Perioperative Ischemic and Hemorrhagic Stroke in Spine Surgery: A Series of 5 Cases

François Dantas[1,2], Antônio Carlos Vieira Caires[1], Gustavo Agra Cariri[1], Fernando Luiz Rolemberg Dantas[1,3]

■ BACKGROUND: **Stroke is a potentially life-threatening condition that can lead to disability and prolonged hospital stay. Perioperative stroke is a rare complication of spine surgery, especially in elective procedures. The prevalence of this complication varies in the literature, and the physiopathology is uncertain in many cases. Our objective was to describe 5 cases of patients who underwent spine surgery complicated by perioperative stroke and to analyze their characteristics and clinical outcomes.**

■ METHODS: **We retrospectively analyzed data from spine surgeries performed at a single institution from January 2016 to December 2019. Patients who presented with perioperative stroke were included. Data related to patient demographics, postoperative status, hospital stay, type of surgery, American Society of Anesthesiologists (ASA) score, neurologic status at discharge, and mortality were registered.**

■ RESULTS: **Five of 1002 consecutive patients (0.49%) had complication of stroke during surgery. The surgeries included occipitocervical fusion, anterior cervical fusion, lumbar fusion, lumbosacral fusion, and thoracolumbar fusion. The mean age of patients was 52.2 ± 15.73 years (range, 39–78 years), and the mean time of hospitalization was 20 ± 26.93 days (range, 6–68 days). The majority of patients were women (80%). Three patients (60%) presented with ischemic stroke, and 2 patients (40%) had hemorrhagic stroke. Two patients were severely disabled, and 3 showed good neurologic outcomes; no in-hospital deaths were observed. The etiology of stroke remained uncertain in the majority of cases.**

■ CONCLUSIONS: **Despite the rarity of this complication, perioperative stroke in spine surgery can lead to considerable morbidity. Precocious diagnosis and treatment may improve patient outcomes.**

INTRODUCTION

Stroke is a potentially life-threatening condition that can lead to disability and prolonged hospitalization, and it is usually associated with high costs for the health care system. Stroke can be ischemic or hemorrhagic. Ischemic stroke is the most common type and currently the second leading cause of death worldwide.[1] Perioperative stroke is a rare complication of spine surgeries, especially in elective procedures.[2-5] Its physiopathology is often unknown, and the prevalence of this complication is variable in the literature.

OBJECTIVES

We describe 5 cases of patients who underwent spine surgery that was complicated by perioperative stroke and analyze patient characteristics and outcomes.

METHODS

Between January 2016 and December 2019, a total of 1002 consecutive patients underwent spine surgery at a single private

Key words
- Cerebrovascular accident
- Complications
- Hemorrhagic stroke
- Ischemic stroke
- Perioperative
- Spine surgery
- Stroke

Abbreviations and Acronyms
ASA: American Society of Anesthesiologists
CT: Computed tomography
DSA: Digital subtraction angiography
GCS: Glasgow Coma Scale
ICU: Intensive care unit
MRA: Magnetic resonance angiography
MRI: Magnetic resonance imaging
TE: Transesophageal echocardiogram

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center and were included in the study. Patients who underwent percutaneous procedures such as radiofrequency ablation and vertebroplasty were not part of the analysis. Medical records of the patients were analyzed, and those who had perioperative stroke were noted. Data related to patient demographics, postoperative status, hospital stay, type of surgery, American Society of Anesthesiologists (ASA) score, neurologic status at discharge, and mortality were registered.

RESULTS

Five of 1002 patients (0.49%) complicated with stroke during the surgical procedure. Surgeries included occipitocervical fusion, anterior cervical fusion, lumbar fusion, lumbosacral fusion, and thoracolumbar fusion. Preoperative examinations related to coagulation and platelet count were normal, and all patients underwent general anesthesia. The mean age of patients was 52.2 ± 15.73 years (range, 39–78 years), and the mean hospitalization time was 20 ± 26.93 days (range, 6–68 days). The majority of patients were women (80%). Three patients (60%) had ischemic stroke, and 2 patients (40%) had hemorrhagic stroke. Two patients were severely disabled and 3 showed good neurologic outcomes; no in-hospital deaths were observed. The etiology of stroke remained uncertain in the majority of cases.

Patient demographics, surgical characteristics, and clinical/radiologic features are summarized in **Table 1**.

CASE PRESENTATIONS

Case #1

A 78-year-old man presented with paresthesia in the lower limbs and neurogenic claudication, refractory to clinical treatment. Lumbar spine magnetic resonance imaging (MRI) showed severe lumbar spine stenosis. The patient had a history of hypertension, diabetes, Chagas cardiomyopathy, dyslipidemia, and obesity. He underwent an elective lumbar spine decompression followed by L2-L5 posterior fusion with pedicle screws. There were no abnormalities in the perioperative period, except for a hypertensive peak at the end of the surgery, which was controlled with vasoactive drugs. Blood loss was not significant, and no dural tear occurred. He presented with a seizure right before extubation and immediately underwent a computed tomography (CT) scan of the brain, which showed subarachnoid hemorrhage in the sylvian fissure and high convexity bilaterally, a frontal acute subdural hematoma, and a large frontoparietal intracerebral hemorrhage in the right hemisphere, with moderate midline shift (**Figure 1**). Digital subtraction angiography (DSA) showed no acute alterations other than a hypovascular area that corresponded to the hemorrhage. Cerebral venous thrombosis and reversible cerebral vasoconstriction syndrome were considered as possible diagnosis before the DSA, but no sign of arterial vasoconstriction was observed, and filling of the cortical veins and venous sinus was completely normal; a dominant vein of Trolard and a hypoplastic vein of Labbé were observed on the right side. The patient was then sent to the intensive care unit (ICU) for hemodynamic stabilization under sedation, and a new CT scan was performed on the same day, which showed worsening of the edema surrounding the hemorrhage and intraventricular hemorrhage (**Figure 2**). A coagulogram and platelet count after surgery were normal. Surgical hematoma drainage was performed simultaneously with the implant of an external ventricular drain. The patient was maintained in the ICU, and 5 days later, a control CT scan showed a hypertensive frontal subdural collection, with severe midline shift, which was drained with trepanation. The patient was diagnosed subsequently with pneumonia and maintained a Glasgow Coma Scale (GCS) score varying from 4 to 6 when sedation was withdrawn. At the family's request, the patient was transferred to another institution in the patient's hometown, and some weeks later, he was discharged with home care service, severely disabled and bedridden.

Case #2

A 39-year-old woman with a diagnosis of idiopathic scoliosis since the age of 10 years presented with worsening of the scoliosis and breathing disorders. Except for scoliosis, her medical history was unremarkable. She underwent an elective thoracolumbar spinal fusion (T2-L4), with no intraoperative adverse events other than a considerable amount of blood loss, which is already expected in a major surgery. An intraoperative autotransfusion system was used during the surgery. In the immediate postoperative period, just after being admitted in the ICU, the patient presented with severe coma (GCS score 3) and bilateral mydriasis. A CT scan demonstrated bilateral hypodensities in the cerebellum and a hypodense area in the right thalamus. Cervical and brain CT angiography showed no large vessel occlusion, and only a hypoplastic right vertebral artery was observed. A few hours later, brain MRI and brain and cervical magnetic resonance angiography (MRA) were performed. The MRA was completely normal except for a hypoplastic right vertebral artery, with no signs of arterial occlusions or signs of arterial dissection. Brain MRI showed bilateral acute ischemia in the cerebellum, midbrain, pons, and thalamus, and in the right portion of the splenium of the corpus callosum and occipital lobe (**Figure 3**). As the patient had no large vessel occlusions and had formal contraindications for intravenous thrombolysis, neither thrombolysis nor thrombectomy was possible, and only clinical treatment for acute ischemic stroke was performed. Two days later, she was extubated and could obey some commands. On the third postoperative day, she once again presented with acute coma. A new CT scan showed severe edema in the posterior fossa, with compression of the fourth ventricle and hydrocephalus, warranting emergency posterior fossa decompression with the implant of an external ventricular drain. The patient evolved with progressive wakening and was transferred to a rehabilitation facility. Cardiovascular examinations such as transesophageal echocardiogram (TE) and 24-hour Holter monitoring were normal. At the time of hospital discharge, the patient could understand some commands and speak a few words but maintained quadriparesis (grade 4 in the upper limbs, and grade 3 in the lower limbs) and mild dysphagia.

Case #3

A 43-year-old woman with no previous medical conditions had progressive right cervicobrachialgia with poor response to clinical treatment. A cervical MRI showed disc herniations at the levels of C5-C6 and C6-C7, leading to root compression. She was submitted to elective C5-C6 and C6-C7 discectomy and anterior cervical

Table 1. Demographics, Surgical Characteristics, and Clinical/Radiologic Features

Case	1	2	3	4	5
Age (years)	78	39	43	45	56
Sex	M	F	F	F	F
ASA score	3	2	2	2	1
Type of surgery	Lumbar fusion (L2-L5)	Thoracolumbar fusion (T2-L4)	Anterior cervical fusion (C5-C7)	Posterior fossa decompression, occipitocervical fusion (C0-C3)	Lumbosacral fusion (L4-S1)
Position during surgery	Ventral decubitus	Ventral decubitus	Dorsal decubitus	Ventral decubitus	Ventral decubitus
Duration of surgery	6 h 15 min	10 h	3 h 25 min	7 h 35 min	5 h 15 min
Pre/postoperative hematocrit and hemoglobin	Hct: 47.1/38 Hb: 15.7/12.5	Hct: 38.7/22.8 Hb: 12.9/8.2	Hct: 40.4/38 Hb: 13.4/12.5	Hct: 41.2/38.2 Hb: 14.1/12.5	Hct: 40/36 Hb: 13.9/11.9
Perioperative transfusion	No	Yes	No	No	No
Clinical manifestations	Seizure and coma	Coma	Diplopia	Coma	Homonymous hemianopsia
Radiologic findings	Intracerebral hemorrhage, subarachnoid hemorrhage	Ischemic stroke	Ischemic stroke	Subarachnoid hemorrhage, diffuse segmental narrowing of cerebral arteries	Ischemic stroke
Hospital stay (days)	12 (transferred to another institution)	68	7	6	7
Discharge disposition	GCS score 5, bedridden	Quadriparesis, dysphagia, and dysphasia	Diplopia	Asymptomatic	Homonymous hemianopsia

ASA, American Society of Anesthesiologists; GCS, Glasgow Coma Scale; M, male; F, female; Hct, hematocrit; Hb, hemoglobin.

fusion using cages, and no intraoperative adverse events occurred. Carotid artery retraction was typical, and there was no intraoperative vertebral artery injury. On the second postoperative day, the patient mentioned that she had been having diplopia since the immediate postoperative period. A CT scan was performed, which demonstrated a hypodensity in the right thalamus, and brain MRI showed small areas of acute ischemia in the left cerebellar hemisphere, midbrain, and right thalamus (Figure 4). The brain

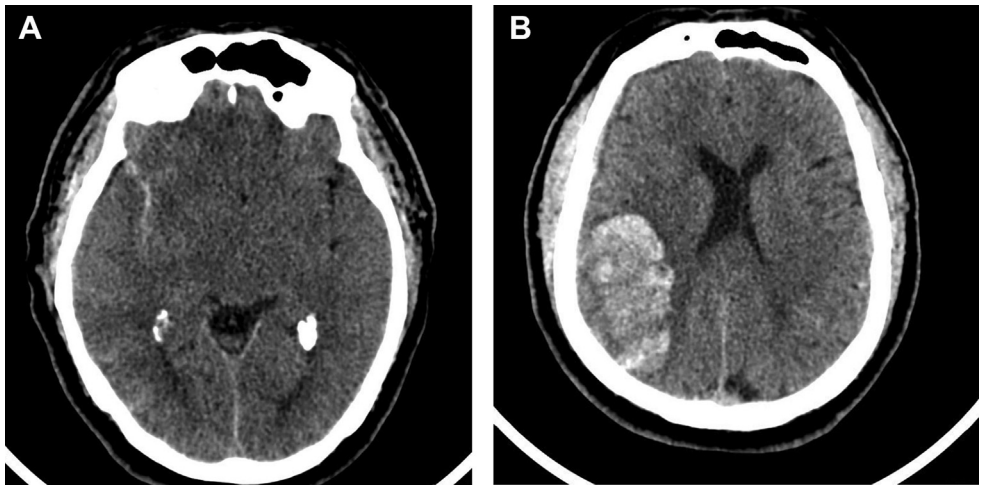

Figure 1. Images from case #1. Computed tomography scan demonstrating subarachnoid hemorrhage in the sylvian fissure (**A**), a frontal acute subdural hematoma, and a large frontoparietal intracerebral hemorrhage in the right hemisphere (**B**).

Figure 2. Image from case #1. Computed tomography scan showing worsening of the edema surrounding the hemorrhage, intraventricular hemorrhage, and severe midline shift.

and cervical MRAs were normal, and only a persistent fetal configuration of the right posterior communicating artery was observed. The patient was given a TE and 24-hour Holter monitoring, both of which were completely normal. At the time of discharge, she maintained a mild diplopia, with no other neurologic deficits.

Case #4

A 45-year-old woman, who had previously undergone a thoracolumbar fusion at the age of 12 years for the treatment of idiopathic scoliosis, presented with progressive paresthesia in the 4 limbs, ataxia, hyperreflexia, and bilateral clonus, and was diagnosed with Chiari malformation type 1 and cervical syrinx. She underwent an elective posterior fossa decompression and occipitocervical fusion (Co-C3). Hypertension was noted during the last hour of the surgery and controlled with antihypertensive drugs. In the immediate postoperative period, when sedation was withdrawn, the patient had an impaired level of consciousness and maintained a persistently high blood pressure. Her GCS score was 3 associated with bilateral mydriasis and absence of brainstem reflexes. An immediate CT scan was performed, which showed bilateral subarachnoid hemorrhage in the high convexity and in the posterior fossa (Figure 5). Cervical and brain CT angiography showed no signs of large vessel occlusions but demonstrated poor filling of the basilar artery. A DSA was promptly performed, and a diffuse segmental narrowing of cerebral arteries was observed in the anterior and posterior circulation (Figure 6) with no arterial occlusions. After the DSA, the hypothesis of reversible cerebral vasoconstriction syndrome was suggested. She was sent to the ICU under intubation, and intensive blood pressure control was initiated. On the first postoperative day, the patient was awake, could obey some commands, and had normal brainstem reflexes. On the second postoperative day, she was completely asymptomatic, with no motor or sensitive deficits, and was discharged a few days later.

Case #5

A 56-year-old woman with generalized anxiety disorder, who had previously undergone an L4-L5 and L5-S1 microdiscectomy, presented with chronic low back pain. Lumbar MRI showed degenerative disease and lumbar spine stenosis. She then underwent lumbar spine decompression and L4-S1 posterior fusion with pedicle screws, with no adverse events. On the first postoperative day, she mentioned an unspecific visual alteration that she had been noticing since the moment she woke up from the anesthesia. At her examination, a right homonymous hemianopsia was noted. Brain MRI showed 2 areas of acute ischemia, 1 in the right cerebellar hemisphere and another in the left occipital lobe (Figure 7). Cervical and brain MRAs were completely normal, with no stenosis or signs of arterial dissection. Other cardiovascular examinations were requested, such as TE and 24-hour Holter monitoring, with no abnormalities. She was discharged a few days later, with maintenance of hemianopsia. Thrombophilia screening examinations were requested for outpatient follow-up.

DISCUSSION

Stroke is a well-known life-threatening condition that can lead to disability, prolonged hospital stay, and increased costs for patients, their families, and the health care system. Approximately 85% of strokes are ischemic, and 15% are hemorrhagic. Stroke is currently the second leading cause of death globally. Known risk factors include hypertension, hyperlipidemia, diabetes mellitus, tobacco use, antithrombotic therapy, and less commonly, thrombophilia and other conditions.[1]

Surgery-related stroke can be linked to anesthesia, intraoperative maneuvers, or both.[6,7] Risk factors for perioperative stroke include advanced age, previous stroke or transient ischemic attacks, coronary artery disease, and renal disease. Some studies have shown that general anesthesia is associated with a higher risk of perioperative stroke. In general, only approximately 5%–15% of surgery-related strokes occur intraoperatively or in the immediate postoperative setting, and most postoperative strokes present at least 24 hours after surgery. Mortality from this complication can be as high as 20%–60%.[8]

Currently, the incidence of perioperative stroke in noncardiac, nonneurologic, and nonmajor vascular surgery is approximately 0.1%–1.9%. The incidence of covert stroke in high-risk noncardiac surgery, however, may be as high as 10%.[8] Covert strokes represent brain infarcts that are not recognized acutely because of unappreciated, subtle, or misclassified manifestations, but which are detected on brain imaging. In a recent study by the NeuroVISION investigators, 78 of 1114 analyzed patients (7%) had imaging findings of an acute perioperative covert stroke after all types of elective noncardiac surgery (spinal surgeries represented only 3% of the cases), which was associated with an increased risk of cognitive decline at 1 year after surgery.[9]

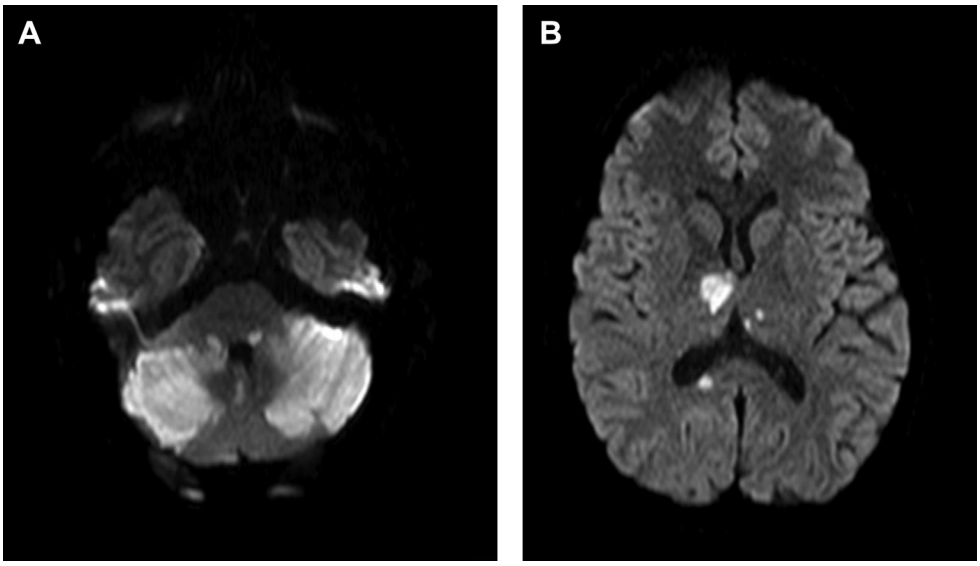

Figure 3. Images from case #2. Diffusion-weighted magnetic resonance imaging demonstrating bilateral acute ischemia in the cerebellum (**A**), both thalami, and in the right portion of the splenium of the corpus callosum (**B**).

Thrombosis, embolism, anemic tissue hypoxia, and cerebral hypoperfusion have been described as etiologic pathways contributing to perioperative ischemic stroke. Thrombosis is related to systemic inflammation and hypercoagulability precipitated by surgery, which may contribute to thrombogenesis and vessel plaque rupture in the perioperative setting. Rebound hypercoagulation may also occur in patients receiving anticoagulation or antiplatelet therapy preoperatively. Cardioembolic stroke is usually related to atrial fibrillation combined with a hypercoagulable state in the perioperative setting. Cerebral hypoxia may also be caused by hemodilution and anemia, and patients who experience significant bleeding during surgery are at higher risk for perioperative ischemic stroke.[8] Intraoperative hypotension has also been related to stroke, especially with a decrease of >30% from the baseline blood pressure. However, the exact role of hypotension in the etiology of perioperative stroke is not well established.[10]

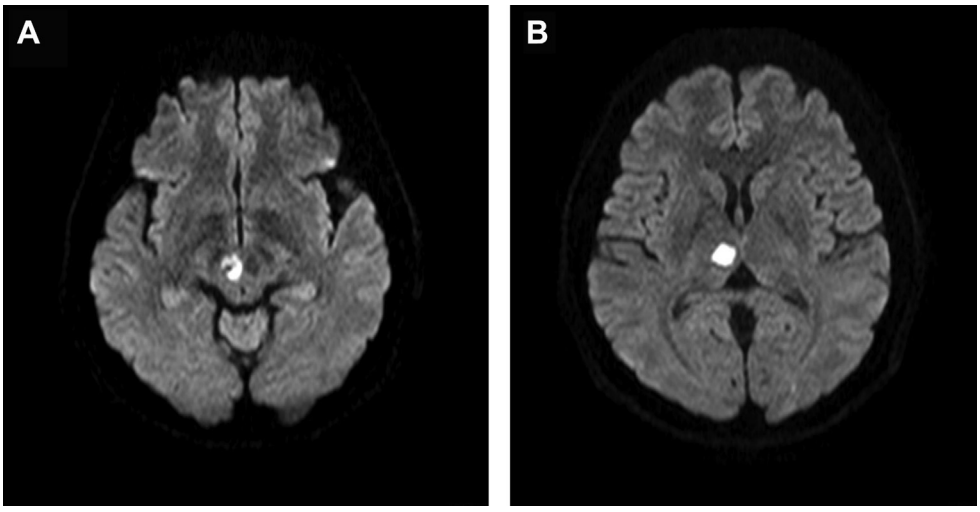

Figure 4. Images from case #3. Diffusion-weighted magnetic resonance imaging showing acute ischemia in the right portion of the midbrain (**A**) and right thalamus (**B**).

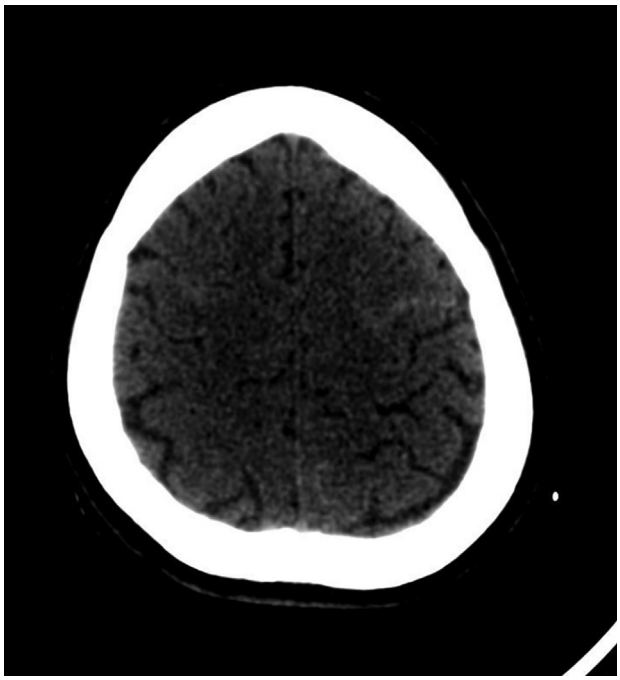

Figure 5. Image from case #4. Computed tomography scan showing high convexity bilateral subarachnoid hemorrhage.

Hemorrhagic stroke represents only 1%–4% of all perioperative strokes.[8] However, its mortality rate ranges from 35%–44%.[11] Factors such as uncontrolled hypertension, cerebral vascular malformations, and administration of anticoagulant of antiplatelet therapy may contribute to hemorrhagic events perioperatively.[8] Expansion of the hematoma is usually associated with coagulation abnormalities often seen in liver dysfunction, renal insufficiency, or anticoagulation therapy.[11]

Risk factors for perioperative ischemic stroke specifically related to spine surgeries are often unknown.[2] However, hemorrhagic stroke has been associated with intraoperative cerebrospinal fluid leak, leading to intracranial hypotension.[12-16]

Perioperative stroke in spine surgery is a rare complication of which surgeons should be aware, thus allowing precocious diagnosis and treatment. Its incidence is variable in the literature, and there are few articles concerning the prevalence of intraoperative stroke in spine surgery,[2-5] although many case reports and case series have been reported.[16-21] However, postoperative complications are widely described in the literature.[12-16,22-34]

A recent retrospective study conducted by Ishak et al.[2] that included 5029 patients reported a prevalence of perioperative ischemic stroke of 0.15% in spine surgeries. A total of 7 patients had an ischemic stroke during the procedure, with a predominance of female patients (6). The mean patient age was 67.4 years (range, 46–85 years), and 4 patients (57%) had an ASA 3 score. All 7 patients had a history of hypertension and diabetes, 3 (43%) of those were smokers, 4 (57%) had cardiovascular diseases, and 4 (57%) had dyslipidemia. Furthermore, HbA1c levels were elevated in 6 of the 7 patients (86%). Cerebrospinal fluid leak occurred in 5 of the 7 cases (71%), and 1 patient presented new onset intraoperative atrial fibrillation. Intraoperative autotransfusion was necessary in 3 patients, and 4 patients received inotropes during surgery. An in-hospital mortality rate of 29% was noted, and 3 patients (43%) developed persistent neurologic deficits during the hospital stay. The mean hospital stay was 15 days (range, 4–31 days).

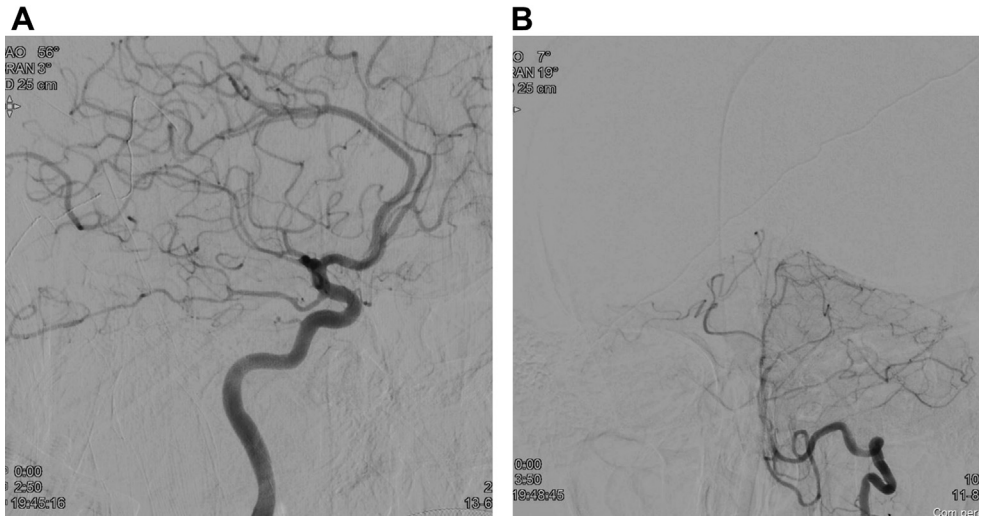

Figure 6. Images from case #4. Digital subtraction angiography showing diffuse segmental narrowing of cerebral arteries in the anterior (**A**) and posterior (**B**) circulation, with no arterial occlusions. Bilateral persistent fetal configuration of the posterior communicating artery was observed.

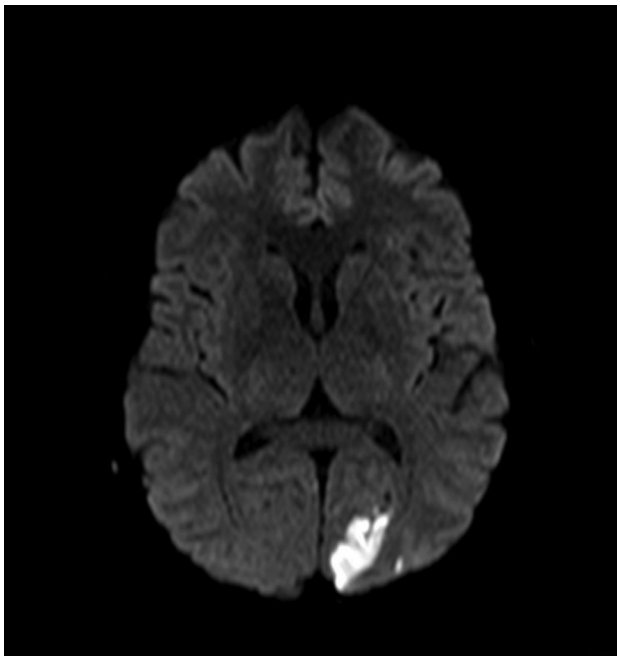

Figure 7. Image from case #5. Diffusion-weighted magnetic resonance imaging demonstrating acute ischemia in the left occipital lobe.

Ohya et al.[3] conducted a large nationwide retrospective study in Japan that included 167,106 patients and reported a perioperative stroke rate of 0.22% (371 patients) after elective spine surgery. Of these, 207 were men and 164 were women. Hemorrhagic stroke occurred in 53 patients (14.2%), and ischemic stroke occurred in 318 (85.7%). The death rate was 4.9%, and subjects who underwent resection of spinal cord tumors had a higher risk of stroke than those undergoing discectomy, decompression surgery, or arthrodesis surgery. Other identified risk factors for intraoperative stroke were age 80 years or older, history of cardiac disease, diabetes, hypertension, cervical spine surgery, surgery in a teaching hospital, and length of stay.

A study involving 3475 registered patients in their National Surgical Quality Improvement Program database conducted by Schoenfeld et al.[22] found an incidence of immediate postoperative stroke of 0.1% following spine surgeries. The identified risk factors for immediate postoperative complications were age, female sex, surgical time, and number of medical comorbidities.

Du et al.[17] reported 3 cases of carotid artery-related perioperative ischemic stroke following anterior cervical spine surgery and found only 4 detailed cases previously described in the literature. In their institution, the incidence of this complication was 0.4%, and it occurred more frequently in men (2 of 3). Prolonged retraction of the common carotid artery, especially in cases of atherosclerotic disease, was considered the main cause of intraoperative ischemic stroke related to anterior cervical spine surgeries. A 30%–67% decrease in the vessel cross-sectional area can be caused by prolonged retraction of the carotid artery, which can lead to a decrease in the blood flow. Blood stasis may further cause thrombosis, especially at the site of atherosclerotic plaque or stenosis. A stroke may also occur when the duration of hypoperfusion is prolonged or the collateral compensation is inadequate, and intraoperative hypotension can aggravate hypoperfusion.

The first case of a perioperative vertebrobasilar stroke in a patient who underwent an anterior cervical decompression and arthroplasty was reported by Berg et al.[18] The patient was a 60-year-old woman with no medical conditions other than controlled hypertension. After an elective C4-C5, C5-C6, and C6-C7 arthroplasty, she woke up from anesthesia with hemiparesis and diplopia, and a large left cerebellar hemisphere and brainstem ischemia was diagnosed. Brain and cervical angiography and echocardiogram were normal, and the etiology of stroke could not be precisely defined.

We found some case reports in the literature concerning perioperative hemorrhagic stroke following spine surgeries.[16,19-21] In all those reports, patients presented with delayed emergence from anesthesia or impaired level of consciousness after the surgery, similarly to that observed in cases 1 and 4 of our series.

In our study, 1002 consecutive patients were analyzed, and 3 cases of perioperative ischemic stroke and 2 cases of hemorrhagic stroke were identified, with a total rate of 0.49%, slightly higher than the one found in the literature. All patients underwent general anesthesia. Four of 5 patients were women, with a mean age of 52.2 ± 15.73 years (range, 39–78 years) and a mean hospitalization time of 20 ± 26.93 days (range, 6–68 days). Two patients were severely disabled (cases 1 and 2), and 3 presented good neurologic outcomes; no in-hospital deaths occurred. The etiology of stroke remained uncertain in the majority of cases. Only 1 patient (case 1) had known risk factors for stroke. Perioperative severe hypotension or arrythmias were not observed during the surgeries.

It is interesting to note that in our series, patients who presented with ischemic stroke (cases 2, 3, and 5) were only affected in territories vascularized by the vertebrobasilar system, but no alterations in the vertebrobasilar system or echocardiographic alterations were found. Even when an anterior cervical approach was performed (case 3), cerebral ischemia was not related to the territory vascularized by the carotid artery. Despite the persistent fetal configuration of the right posterior communicating artery in her case (that could explain the right thalamic ischemia as a consequence of intraoperative carotid retraction), ischemia was also observed in the left cerebellar hemisphere, which is more suggestive of a cardioembolic pattern of stroke.

One patient (case 4) had a subarachnoid hemorrhage, and her DSA demonstrated a diffuse segmental narrowing of cerebral arteries in the anterior and posterior circulation. The hypothesis of reversible cerebral vasoconstriction syndrome was then considered after the findings of the DSA and patient's dramatic recovery. Both patients who presented with hemorrhagic stroke (cases 1 and 4) evolved with hypertension intraoperatively, demanding the use of vasoactive drugs. Only 1 patient (case 2) underwent intraoperative autotransfusion during the surgery, which was also used in some patients who complicated with stroke in the series by Ishak et al.[2]

LIMITATIONS OF THIS STUDY

The present study had some limitations. It is a case series of a single private institution with a small number of patients and with

no control group. Patients with mild stroke may have been overlooked. Stroke etiology was not defined in the majority of cases, but not all patients underwent DSA, which is the gold-standard examination for the diagnosis of arterial dissection. We presumed that stroke ictus was the complication during surgery in all cases because all patients presented with symptoms in the immediate postoperative period, and neuroimaging already showed cerebral ischemia or hemorrhage, some with subacute ischemia.

CONCLUSIONS

Stroke is a rare but potentially devastating perioperative complication following spine surgery. It should be considered as a possible complication whenever patients present with neurologic deficits or complaints in the immediate postoperative period, or in cases with delayed emergence from anesthesia and no improvement in the level of consciousness. Further studies are necessary to elucidate the physiopathology of intraoperative stroke and help prevent this complication in spine surgeries.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

François Dantas: Conceptualization, Methodology, Investigation, Writing - original draft, Visualization. **Antônio Carlos Vieira Caires:** Investigation, Supervision, Visualization. **Gustavo Agra Cariri:** Investigation, Supervision, Visualization. **Fernando Luiz Rolemberg Dantas:** Conceptualization, Methodology, Investigation, Writing - review & editing, Visualization.

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