Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

The hidden risk: Intracranial hemorrhage following durotomies in spine surgery

Julius Gerstmeyer, MD[a,b,d,*], August Avantaggio[b], Clifford Pierre, MD[a,b], Neel Patel, MD[a,b], Donald D. Davis, MD[a,b], Bryan Anderson, DO[a,b], Periklis Godolias, MD[c], Thomas Schildhauer, MD[d], Amir Abdul-Jabbar, MD[a], Rod J. Oskouian, MD[a], Jens R. Chapman, MD[a]

[a] Swedish Neuroscience Institute, Swedish Medical Center, 550 17th Ave, Suite 500, Seattle, WA 98122, United States
[b] Seattle Science Foundation, 550 17th Avenue, Suite 600, Seattle, WA 98122, United States
[c] Department of Orthopedics and Trauma Surgery, St. Josef Hospital Essen-Werden, Propsteistrasse 2, 45239 Essen, Germany
[d] Department of General and Trauma Surgery, BG University Hospital Bergmannsheil, Ruhr University Bochum, Bürkle-de-la-Camp-Platz 1, 44789 Bochum, Germany

ARTICLE INFO

Keywords:
Intracranial hemorrhage
Spinal surgery
Dural tear
Postoperative cerebrospinal fluid leakage
Durotomy

ABSTRACT

Objective: Intracranial hemorrhage (ICH) after durotomy in elective spine surgery, though rare, can pose a significant risk to patient outcomes. Spine surgeries bear a risk of dural tears (DT) with potential of postoperative cerebrospinal fluid leakage (PCSFL). Excessive PCSFL can precipitate a decrease in intracranial pressure, potentially leading to ICH. Literature on ICH as a postoperative complication is scarce. The aim was to assess the incidence and risk factors of ICH in patients undergoing elective spine surgery.

Methods: Utilizing the 2020 National Impatient Sample (NIS) adults (>18 years) were selected by primary procedure category codes for spine fusion, discectomy, spinal cord decompression and cervicothoracic/lumbosacral nerve decompression. Exclusion criteria were trauma and malignancy. The primary outcome was occurrence of ICH. Comparative analysis and a multivariable logistic regression were used to identify independent risk.

Results: In total, 40,990 patients met our criteria with an incidence of ICH at 0.08%. The ICH-group showed an increased length of stay and higher mortality compared to the control group. Spinal cord decompression, DT and PCSFL were significantly more frequent in patients with ICH. Alcohol, drug abuse and hypertension were significantly more prevalent in patients with ICH. DT, alcohol abuse and hypertension were independent risk factors for ICH.

Conclusions: This study underscores the rarity and severity of ICHs following elective spine surgery, emphasizing awareness and looking for possible preventive measures. Our finding suggests that DT, as a complication of surgical techniques, as well as alcohol abuse and hypertension are significant predictors of ICH.

Introduction

It is well established that every spine surgery especially when involving decompression of neural elements generally bears a risk of unintentional iatrogenic dural tear (DT). A pooled DT incidence of 5.2 % has been reported. Rates depend on multiple variables such as type of surgery, approach, underlying condition, and location in the spine [1,2]. Removal of the lamina and usage of Kerrison rongeur has been shown to be particularly risky [3]. DT may lead to loss of cerebrospinal fluid leakage (CSFL) with consequences such as postural headache, development of a pseudomenigocele or chronic CSFL loss if the tear has not been sealed properly. Treatment strategies of DT are still under debate and depend on location and seize [4,5]. Intracranial hemorrhage (ICH) after spine surgery is a recognized albeit rare and potentially debilitating or life-threatening complication. Previous reports are highly variable and may reach up to an incidence of 0.8% [6-8]. The underlying patho-

FDA device/drug status: Not applicable.

Author disclosures: ***JG***: Nothing to disclose. ***AA***: Nothing to disclose. ***CP***: Nothing to disclose. ***NP***: Nothing to disclose. ***DDD***: Nothing to disclose. ***BA***: Nothing to disclose. ***PG***: Nothing to disclose. ***TS***: Nothing to disclose. ***AAJ***: Nothing to disclose. ***RJO***: Royalties: Stryker (F); Consulting: Medtronic (D), Globus Medical (D), Seaspine (D), Depuy Synthes (D). ***JRC***: Consulting: Globus Medical (F), XTANT (D).

* Corresponding author at: Julius Gerstmeyer, MD, Swedish Neuroscience Institute, Swedish Medical Center, 550 17th Ave, Suite 500, Seattle, WA 98122, United States.

E-mail address: julius.gerstmeyer@swedish.org (J. Gerstmeyer).

https://doi.org/10.1016/j.xnsj.2024.100555
Received 5 July 2024; Received in revised form 28 August 2024; Accepted 29 August 2024
Available online 3 September 2024

Table 1
Demographics of study population.

	Control group N=40,958	Intracranial hemorrhage N=32	p-value
	N (%) or	Mean (± SD)	
Male	20924 (51)	20 (62.5)	.197
Age	60.9 (±13.5)	64.2 (±12.1)	.152
Length of stay (d)	**3.3 (4.1)**	**7.4 (5.5)**	**<.001**
In-hospital death	**61 (0.15)**	*	**<.001**
Elective admission	**33,122 (81)**	**15 (46.88)**	**<.001**
Elixhauser in-hospital mortality index	**1.7 (3.3)**	**3.1 (4.0)**	**.015**
Elixhauser 30 d readmission index	−2.9 (6.0)	−4.0 (7.9)	.309

Bold values identify statistical significance.
* Indicates that value was below the HCUP reporting minimum of 11 and excluded from tabulation due to privacy protection guidelines.

mechanism has been described to be due to excessive CSFL leading to intracranial hypotension with different types and locations of ICH [6]. Decreased intracranial pressure may enlarge the dural venous sinuses with secondary displacement of the brain rupturing vessels [6]. These mechanisms remain of hypothetical nature and have not been proven in studies. Treatment of this complication heavily relies on location and type of ICH, with surgical and nonsurgical management options. Cerebellar hemorrhage was most commonly described, with supratentorial or multifocal variances [6].

Due to the rarity of ICH the evidence base of causation remains largely limited to case series. However, a recent literature review and a retrospective analysis have been published identifying dural tears as a risk factor for ICH [6,9].

This study utilizes a large, controlled patient system provided by the National Inpatient Sample Database to provide a more differentiated insight into risk factors associated with cranial hemorrhages after elective spine surgery.

Methods

A retrospective analysis utilizing data from the 2020 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality was performed [10]. Patients were selected for adult patients (>18years) and primary clinical classifications software refined (CCSR) for International Classification of Diseases (ICD)-10-PCS procedures category codes, Version 2023.1 [11]. Codes included spine fusion (MST013), discectomy (MST016), spinal cord decompression (CNS008), cervicothoracic nerve decompression (PNS002) and lumbosacral nerve decompression (PNS001). Demographic information, admission details such as elective admission, length of stay and in-hospital death was extracted. We excluded patients with presence of acute spine fracture and malignancy.

Comorbidities were identified using ICD-10 codes and CCSR-category codes, Version 2023.1 [11,12]. A postoperative CSFL was defined through ICD-10 Codes G96.0, G96.00 and G96.09, DT (G97.41 and G96.11), long term usage of antiplatelet agents (Z79.01) and anticoagulants (Z79.02) respectively. Cranial hemorrhages were identified by secondary CCSR code CIR021 which includes parenchymal, subarachnoid, epidural, and subdural hemorrhages both supra- and infratentorial. The Elixhauser Comorbidity Index for in-hospital mortality and all-cause 30-days readmission was calculated for each case [13]. As per HCUP data use agreement, any risk factors, comorbidities or complications were excluded from tabulation, if numbers were 10 or fewer.

Statistical analysis was performed using SPSS (IBM SPSS Statistics, Version 29.0.2.0 (20) Armonk, NY, USA). Descriptive analyses are presented as mean with standard deviation (SD), or frequencies with their percentages where appropriate. To compare categorical variables, the Chi-square test was used. For continuous outcomes a t-test was used. A multivariable logistic analysis was conducted to evaluate the association between specific risk factors and Intracranial hemorrhage. The effect of each risk factor, controlling for the others in the model, were reported using odds ratios (OR), 95% confidence intervals (CI) and p-value. The level of significance was set at p=.05. Since the data is publicly available, no approval from an institutional or national research committee was required.

Results

Overall, 40,990 patients met our inclusion criteria. Thirty-two patients suffered a cranial hemorrhage following spine surgery, giving an incidence of 0.08% (Table 1). We found a marginal, not significant, difference of age and gender distribution of the study groups. Patients with ICH were commonly male (62.5% compared to the control group 51%) and older (64.2±12.1 years to 60.9±13.5 years). In the ICH-group the length of stay with 7.4 days, in-hospital mortality rate at 6.25%, and the Elixhauser comorbidity index for in-hospital mortality (3.1±4.0) were all significantly higher (p≤.001). The likelihood of elective admission was much higher in the group without ICH (81%) compared to those with ICH (46.88%).

Table 2 highlights the surgical characteristics. While fusion procedures were most common in both groups, this percentage dropped from 81% to 47% in the ICH group (p=.028). However, significantly greater number decompression procedures were performed in the ICH group (25% vs. 8.1%, p<.001). Dural tears were present in 3.1% of patients in the control group, whereas the prevalence increased to 12.5% in patients who suffered ICH (p=.002). Similarly, the rate of postoperative PCSFL increased significantly from 0.9% to 6.3% in the ICH-group (p=.002).

Comorbidities, summarized in Table 3, were used to help calculate the Elixhauser comorbidity indices. Hypertension without complication and obesity were found to be the most common comorbidities in both groups. Notably alcohol abuse, drug abuse and hypertension with complications were significantly more common in the ICH group (9.4% to 1.8%; 9.4% to 2.3% and 25% to 9.8% respectively). However, conditions such as diabetes mellitus (both with and without complications), chronic lung disease, obesity, and hypothyroidism did not show a statistically significant difference between the 2 groups. Antiplatelet agent usage was higher in the ICH group (6.25% vs. 1.9%). Though this did not reach statistical significance at p=.079 it suggested a potential trend. Overall usage of anticoagulation did not differ between the groups.

In essence our multivariate regression analysis revealed dural tears, alcohol abuse and hypertension with complication to be independent risk factors for ICH (Table 4). Spinal cord level decompression and PCSFL did not reach significance but suggests a potential trend towards ICH. No correlation was noted with regards to ICH and fusion surgery without decompression.

Discussion

Intracranial hemorrhage following elective spine surgery is a rare but can be a serious complication. A paucity of previous literature de-

Table 2
Surgical characteristics.

	Control group N=40,958	Intracranial hemorrhage N=32	p-value
	N (%) or	Mean (± SD)	
Fusion	**27,892 (81)**	**15 (47)**	**.028**
Discectomy	5,121 (12.5)	*	.594
Spinal cord decompression	**3,336 (8.1)**	*	**<.001**
Cervicothoracic nerve decompression	442 (1.1)	*	.555
Lumbosacral nerve decompression	4,167 (10.2)	*	.881
Postoperative cerebrospinal fluid leakage	**384 (0.9)**	*	**.002**
Dural tear	**1,279 (3.1)**	*	**.002**

Bold values identify statistical significance.
* Indicates that value was below the HCUP reporting minimum of 11 and excluded from tabulation due to privacy protection guidelines.

Table 3
Comorbidities.

	Control group N=40,958	Intracranial hemorrhage N=32	p-value
	N (%) or	Mean (± SD)	
Antiplatelet agent usage	798 (1.9)	*	.079
Anticoagulation usage	1,646 (4)	*	.797
Alcohol abuse	**725 (1.8)**	*	**.001**
Diabetes mellitus with complication	4,604 (11.2)	*	.433
Diabetes mellitus without complication	5,403 (13.2)	*	.246
Drug abuse	**927 (2.3)**	*	**.007**
Hypertension with complication	**4,031 (9.8)**	*	**.004**
Hypertension without complication	20,250 (49.4)	13 (40.6)	.319
Chronic lung disease	7,620 (18.6)	*	.353
Obesity	10,044 (24.5)	*	.636
Peripheral vascular disease	1,264 (3.1)	*	.301

Bold values identify statistical significance.
* Indicates that value was below the HCUP reporting minimum of 11 and excluded from tabulation due to privacy protection guidelines.

Table 4
Multivariant regression analysis based on comorbidities, surgical techniques and complications.

	Odds ratio	95% confidence intervals	p-value
Fusion	0.775	0.330–1.821	.558
Spinal cord decompression	2.570	0.958–6.899	.061
Postoperative cerebrospinal fluid leakage	3.759	0.784–18.026	.098
Dural tear	**3.216**	**1.023–10.108**	**.046**
Alcohol abuse	**4.651**	**1.328–16290**	**.016**
Drug abuse	3.068	0.869–10.624	.082
Hypertension with complication	**2.835**	**1.267–6.341**	**.011**

Bold values identify statistical significance.

scribes this complication. To our knowledge, the present study entails the largest cohort on this topic.

Chadduck et al. [14] reported the first case of ICH following a dural opening during a cervical laminectomy in 1981, with an increase in case reports over subsequent years. To date the reported number of cases remains low [6]. The mechanism of ICH following spine surgery is hypothesized to be related to intracranial hypotension following cerebrospinal fluid leakage which may lead to different types of hemorrhage. Acute CSFL is thought to possibly lead to cerebellar hemorrhage and more rarely epidural hematoma. Chronic CSFL may also be associated with subdural hematoma. Herein decreased intracranial pressure may enlarge the dural venous sinuses with secondary displacement of the brain rupturing vessels [6]. Although these theories are widely accepted, they are yet to be proven and understood in full detail.

Previous reported incidences of ICH varied widely between 0.08% and 0.6%. The variability in reported rates may be attributable to differences in study design and populations. The rates vary based on the type of intracranial hemorrhage, with cerebellar hemorrhage being most frequent [7,8,15,16]. Our study found a 0.08% incidence of ICH after elective spine surgery. Indeed, the length of stay and rate of mortality were significantly higher in the ICH-group, underlining the impact of this complication. The exclusion of trauma and malignancy from this study might bias the results as cases of iatrogenic durotomy might induce a higher rate of ICH and PCSFL by CSF loss.

Our results show that DT and PCSFL were significantly more frequent in patients suffering an ICH. Furthermore, DT was identified as an independent risk factor for ICH-group (p=.046). However, PCSFL was not significant at p=.098, but indicating a trend towards ICH. These results are consistent with the existing literature. Previous studies identified DT and postoperative CSFL as risk factors for ICH, with the caveat that smaller case numbers can bias statistical results [6,9,17]. Relative to DT the possibility has to be considered that DT might be undetected during surgery. Consequently, intraoperative CSFL may occur unrecognized and thus not be recorded. A case series by Kaloostian et al. [17] showed that ICH was associated with a DT and use of a postoperative drain. Unnoticed DT might explain the strong statistical correlation observed in our data, despite a relatively small number of reported cases. A detailed assessment of the DT, including repair techniques used, would be beneficial in further understanding the patho-mechanism of ICH following spine surgery. However, due to the lack of clinical detail in ICD-10 codes regarding DT, we could not include this analysis into our study.

DT within different regions of the spine and surgical techniques might be more susceptible to ICH. The risk of DT in the lumbar spine was reported to be greater than in the cervical spine and laminectomies similarly had a higher incidence of DT [2,3,6].

Our results also showed significantly more ICH patients following spinal cord decompression surgery and fusion surgery. Interestingly, nerve root level decompression surgery showed no statistical significance in terms of ICH development. Due to the limited literature available there are no validated preventive measures known to this date.

Analysis of comorbidities showed that alcohol abuse, as well as hypertension with complication were more common in the ICH-group and were identified as the strongest independent risk factors. Both were well known risk factors for spontaneous ICH [18,19]. Although drug abuse was more common among the ICH group, it was not significant. We found no differences for other chronic diseases or even the usage of anticoagulation/antiplatelet agents. Our association analysis suggests that patients with these comorbidities may be generally more susceptible to ICH, which could be exacerbated by the additional physiologic strain of spine surgery and subsequent DT.

Limitation

As a retrospective database analysis, this study is limited by the accuracy, completeness, and selection of the recorded data. The NIS may not capture all relevant clinical details, leading to missed or unmeasured confounders. This may be particularly important regarding unnoticed dural tears or minor cerebrospinal fluid leaks. In addition to that ICD-10 codes can lack clinical details. For example, in the case of dural tears, there is no further differentiation account for size or location. The relatively small number of ICH events, despite a large overall sample size, restricts the study's statistical power to detect significant associations for less common risk factors or surgical techniques. The underreporting of dural tears and postoperative cerebrospinal fluid leakage, particularly if minor or unrecognized during surgery, poses a significant challenge to accurately identify these factors.

Conclusion

Intracranial hemorrhage after elective spine surgery is very rare but potentially life threatening. Our analysis revealed an incidence of 0.08% and statistically significant increased length of stay and rate of in-hospital death. The multivariate regression analysis revealed independent surgical and medical risk factors with dural tear, as complication of a surgical technique, and certain pre-existing comorbidities being most predictive. Larger database collection of ICH with more dedicated phenotypical descriptors, including assessment of DT and quantification of cerebrospinal fluid loss, and causation analysis would seem beneficial for a better understanding of this pathoentity.

Consent for publication

All authors have given a written declaration of consent for publication of the data obtained in this study.

Availability of data and materials

The dataset is publicly available from the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality.

Ethics approval

This retrospective study utilizes data from the 2020 National Inpatient Sample (NIS), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality. Therefore, no approval from an institutional and national research committee was needed.

Declarations of competing interests

The authors declare that they have no conflict of interests.

Acknowledgments

None.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The authors have no relevant financial or nonfinancial interests to disclose.

References

[1] Murphy ME, Kerezoudis P, Alvi MA, et al. Risk factors for dural tears: a study of elective spine surgery. Neurol Res 2017;39(2):97–106. Available at https://typeset.io/papers/risk-factors-for-dural-tears-a-study-of-elective-spine-ooqjwvo56k Accessed March 16, 2024.
[2] Alshameeri ZAF, El-Mubarak A, Kim E, et al. A systematic review and meta-analysis on the management of accidental dural tears in spinal surgery: drowning in information but thirsty for a clear message. Eur Spine J 2020;29(7):1671–85. Available at https://typeset.io/papers/a-systematic-review-and-meta-analysis-on-the-management-of-27urdpbkos Accessed March 16, 2024.
[3] Milton R, Kalanjiyam GP, S R, et al. Dural injury following elective spine surgery – a prospective analysis of risk factors, management and complications. J Clin Orthop Trauma 2023;41:102172. Available at http://www.journal-cot.com/article/S0976566223000802/fulltext Accessed March 22, 2024.
[4] Kamenova M, Leu S, Mariani L, et al. Management of incidental dural tear during lumbar spine surgery. To suture or not to suture? World Neurosurg 2016;87:455–62. Available at https://pubmed.ncbi.nlm.nih.gov/26700751/ Accessed August 11, 2024.
[5] Taylor C, Khan A, Shenouda E, et al. Dural tear repair surgery comparative analysis: a stitch in time saves nine. Eur Spine J 2022;31(3):575–95. Available at https://pubmed.ncbi.nlm.nih.gov/34889999/ Accessed August 11, 2024.
[6] Huang H, Zhu C, Qin H, et al. Intracranial hemorrhage after spinal surgery: a literature review. Ann Transl Med 2022;10(20):1141.
[7] Cevik B, Kirbas I, Cakir B, et al. Remote cerebellar hemorrhage after lumbar spinal surgery. Eur J Radiol 2009;70(1):7–9. Available at https://pubmed.ncbi.nlm.nih.gov/18294795/ Accessed March 16, 2024.
[8] Khalatbari MR, Khalatbari I, Moharamzad Y. Intracranial hemorrhage following lumbar spine surgery. Eur Spine J 2012;21(10):2091–6. Available at https://pubmed.ncbi.nlm.nih.gov/22349967/ Accessed March 16, 2024.
[9] Yan X, Yan L-R, Ma Z-G, et al. Clinical characteristics and risk factors of intracranial hemorrhage after spinal surgery. World J Clin Cases 2023;11(23):5430–9. Available at http://www.ncbi.nlm.nih.gov/pubmed/37637679 Accessed March 19, 2024.
[10] HCUP National Inpatient Sample (NIS) Healthcare cost and utilization project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2012 www.hcup-us.ahrq.gov/nisoverview.jsp.
[11] HCUP clinical classifications software refined (CCSR) for ICD-10-CM diagnoses, v2023.1. Healthcare cost and utilization project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2023 www.hcup-us.ahrq.gov/toolssoftware/ccsr/dxccsr.jsp Accessed March 27.
[12] HCUP clinical classifications software refined (CCSR) for ICD-10-PCS procedures, v2023.1. Healthcare cost and utilization project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2023 www.hcup-us.ahrq.gov/toolssoftware/ccsr/prccsr.jsp Accessed March 27.
[13] HCUP elixhauser comorbidity software refined for ICD-10-CM, v2023.1. Healthcare cost and utilization project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2023 www.hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp Accessed March 27.
[14] Chadduck WM. Cerebellar hemorrhage complicating cervical laminectomy. Neurosurgery 1981;9(2):185–9. Available at https://pubmed.ncbi.nlm.nih.gov/7266820/ Accessed March 18, 2024.
[15] Floman Y, Millgram MA, Ashkenazi E, et al. Remote cerebellar hemorrhage complicating unintended durotomy in lumbar spine surgery. Int J Spine Surg 2015;9:29. Available at https://pubmed.ncbi.nlm.nih.gov/26273547/ Accessed March 16, 2024.
[16] Pham MH, Tuchman A, Platt A, et al. Intracranial complications associated with spinal surgery. Eur Spine J 2016;25(3):888–94. Available at https://pubmed.ncbi.nlm.nih.gov/26377547/ Accessed March 16, 2024.

[17] Kaloostian PE, Kim JE, Bydon A, et al. Intracranial hemorrhage after spine surgery. J Neurosurg Spine 2013;19 3(3):370–80 Available atAccessed March 16, 2024. doi:10.3171/2013.6.SPINE12863.

[18] Avellaneda-Gómez C, Serra Martínez M, Rodríguez-Campello A, et al. Alcohol overuse and intracerebral hemorrhage: characteristics and long-term outcome. Eur J Neurol 2018;25(11):1358–64. Available at https://typeset.io/papers/alcohol-overuse-and-intracerebral-hemorrhage-characteristics-kfu5g512j7 Accessed March 22, 2024.

[19] Sallinen H, Pietilä A, Salomaa V, et al. Risk factors of intracerebral hemorrhage: a case-control study. JStroke Cerebrovasc Dis 2020;29(4):104630. Available at https://typeset.io/papers/risk-factors-of-intracerebral-hemorrhage-a-case-control-1nukytqjo0 Accessed March 22, 2024.