Intracranial hemorrhage after spinal surgery: a literature review

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Background and Objective: Intracranial hemorrhage following spinal surgery is an infrequent but severe complication. Due to its rarity, the etiology, clinical characteristics, and treatment have not yet been fully elucidated. This literature review analyzed the incidence, clinical manifestations, hemorrhage location, current therapeutic strategies, location of operation, and interval time between surgery and bleeding. The objectives of the article were to provide insights for clinicians to promptly identify and prevent potential cases of intracranial hemorrhage.

Methods: The authors queried PubMed and Web of Science databases using predefined keywords and included published literature reporting on intracranial hemorrhage after spinal surgery. Relevant case reports, case series, and reviews describing the mechanism of intracranial hemorrhage after spinal surgery and meeting diagnostic criteria for intracranial hemorrhage related to spinal surgery were included. Clinico-demographhc data, presentations symptoms, location, index surgery type, and neurological outcomes after brain hemorrhage. Oxford Centre Level of Evidence guidelines was used to evaluate the quality of included studies. Descriptive statistics were used to synthesize the results.

Key Content and Findings: A total of 80 publications of level of evidence IV involving 108 patients with median age at diagnosis was 58.5 years (inter-quartile range: 6–85) were analyzed. The incidence of intracranial hemorrhage was 0.08–0.37% among patients who underwent spinal surgery, and this complication occurred predominantly within 48 hours postoperatively. The initial presentation included headache, reduced level of consciousness, dysarthria, nausea, vomiting, hearing loss, blurred vision, neck rigidity, and delayed recovery from anesthesia. More than half (58.3%) of patients improved, while 23.1% still experienced neurological dysfunctions, and 7.4% died.

Conclusions: The present study is limited by the levels of evidence of the included studies. There is heterogeneity among cases with respect to patient demographics and medical history. Angiography is critical in assessing the presence and extent of underlying vascular diseases. Intracranial hemorrages may be caused by intraoperative or postoperative cerebrospinal fluid leakage that will lead to intracranial pressure change

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and induced by intracranial venous or arterial bleeding. The treatment strategies include conservative medical management and surgical treatment. Individualized treatment should be emphasized.

Keywords: Intracranial hemorrhage; spinal surgery; dura tear; cerebrospinal fluid leakage; literature review

Submitted Sep 05, 2022. Accepted for publication Oct 19, 2022.
doi: 10.21037/atm-22-4929
View this article at: https://dx.doi.org/10.21037/atm-22-4929

Introduction

Intracranial hemorrhage following spinal surgery is an uncommon but exceedingly severe complication, which can lead to permanent disability (1). Due to its rarity, the mechanism, clinical characteristics, and treatment have not yet been fully elucidated. A previous study indicated that this complication might be associated with intraoperative dural tears or durotomy (2). However, some cases involving remote cerebellar hemorrhage after lumbar spine surgery without an intraoperative dural tear have also been reported (3). Thus, although dural tears and the secondary leakage of cerebrospinal fluid (CSF) seem to play an important role in the pathogenesis of this complication, the definitive mechanism of intracranial hemorrhage after spinal surgery remains unclear. Additionally, very limited clinical evidence exists regarding the prevention and early diagnosis of spinal surgery-related intracranial hemorrhage, and the misdiagnosis of this complication in clinical practice usually results in poor outcomes (4). The objective of this systematic literature review was to analyze the incidence, clinical manifestations, hemorrhage location, and current therapeutic strategies, and discuss the epidemiological features, risk factors, and prognosis. This review aims to provide insights for clinicians regarding the timely identification and prevention of potential intracranial hemorrhage cases. Such a review summarizing the current literature and analyzing the pathophysiological mechanisms behind this rare occurrence may help the surgeon identify risk factors and possibly prevent the event. We present the following article in accordance with the Narrative Review reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4929/rc).

Methods

The authors searched the PubMed and Web of Science for English based literature databases from Jan. 1980 to Feb. 2022 for publications with predefined search terms without language restrictions. The keywords were as follows: "intracranial" or "intracerebral" or "cerebral" or "cerebellar" or "brain"), ("hemorrhage" or bleeding"), ("spine" or "spinal"), and ("surgery" or "surgical" or "operation") (*Table 1*).

The inclusion criteria were: (I) relevant case reports and case series of intracranial hemorrhage after spinal surgery published in last 30 years; (II) relevant articles describing the mechanism of intracranial hemorrhage after spinal surgery; (III) literature involving patients who met the diagnostic criteria for intracranial hemorrhage, and articles in which the intracranial hemorrhage was related to spinal surgery.

The exclusion criteria were as follows: (I) reports of simple intracranial hemorrhage that were not associated with spinal surgery; (II) articles that were irrelevant to the study topic; and (III) literature with incomplete data and a lack of important clinical information.

Eligible case reports were selected according to the above criteria. The inclusion criteria were strictly applied and irrelevant cases were excluded. Multiple case reports with complete data and clear outcomes were cited in this article. Risk of bias of each study was determined using Oxford Centre Level of Evidence criteria and a single author review without automation tools.

The authors collected information on gender, onset ages, preoperative diagnoses, surgery histories, concomitant chronic diseases, intraoperative logs, hemorrhage characteristics, site of operation, and interval time between operation and bleeding. Treatments and outcomes were recorded on a standard data extraction form. The entries were counted to understand the ratio of different genders, surgical sites, bleeding sites, and other characteristics among the included patients. Descriptive statistics were conducted for the demographic and outcome variables.

Content and findings

A detailed description of the references containing patient data is provided in website: https://cdn.amegroups.cn/static/

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Table 1 The search strategy summary

Items	Specification
Date of search	Jan 1st, 2022 – July 31st, 2022
Databases and other sources searched	PubMed and Web of Science databases
Search terms used	(intracranial or intracerebral or cerebral or cerebellar), (hemorrhage or bleeding), (spine or spinal), and (surgery or surgical or operation)
Timeframe	Jan 1st, 1981 – Dec 31st, 2021
Inclusion and exclusion criteria	Case reports and series was included
	Language in English is included
Selection process	Hongxiang Huang and Qingchun Mu conducted the selection
	Discussion was made to get consensus

Table 2 Location of the intracranial hemorrhage

	Isolated cerebellar hemorrhage	Isolated non-cerebellar hemorrhage	Multi-site hemorrhage	Total
Cervical surgery	7	6	4	17
Thoracic surgery	7	3	5	15
Lumbosacral surgery	34	26	12	72
T&L surgery	3	1	0	4
Total	51	36	21	108

T as Thoracic and L as Lumbar. T&L surgery means thoracic and lumbar surgery at the same time.

public/atm-22-4929-01.pdf. Included articles were of level of evidence IV.

Demographic characteristics

Among the included literature, there were a total of 48 (44.4%) males and 60 (55.6%) females (male to female ratio, 1:1.3). The mean age of patients at diagnosis was 58.5 years (range, 6–85 years), and 83 (76.9%) of the 108 cases were aged over 50 years.

Clinical features

Twenty-one (19.3%) of 108 patients had a previous history of spinal surgery. The preoperative diagnoses included cervical diseases in 17 patients (15.7%), thoracic diseases in 15 patients (13.9%), and lumbosacral diseases in 72 patients (66.7%). Surgery for thoracic and lumbosacral disease was done at same time in 4 patients (3.7%). There were 61 cases of spinal degeneration (spinal compression, spinal stenosis, and intervertebral disc prolapse), five cases of spinal deformity, 15 cases of spinal tumor, and two cases of spine trauma. The remaining cases were not mentioned. All of the included cases received surgical treatment, which involved laminectomy in 56 cases, spinal fusion in 29 cases, and discectomy in nine cases (some patients underwent multiple types of surgery).

22 patients (20.4%) had chronic diseases such as hypertension, diabetes, and atrial fibrillation, while no medical history was mentioned in the literature regarding the remaining 86 patients (79.6%). According to the available intraoperative logs, there were intraoperative dural tears or incisions in 85 cases (85%), and no dural tears or incisions in 15 cases (15%). Furthermore, eight cases (7.4%) were either not described or only lowly/moderately described. Cerebrospinal fluid leakage was temporary, and no continuous cerebrospinal fluid leakage was found among the included cases.

Intracranial hemorrhage

The relationship between the bleeding and surgical sites is illustrated in *Table 2*. The intervals between spinal surgery

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and intracranial hemorrhage varied: 36 patients (33.3%) developed intracranial hemorrhage within 24 hours postoperatively, 25 patients (23.1%) within 24–48 hours postoperatively, 31 patients (28.7%) over 2 days after surgery; and the longest interval was measured at up to 4 weeks postoperatively. This interval was not mentioned in the remaining cases. Secondary hydrocephalus after intracranial hemorrhage was observed in 27 cases (25.0%), and concomitant pneumocephalus, dura leakage, or spinal meningocele was noted in 16 patients (14.8).

Treatment and prognosis

Computed tomography (CT) was performed for 48 patients, and magnetic resonance imaging was done for 13 patients. Both of these modalities were performed in 33 cases, and relevant documentation was unavailable in seven cases. Seven patients underwent angiography to rule out hemorrhage from vascular malformations, abnormal blood vessels in the neck, or aneurysms.

Once a diagnosis of intracranial hemorrhage was made, 59 patients underwent surgical treatment including external ventricular drainage or decompressive craniectomy, and 45 patients were treated conservatively with medications. The treatment status was unknown in four cases. After hydrocephalus appeared, three patients received shunt surgery, all of which were temporary without permanent shunting.

During the follow-up period, 63 patients (58.3%) achieved a significant improvement; 25 patients (23.1%) still experienced neurological dysfunctions such as dysarthria, ataxia, and extremity sensorimotor disorders; and eight (7.4%) died. The prognostic profiles were unavailable in 12 cases (11.1%). The median age of patients with functional impairment was 58.2 years old, while the youngest was only 14 years old. The average age of the deaths was 65.5 years old, and all of these patients were over 50 years old.

In summary, the difference between male and female patients was not significant. Most of these patients underwent laminectomy and decompression due to degenerative diseases. The postoperative bleeding interval mostly occurred within 48 hours of surgery.

Discussion

It is well known that age is related to spinal degenerative diseases. Most of these patients underwent laminectomy and decompression due to degenerative diseases. The occurrence of dural damage during surgery should be noted after evaluating for intracranial hemorrhage after spine surgery. In this study, intracranial hemorrhage was significantly associated with dura mater tears or incisions caused by surgery and the cerebellar hemorrhage was more common. The postoperative bleeding interval mostly occurred within 48 hours of surgery. The prognosis of intracranial hemorrhage after spinal surgery is optimistic, but prompt detection and treatment are needed. Angiography may be used as a reference for the exclusion of basic vascular diseases; however, it is not the first consideration.

Intracranial hemorrhage related to spinal surgery was firstly reported by Chadduck WM in 1981 in a patient who underwent cervical laminectomy in a sitting position; it was speculated that the occurrence of this severe complication was secondary to the excessive leakage of cerebrospinal fluid intraoperatively (5). Since then, reports regarding intracranial hemorrhage following spinal surgery have been increasingly disclosed, attracting the attention of neurosurgeons. The incidence of this complication has not yet been established. According to previous reports, intracranial hemorrhage secondary to spinal surgery is less infrequent than that secondary to craniotomy; the incidence of remote intracranial hemorrhage after craniotomy is approximately 0.08–0.6% (6) among included cases. Cevik *et al.* and Bozkurt *et al.* investigated 2,444 patients who underwent spinal surgery and found that only 0.08% of them developed intracranial hemorrhage postoperatively (7,8). Khalatbari *et al.* determined that only four patients (0.37%) suffered this complication in a cohort of 1,077 cases (9), Pham *et al.* found two patients (0.14%) in a cohort of 1,396 cases (10), and Floman *et al.* reported three patients in a cohort of 1,196 cases (11). Herein, we performed a comprehensive analysis and observed that the incidence of intracranial hemorrhage after spinal surgery was approximately 0.08–0.37% among included cases. Considering that results were obtained through reviewing published literature and not directed patients contact, some statistical items may be missing, such as weight, length of operation, and surgical position.

The onset and clinical manifestation of intracranial hemorrhage varied considerably. In this review, we found that the majority of patients developed intracranial hemorrhage within 48 hours postoperatively and only five patients developed this complication over 1 week postoperatively, indicating the first 2 days postoperatively may be a high-risk period. The onset presentations included

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headache (n=30), somnolence or consciousness disturbance (n=30), dysarthria (n=15), nausea and vomiting (n=17), and hemiparalysis or ataxia (n=7). Patients rarely manifested with visual impairment, neck rigidity, or irritability. These symptoms encountered in the early phase after spinal surgery can indicate a potential intracranial hemorrhage, and timely radiological examination is warranted (12,13). CT is generally the first-line imaging modality for diagnosis. Magnetic resonance imaging can identify Chiari malformation, dural enhancement, venous dilatation, etc. more clearly (14).

This complication is not well understood. Some studies have suggested that intracranial venous or arterial hemorrhage may be caused by low intracranial pressure secondary to excessive intraoperative or postoperative leakage of cerebrospinal fluid (12). When the intracranial pressure decreases, the cerebella shift may lead to the traction or occlusion of superior cerebellar veins, resulting in subsequent hemorrhagic venous infarction (13). Pallud *et al.* also pointed out that cerebellar hemorrhage may be secondary to cerebellar occlusion and edema caused by traction and tear of the superior cerebellar veins (15). Floman *et al.* found that hemorrhage was predominantly attributed to the rupture of veins in the cerebellar vermis or sulcus (11). Some researchers postulated that bilateral cerebellar hemorrhage might be related to venous rupture, which accounts for the majority of cerebellar hemorrhages. Meanwhile, unilateral hemorrhage was more likely caused by arterial rupture, including spontaneous arterial bleeding and secondary hemorrhage following arterial infarction (16). Chalela *et al.* proposed that the rupture of cerebellar veins might be caused by excessive venous congestion as a result of cerebrospinal fluid over-leakage (17).

In addition to solitary cerebellar hemorrhage, we also identified 11 cases of supratentorial hemorrhage and 13 cases of combined supra- and infra-tentorial hemorrhage was identified (18). The cerebrospinal fluid leakage hypothesis has been widely accepted for the pathogenesis of cerebellar hemorrhage and subdural hematoma (3). Khalatbari *et al.* pointed out that the difference between these two conditions lies in the following pathophysiological processes: cerebellar hemorrhage is caused by significant cerebrospinal fluid leakage during an acute period and the vein flow is not able to compensate for the pressure shortage; meanwhile, subdural hematoma is a result of chronic cerebrospinal fluid leakage (9). The long-term leakage of cerebrospinal fluid volume will lead to decreased intracranial cerebral pressure (ICP), which may induce the enlargement of the dural venous sinus and caudal brain displacement. Caudal brain displacement may produce tension on the enlarged venous sinus, making the patient prone to venous tears, thereby resulting in subdural hematoma (19). Epidural hematoma was also reported as an extremely rare complication, but the mechanism remains unclear (20). Khalatbari *et al.* posited this complication may be related to the surgery location (9); the frontal lobe is the highest tissue in the cerebrum, and spinal surgery-induced low intracranial pressure may lead to the separation of the dura and the skull inner plate, thereby resulting in epidural hematoma (20).

According to the current literature, dural tears, cerebrospinal fluid leakage, and secondary cerebral tissue shift have been widely accepted as the leading causes of intracranial hemorrhage following spine surgery (2). In the present review, we observed intraoperative dural tears or incisions in 56 cases, and no dural tears or incisions were found in five cases. One postulation is that latent dural tears contribute to intracranial hemorrhage (2). If too much serosanguineous fluid drains postoperatively, the possibility of occult cerebrospinal fluid leakage should be considered. In such cases, drainage should be stopped or gravity drainage should be applied instead of suction drainage (21).

Intraoperative dural tear is a common complication of spinal surgery (2). Williams *et al.* observed a dural tear incidence of 1.6% in a 100,000-case spinal surgery cohort (22). Dural tears are one etiology of intraoperative or postoperative cerebrospinal fluid leakage but are not the only mechanism. Intracranial hemorrhage is related to the velocity and volume of cerebrospinal fluid leakage (23). The mainstream hypotheses can be summarized as follows: (I) intracranial hemorrhage may be caused by brain tissue shift and vascular traction secondary to cerebrospinal fluid leakage-induced low intracranial pressure; (II) intracranial hemorrhage may be caused by vascular rupture as a result of excessive congestion of veins; (III) epidural hematoma is caused by the separation of the dura and skull inner plate as a result of spinal surgery-induced low intracranial pressure; and (IV) subdural hematoma is caused by subdural venous rupture as a result of low intracranial pressure following chronic cerebrospinal fluid leakage. The risk factors of intracranial hemorrhage should also be highlighted, including hypertension, diabetes, coagulation disturbance, anti-coagulation medication administration, and vascular malformations should be highlighted and considered in management of patients undergoing spine surgery (24).

The optimal treatment for spinal surgery-induced

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intracranial hemorrhage has not yet been established. Medical management, including blood pressure control, identification and correction of coagulopathic abnormalities, and intracranial pressure control, can be recommended for patients with mild symptoms and those who undergo duraplasty intraoperatively (11). For patients with pneumocephalus or spinal meningocele, duraplasty can be effective (25). For patients with hydrocephalus, surgical treatments include decompressive craniectomy, burr-hole drainage, and craniotomy and evacuation of the hematoma, can improve prognosis (5). If a cerebrospinal fluid drainage tube has been inserted, clinicians should consider closing or removing the tube (26).

The present study is limited by the level of evidence of the included studies. Access to cases was limited to the information in the published case reports. The included databases include all study designs and only include published case reports in indexed journals.

Conclusions

Intracranial hemorrhage after spinal surgery is rare. The present literature review aimed to delineate diagnostic, therapeutic, and prognostic profiles. For patients diagnosed with degenerative spine disease, the postoperative recovery in those requiring laminectomy should be closely monitored. Computed tomography or magnetic resonance imaging and should be initial modalities for diagnosis. Angiography can evaluate potential sources of bleeding, including vascular malformations, abnormal neck vessels, aneurysms. Proposed mechanisms are intracranial venous or arterial hemorrhage caused by low intracranial pressure secondary to intraoperative or postoperative cerebrospinal fluid leakage. Therapeutic strategies include conservative observation and surgical treatment, and individualized treatment should be emphasized.

Acknowledgments

The authors appreciate the academic support from the AME Spine Surgery Collaborative Group.
Funding: This work was supported by the grant from Maoming Science and Technology Project (No. 2020155).

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-4929/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4929/coif). OD received Royalties from Globus medical for development of a cervical implant since 2008, and serves on the American Board of Orthopedic Surgeons as an oral examiner and is reimbursed for travel and lodging to Chicago. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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(English Language Editor: A. Kassem)

Cite this article as: Huang H, Zhu C, Qin H, Deng L, Huang C, Saifi C, Bondar K, Giordan E, Danisa O, Chung JH, Elgafy H, Fonseka RD, Huang C, Mu Q. Intracranial hemorrhage after spinal surgery: a literature review. Ann Transl Med 2022;10(20):1141. doi: 10.21037/atm-22-4929

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