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R. Khatri
M. Ansar
F. Sultan
S.A. Chaudhry
A.A. Khan
G.J. Rodriguez
R.P. Tummala
A.I. Qureshi

EDITOR'S
CHOICES

BACKGROUND AND PURPOSE: Provisions for an emergent neurosurgical procedure have been a mandatory component of centers that perform neuroendovascular procedures. We sought to determine the need for emergent neurosurgical procedures following neuroendovascular interventions in 2 comprehensive stroke centers in settings with such provisions.

MATERIALS AND METHODS: Analysis of retrospectively collected data from procedure logs and patient charts was performed to identify patients who required immediate (before the termination of the intervention) or adjunctive (within 24 hours of the intervention) neurosurgical procedures related to a neuroendovascular intervention complication. The types of neurosurgical procedures and in-hospital outcomes of identified patients are reported as an aggregate and per endovascular procedure-type analyses.

RESULTS: We reviewed a total of 933 neuroendovascular procedures performed during 3.5 years (2006–2010). A total of 759 intracranial procedures were performed. There was a need for emergent neurosurgical procedures in 8 patients (0.85% cumulative incidence and 1.05% for major intracranial procedures) (mean age, 46 years; 7 were women); the procedures were categorized as 3 immediate and 5 adjunctive procedures. There were 5 in-hospital deaths (62.5%) among these 8 patients. Neurosurgical procedures performed were external ventricular drainage placement in 6 (6 of 8, 75%) patients, decompressive craniectomy in 1 (12.5%) patient, and both surgical procedures in 1 (12.5%) patient.

CONCLUSIONS: The need for emergent neurosurgical procedures is very low among patients undergoing intracranial neuroendovascular procedures. Survival in such patients despite emergent neurosurgical procedures is quite low.

ABBREVIATIONS: AIS = acute ischemic stroke; EVD = external ventricular drainage; ICH = intracranial hemorrhage; ICP = intracranial pressure; IPH = intraparenchymal hemorrhage; mRS = modified Rankin scale

C urrent recommendations for a comprehensive stroke center mandate 24/7 availability of a neurosurgeon in-house (or able to provide services at the center within 30 minutes) who can perform emergent neurosurgical procedures and treat life-threatening intracranial conditions such as increased ICP and/or mass effect from IPH.[1] Neuroendovascular surgery is a multidisciplinary specialty, which has been evolving rapidly during the past few decades.[2] Despite technical and pharmacologic advancements, major complications such as IPH or SAH may occur during these interventions. As use of these procedures expands from selected teaching hospitals to various settings, the resources required beyond the neurointerventionalist and angiographic equipment to support safe and effective performance need to be evaluated. In particular, the safety of performing neuroendovascular interventions without emergent neurosurgical backup remains uncertain. We sought to determine the frequency, indications, in-hospi-

tal complications, and outcome of patients undergoing intracranial neuroendovascular procedures in which neurosurgical assistance was required on an emergent basis. The purpose of the study was to determine the need for neurosurgical procedures on an emergent basis related to the neuroendovascular interventions.

Materials and Methods

We retrospectively reviewed our procedure log data of all neuroendovascular interventions ($n = 933$) performed during 3.5 years (2006–2010) at 2 academic centers, which are both comprehensive stroke centers, in the metropolitan Minneapolis-St. Paul (Minnesota) area. Our endovascular surgical neuroradiology training program is Accreditations Council for Graduate Medical Education–accredited. All complications related to neuroendovascular procedures and unexpected treatments are recorded in the database. To ensure the accuracy of the data, we also performed an independent chart review, including procedure notes and discharge summary of all the patients to find cases in which emergent neurosurgical assistance was required. Demographic, clinical, and procedural data and in-hospital outcomes were collected for each event. "Emergent neurosurgical intervention" was defined as an unplanned surgical treatment instituted to directly manage a complication of a neuroendovascular procedure on an emergent basis. Emergent neurosurgical procedures were di-

INTERVENTIONAL ORIGINAL RESEARCH

Rates of complications requiring emergent neurosurgical intervention according to per-procedure analysis			
Procedure	No.	Complication (%)	Neurosurgical Procedure
Ruptured intracranial aneurysm embolization	134	2 (1.50%)	Immediate ($n = 2$), EVD, adjunctive ($n = 0$)
Unruptured intracranial aneurysms embolization	98	2 (1.02%)	Immediate ($n = 1$), EVD adjunctive ($n = 1$) EVD plus DC
Intracranial angioplasty/stent placement	92	1 (2.17%)	Immediate ($n = 0$), EVD adjunctive ($n = 2$) EVD
Acute ischemic stroke treatment	165	1 (0.60%)	Immediate ($n = 0$), adjunctive ($n = 1$) EVD
AVM embolization	34	1 (2.94%)	Immediate ($n = 0$), adjunctive ($n = 1$) DC
CAS (symptomatic)	117	0	NA
CAS (asymptomatic)	36	0	NA
Endovascular treatment of vasospasm related to SAH	209	0	NA
Cerebral venous sinus procedures	18	0	NA
Dural arteriovenous fistula	9	0	NA
Tumor embolization (intracranial)	21	0	NA

Note:—CAS indicates carotid angioplasty and stent placement; DC, decompression craniectomy with hematoma evacuation; NA, not applicable.

vided into 2 categories: neurosurgical procedures for immediate assistance (before the termination of the neuroendovascular intervention) or adjunctive assistance (within 24 hours of the intervention). We excluded patients who had neurosurgical procedures planned to address direct consequences of primary disease such as decompressive craniectomy for large cerebral infarctions or surgical excision of AVMs. Intracranial procedures ($n = 759$) included cerebral aneurysm coil embolization, endovascular treatment of acute ischemic stroke, intracranial angioplasty/stent placement, cerebral AVM and dural arteriovenous fistula embolization, endovascular treatment of cerebral vasospasm related to SAH, and treatment of cerebral venous sinus thrombosis.

At our institution, there is a member of the neurosurgery team (usually a resident) available 24/7 on site in the hospital. Whenever there was an emergent need for EVD, we paged the on-call neurosurgery resident who responded within a few minutes. While arrangements for EVD placement were made, we stabilized the patient medically with osmotherapy (mannitol/hypertonic saline), blood pressure control, reversal of heparin, and emergent intubation if the patient was not already intubated. In cases of iatrogenic rupture of intracranial aneurysms, we attempted to secure the aneurysm by embolization and inflating the balloon in cases of balloon-assisted coil embolization. In 1 case of vessel rupture, we occluded the vessel by using coils after inflating the balloon in the middle cerebral artery. Intubation was performed by an anesthesiologist on call who was also present in the hospital with 24/7 availability. A head CT scan was obtained after stabilizing the patient, and the need for hematoma evacuation/ decompression craniectomy/craniotomy was assessed by the neurosurgery team. After the procedure, patients were usually transferred to the neurosurgery service and co-managed by the surgical intensivist/neurointensivist along with the neurointerventional service.

Once the intensive care issue was stabilized, patients were transferred to the step-down facility with the neurointervention service as the primary team in cases of ischemic stroke; however, other patients were usually managed by the neurosurgery team with the neurointervention team acting as consultants.

We performed a detailed medical chart review of all the patients ($n = 8$) in whom emergent neurosurgical procedures were performed. We collected the following information from hospital records of each eligible patient: 1) demographics, including age and sex; 2) angiographic data to obtain details about the technical aspect of the procedure, including the potential mechanism of complication, and antiplatelet agents, thrombolytics or intraprocedural heparin use; and 3) clinical data about the indications for the procedure, antiplatelet agent use before the procedure, the need for endotracheal intubation,

use of protamine, osmotherapy including hypertonic saline or mannitol, hospital course, and discharge disposition. Functional outcome was determined according to the mRS. The mRS of the patients who survived was obtained at the last known clinical follow-up. CT scan of the head was reviewed by 1 of the investigators (R.K.) to evaluate new IPH, SAH, cerebral edema, new or worsened hydrocephalus, and ICH related to EVD placement or decompressive craniectomy. Institutional review board approval was obtained for this retrospective review.

Descriptive statistics are summarized for categoric and continuous variables as frequencies and percentages, respectively. The types of neurosurgical procedures and in-hospital outcomes of identified patients are reported as an aggregate and per neuroendovascular procedure-type analyses.

Results

Of 933 neuroendovascular interventions, 759 intracranial endovascular procedures were performed A total of 62 patients had EVDs placed before the neuroendovascular procedures (26 EVDs in ruptured intracranial aneurysms and 36 patients undergoing vasospasm treatment). Patients were admitted in the surgical intensive care unit under the neurosurgery service, with daily consultation by neurointensivists. Procedures such as EVD placement were performed by the neurosurgery resident on call and managed by a surgical intensivist/neurointensivist along with the neurosurgery team after transfer to the intensive care unit.

There was a need for emergent neurosurgical procedures in 8 patients (0.85% cumulative incidence and 1.05% for major intracranial procedures). Among these 8 patients, the mean age was 46 ± 10.6 years, and 7 were women. Complications that required emergent neurosurgical assistance included various hemorrhages related to the following interventions: embolization of cerebral aneurysms ($n = 4$), cerebral AVM embolization ($n = 1$), endovascular treatment of AIS ($n = 1$), and intracranial angioplasty/stent placement ($n = 2$) (Table). Four of these procedures were performed with the patient under general anesthesia, and the remaining 4 procedures were performed with the patient under conscious sedation. Emergent neurosurgical procedures were categorized as 3 immediate and 5 adjunctive types. The presumed mechanism of the hemorrhagic complication during the procedures included the following: aneurysm rupture during coil embolization, vessel rupture during balloon angioplasty for ischemic stroke, vessel perforation by MicroWire for intracranial stenosis

treatment, and hemorrhage after AVM embolization (On-line Table).

Neurosurgical procedures performed among these 8 patients were EVD placement in 6 patients, decompressive craniectomy in 1 patient, and both surgical procedures in 1 patient. Emergent endotracheal intubation with mechanical ventilation was required in all 4 patients who experienced complications under conscious sedation. Two of these 4 patients required endotracheal intubation in the angiographic suite before the interventions were completed. An EVD was placed in the angiography suite before acquisition of the CT scan of the head in 3 patients. The EVD was placed within 25 minutes, 20 minutes, and 50 minutes for these 3 patients, respectively. Neurosurgical intervention times for both immediate and adjunctive interventions are provided in the On-line Table 1. Initial ICP ranged from 2 to 40 mm Hg among patients who underwent EVD placement. The ICP was >20 mm Hg in 3 patients, all of whom subsequently died. Supplemental treatments included a combination of hyperventilation, mannitol, and hypertonic saline. These measures were used in 6 patients. Protamine to reverse heparin was administered in 4 patients. Three patients were receiving both aspirin and clopidogrel in preparation for the intervention. After the complication, the neuroendovascular procedure was terminated in 1 patient, who subsequently progressed to brain death. In the remaining patients, procedures were completed after the initial stabilization ($n = 4$), or the complication was noted after the procedure was completed ($n = 3$).

Procedures that allowed continuation after the complication were cerebral aneurysm coil embolization after aneurysm rupture ($n = 3$) and parent artery coil occlusion after vessel rupture ($n = 1$). CT scan of the head immediately postprocedure demonstrated IPH ($n = 3$) and/or SAH ($n = 7$). Hydrocephalus was noted in 1 patient. Decompressive craniectomy with IPH evacuation was performed in 2 patients, at 6 and 10 hours after termination of respective neuroendovascular procedures. Follow-up CT scans were obtained after the immediate postprocedure CT scans in all these patients. There was no new significant IPH noted after EVD placement or decompressive craniectomy in these patients requiring neurosurgical intervention.

Discharge outcome in these 8 patients included in-hospital mortality in 5 (62.5%) patients and discharged to a rehabilitation center in 3 patients. The cause of death included brain death after diffuse SAH ($n = 1$) and withdrawal of care after major clinical deterioration ($n = 4$). The 3 survivors underwent ICP monitoring and CSF drainage for a period ranging from 1 to 3 days. All 3 were successfully extubated 1–3 days after the intervention. All 3 surviving patients made a good recovery (mRS, 0–2) at clinic follow-up that ranged from 2 to 24 months.

Discussion

In our retrospective review, we found that the need for an emergent neurosurgical procedure in the management of complications related to neuroendovascular procedures was low (8 of 933 procedures). ICH and/or SAH occurred in all 8 patients. Increased ICP is considered a major contributor to mortality after ICH; thus, its control is essential and could be lifesaving. High ICP may be managed with osmotherapy, con-

trolled hyperventilation, CSF drainage, and barbiturate coma. ICP monitoring is often performed in patients with ICH. However, to our knowledge, only very limited published data exist regarding the frequency of elevated ICP and its management in patients with ICH. In ICH, the use of EVD is common in patients with or at risk for hydrocephalus.[3,4] According to guidelines[4] for spontaneous ICH, patients with a Glasgow Coma Scale score of ≤8, those with clinical evidence of transtentorial herniation, or those with significant IVH or hydrocephalus might be considered for ICP monitoring and CSF drainage. On the other hand, in patients presenting with lobar clots of >30 mL and within 1 cm of the surface, evacuation of supratentorial IPH by standard craniotomy might be considered. Although theoretically attractive, no clear evidence at present indicates that ultra early removal of supratentorial ICH improves functional outcome or decreases mortality rates. In fact, very early craniotomy may even be harmful due to the increased risk of recurrent bleeding.[4] Given the lack of robust data for IPH related to neuroendovascular procedures, it would be intuitive to follow these guidelines for the management of these complications.

There are several unique features among patients undergoing neuroendovascular procedures that may increase their risk of hemorrhagic complications. These patients may be on antiplatelet agents in preparation for interventions such as angioplasty and/or stent placement, increasing the risk of hemorrhage. This has especially been noted with the use of certain glycoprotein IIb/IIIa receptor inhibitors that resulted in a high incidence of ICH and mortality.[5,6] In addition, these patients also receive intravenous heparin during the interventions to decrease the risk of thrombosis and iatrogenic ischemic stroke related to device manipulation. However, these medications can worsen the severity of ICH in case of a complication and can also increase the risk of hemorrhage during the neurosurgical interventions, including EVD placement or decompressive craniectomy. Moreover, reversal of anticoagulation is not exempt from thrombotic complications due to its procoagulant effect.

In a retrospective review by Tummala et al[7] involving 734 intracranial aneurysms that were treated with endovascular coil embolization, 10 patients (1.36%) had perforation during the procedure. Six of the 10 patients made good or fair recovery; all 3 patients with posterior circulation lesions died immediately after rehemorrhage. Elevated ICP was noted for all 5 patients with an EVD in place. Emergency ventriculostomy was performed to rapidly reduce increased ICP for 2 patients, both of whom made good recovery. The authors concluded that an immediate neurosurgical procedure is limited in these cases and focuses on decreasing ICP via emergency EVD placement.[7] Another report by Ricolfi et al,[8] described 4 cases of aneurysmal rupture during coil embolization. Two patients with posterior circulation rupture had major complications, and 1 of them died. They suggested that emergency ventriculostomy (performed within the angiographic suite) is an effective means to reduce ICP. They suggested that recognition of aneurysms associated with a high risk of mortality by rupture in the course of embolizations and use of proper logistics should ensure effective management of this complication.

Another observation from our analysis is that there was only 1 instance when neurosurgical intervention (decompres-

sive craniectomy) was required to address a massive ischemic stroke directly related to the neuroendovascular procedure. This number may seem exceptionally low; however, we did not include procedures like decompression hemicraniectomy or EVD placement that were performed to address events that were secondary to the primary disease.

Our study has some important limitations. It is a retrospective analysis of patients treated at 2 academic centers. The number of individual intracranial neuroendovascular procedures evaluated is small, but it includes the latest technology and treatments offered in the present era of technical advancement, thereby providing the latest data. The definition of emergent neurosurgical procedures required within 24 hours of neuroendovascular procedure may have been overly inclusive and procedures that could be accomplished by transferring patients to another facility are probably also included.

Conclusions

The need for emergent neurosurgical procedures is low among patients undergoing intracranial neuroendovascular procedures. The mortality in patients requiring emergent neurosurgical procedures is quite high. Today in the era of multidisciplinary care of patients, optimal care of patients with cerebrovascular diseases also requires a team-management strategy involving providers from multiple disciplines. The requirement for emergent neurosurgical procedures among patients undergoing neuroendovascular procedures is only 1 small component of such optimal and comprehensive and thus "safe" care.

Our study is limited in making a definite conclusion about the impact of neurosurgical assistance on an emergent basis in the management of complications related to neuroendovascular interventions. It may be considered as a preliminary study, and future studies involving larger population samples are needed.

References

1. Alberts MJ, Latchaw RE, Selman WR, et al. **Recommendations for comprehensive stroke centers: a consensus statement from the Brain Attack Coalition.** *Stroke* 2005;36:1597–616
2. Berenstein A, Song JK, Niimi Y. **Personal accounts of the evolution of endovascular neurosurgery.** *Neurosurgery* 2006;59(5 suppl 3):S15–21, discussion S3–13
3. Broderick JP, Adams HP Jr, Barsan W, et al. **Guidelines for the management of spontaneous intracerebral hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council—American Heart Association.** *Stroke* 1999;30:905–15
4. Morgenstern LB, Hemphill JC 3rd, Anderson C, et al. **Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare professionals from the American Heart Association/American Stroke Association.** *Stroke* 2010;41:2108–29
5. Tcheng JE. **Clinical challenges of platelet glycoprotein IIb/IIIa receptor inhibitor therapy: bleeding, reversal, thrombocytopenia, and retreatment.** *Am Heart J* 2000;139:S38–45
6. Walsh RD, Barrett KM, Aguila MI, et al. **Intracranial hemorrhage following neuroendovascular procedures with abciximab is associated with high mortality: a multicenter series.** *Neurocrit Care* 2011;15:85–95
7. Tummala RP, Chu RM, Madison MT, et al. **Outcomes after aneurysm rupture during endovascular coil embolization.** *Neurosurgery* 2001;49:1059–66, discussion 66–67
8. Ricolfi F, Le Guerinel C, Blustajn J, et al. **Rupture during treatment of recently ruptured aneurysms with Guglielmi electrodetachable coils.,** *AJNR Am J Neuroradiol* 1998;19:1653–58