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Incidence, Pathophysiology, and Prevention Strategies for Cerebral Venous Complications after Neurologic Surgery: A Systematic Review of the Literature

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Key words
- Cerebral edema
- Cerebral veins
- Complications
- Neurosurgery
- Venous injury
- Venous occlusion/sacrifice
- Venous preservation

Abbreviations and Acronyms
CT: Computed tomography
ICGV: Indocyanine green videoangiography
MRI: Magnetic resonance imaging
POVI: Postoperative venous injury

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■ BACKGROUND: **Complications arising from cerebral venous occlusion/sacrifice during neurosurgical procedures have received comparatively less attention in the neurosurgical literature. Consequently, cerebral venous complications are not given due recognition, even though most practicing neurosurgeons would agree that they are not uncommon. We present a review of complications arising from venous sacrifice/occlusion during neurosurgery and discuss strategies described in the literature to prevent such occurrences.**

■ METHODS: **We conducted a systematic review of the literature to provide a synopsis of the current evidence regarding cerebral venous injury after a neurosurgical procedure. The objectives of this review were to assess the incidence of venous injuries after a neurosurgical procedure with their clinical outcome and to evaluate current strategies and technical advances for their prevention. Complications related to dural venous sinuses were not considered in this review.**

■ RESULTS: **Twenty-six relevant articles were identified and reviewed. Complications from cerebral venous occlusion/sacrifice are being increasingly recognized, and venous preservation strategies are being promoted in the neurosurgical literature. Based on our review of literature, the incidence of venous injury can range from 2.6% to 30%. We discuss the pathophysiology after venous injury and factors affecting outcome after cerebral venous injury. An overview of surgical techniques described to prevent or manage venous injury during neurosurgical procedures is presented.**

■ CONCLUSIONS: **The unpredictable response of the brain to venous injury causes catastrophic complications in a few patients. To avoid these complications, meticulous venous preservation should be a goal in all neurosurgical procedures. Increased recognition of cerebral venous complications over the last 2 decades has resulted in the increasing recognition among neurosurgeons that venous preservation is an essential tenet of neurosurgery.**

INTRODUCTION

Complications arising from occlusion/sacrifice of the cerebral venous system during neurosurgery have received scant mention in the literature compared with complications of the cerebral arterial system. This may have contributed to the lack of recognition of venous complications, even though most experienced neurosurgeons would agree that these complications are not uncommon.[1] In addition, cerebral venous injuries have myriad presentations, and as such, the so-called "unpredictable" postoperative neurosurgical complications may be a consequence of venous compromise, especially damage to the dangerous veins.[2]

The cerebral venous system has numerous variations with respect to size and anastomoses, and thus defining a normal pattern has been difficult.[3,4] This difficulty has resulted in significant ambiguity in reporting the damage to the venous anatomy during intracranial surgery. Apart from the treatise on the neurosurgical perspective of the intracranial venous system published by Al-Mefty and Krist[2] in 1996 and the extensive reviews published by Sindou et al.[5] in the previous decade, cerebral venous injury and its consequences have received less attention in neurosurgical literature. Sekhar et al.[6] have appropriately noted that "the so-called innocuous veins of yesteryear are now being shown as not so innocuous." Here we present a review of complications arising from venous sacrifice/occlusion during neurosurgery and discuss strategies to prevent such occurrences described in the literature.

METHODS

We conducted a systematic review of the literature to provide a synopsis of the current evidence about cerebral venous injury after a neurosurgical procedure. The primary objective of this review was to assess the incidence of venous injury after a neurosurgical procedure with clinical outcomes and to evaluate current strategies and technical advances for their prevention. Secondary objectives were to analyze the prognostic factors that might have a significant influence on the incidence of and outcomes after intraoperative cerebral venous injury. We also explored the pathophysiological concepts relevant to the venous injury and their effects on the brain to provide insight into the variable effects of venous injury on clinical manifestations. To limit the scope of this review, the complications related to dural venous sinuses were not included.

Relevant studies were identified by searching the PubMed, Cochrane Library, and Web of Science electronic databases using a search manager with the MeSH terms "cerebral veins," "venous," "injury," "complications," "sacrifice," "occlusion," "preservation," "congestion," "edema," "neurosurgery," "brain," "cortical," "cerebral," and their synonyms using "AND" and "OR" connectors. Our initial search identified a total of 233 articles after removing duplicates. Initially, relevant articles were retrieved in abstract format, and all reference sections were manually reviewed and pertinent articles identified. After a title and abstract review, a total of 26 articles were identified as relevant to the topic of cerebral venous complications. The final decision regarding inclusion of an article in our systematic review was made by the senior author (A. Savardekar) in consultation with the coauthors. A full text review of the final 26 articles was conducted, and our final review and discussion was based on this detailed analysis.

Ethical approval was not required because this study was a review of literature. No patients were included in the data analysis.

RESULTS AND DISCUSSION

Incidence of Venous Injury and Sequelae

Wide variation exists in the literature on reporting of venous injury after neurosurgical procedures. There are multiple reasons for this, the most common being the lack of recognition of the venous injury and inappropriate transference of postoperative complications to other well-recognized causes. Second, the true incidence is difficult to estimate, because a large number of venous injuries are clinically insignificant.[7] Kageyama et al.[8] reported a 13% incidence of postoperative venous injury (POVI) in their 120 cases of cranial surgery. The 2 causative factors identified were the duration of surgery and a "sylvian type" of venous drainage pattern. Kageyama et al.[8] concluded that POVI during the pterional approach is the most important factor in postoperative brain injury. Saito et al.[9] reported POVI in 2.6% cases after the frontotemporal bridging vein was cut during the pterional approach, and Al-Mefty and Krist[2] reported a 10% incidence of brain edema after sacrifice of the superficial Sylvian vein. Kubota[10] reported that 4 of 10 patients with vein sacrifice during an interhemispheric approach suffered from brain damage. Roberson et al.[11] reported a complication rate of venous insufficiency of 1.5 per 1000 cases of neurologic skull base surgery. Agrawal and Naik[1] studied a total of 376 patients undergoing elective major cranial surgeries over an 8-month period and found that 26 patients (7%) developed POVI, including 16 (61%) with eloped hemorrhagic POVI and 10 (39%) with nonhemorrhagic POVI. Koerbel et al.[12] noted that venous-related phenomena may occur up to 30% of the cases in which the superior petrosal vein is sacrificed during surgery for petrous apex meningiomas.

Inadvertent cerebral venous injury during the course of routine neurosurgery and its ensuing consequences have been reported only rarely in the literature. Some reports have even suggested that veins may be sacrificed without any significant neurologic damage.[13] On postoperative computed tomography (CT) scan or magnetic resonance imaging (MRI), an area of cerebral contusion or hypodensity adjacent to the operative site or in the trajectory of the neurosurgical approach may be attributed to several factors, including retraction injury, retraction edema, pial transgression by the surgeon, arterial injury, presence of preoperative tumor edema, and aftereffects of tumor manipulation. The extent of brain damage from venous causes is rarely quantifiable, owing to the interplay of the aforementioned confounding factors, which may explain the limited literature related to cerebral venous injury and its effects. Diffusion-weighted MRI may have a role in differentiating venous congestion/edema from venous/arterial infarction or irreversible retraction injury. In cases of edema or congestion, the area of concern would be hypointense on diffusion-weighted MRI, whereas in cases of venous/arterial infarction or irreversible retraction injury, the area of concern area would be hyperintense.

Consequences of Venous Injury

As mentioned above, the exact incidence of intraoperative venous injury and subsequent POVI is difficult to quantify owing to an unclear definition, myriad presentations, and the presence of other compounding factors during the surgery itself (e.g., brain retraction).[7] Roberson et al.[11] classified the effects of venous compromise as acute and chronic. The acute form manifests in the immediate postoperative period and at times can be life-threatening. The chronic form manifests months or years postsurgery with headaches, disequilibrium, and visual changes due to papilledema. In this setting, venous thrombosis from intraoperative venous injury progresses to the dural sinuses, influencing cerebrospinal fluid absorption and eventually presenting as communicating hydrocephalus.

Nakase et al.[7] further described 2 types of perioperative (acute) venous infarction: severe and mild. The severe type requires extensive treatment, such as internal decompression and barbiturate therapy immediately after the operation. The mild type involves a slow clinical deterioration by gradual thrombus evolution and can be treated conservatively.

The absence of valves in the venous circulation and the ubiquitous collateral venous drainage systems makes it possible for the veins to adapt to an intraoperative venous injury and limit the amount of brain damage. Neurosurgeons often cite this as justification for sacrificing veins during the surgical approach. However, the variability of the cerebral venous system also makes it difficult to predict the dominance of a particular draining vein encountered in the surgical approaches. It should be kept in mind that sacrificing a dominant draining vein from a particular cerebral region intraoperatively can have disastrous consequences for the corresponding brain.

It may be observed that sacrifice of any individual cortical vein only infrequently