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Improvement in venous outflow following superior sagittal sinus decompression after a gunshot wound to the head: Case report

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Abstract

The most commonly described indications for surgical management of closed depressed skull fractures are hematoma evacuation and repair of extensive cosmetic deformity. Venous sinus injury, which occurs in a subset of depressed skull fractures is not typically listed as an indication for surgical treatment due to the potential for major venous hemorrhage associated with operation near these structures. However, if patients exhibit signs and symptoms of intracranial hypertension and radiographic findings demonstrate sinus compromise, surgical elevation of the depressed skull fragments is indicated. The authors present the case of a 25-year-old woman with a depressed skull fracture secondary to a gunshot wound with symptomatic compromise in venous outflow of the posterior one-third of the superior sagittal sinus. The patient was treated with surgical decompression via bilateral craniectomy along with intracranial pressure lowering medical therapy and had almost full resolution of her presenting symptoms with documented improvement in flow through the superior sagittal sinus. While the use of surgical treatment for these types of injuries is highly debated we demonstrate here that safe, effective surgical management of these patients is possible and that surgical decompression should always be considered in the case of symptomatic venous sinus flow obstruction.

Keywords

superior sagittal sinus; intracranial hypertension; gunshot wound; skull fracture; craniectomy

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Disclosure

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While dural venous sinus thrombosis is a well-recognized cause of elevated intracranial pressure, little attention has been given to non-thrombotic causes of occlusion to venous sinuses. Furthermore, depressed skull fractures occur over venous sinuses in 11–18% of cases representing a fairly large proportion of those cases.^{16,19} Nonetheless, very few cases of intracranial hypertension (IH) due to venous sinus compression have been reported.¹² Traditionally, conservative management of depressed skull fractures that lie over venous sinuses has been preferred over surgical treatment due to the risk of hemorrhage associated with operating over a venous sinus.^{16,19} However, in cases where neurological deficits are present with elevated ICP surgical treatment is preferred.^{8,14,15} In this article, we describe the case of a 25-year-old woman presenting with a 3-week history of worsening headache, blurry vision, and diplopia following removal of bullet fragments from a gunshot wound (GSW) to the head. We report on the successful surgical management of a depressed skull fracture compromising flow through the superior sagittal sinus (SSS).

Case

History and Examination

This 25-year-old woman presented with progressive headaches, visual field loss, transient visual obscurations, pulsatile tinnitus, and horizontal double vision developing in the weeks following removal of bullet fragments after a GSW to the posterior head. Urgent ophthalmological evaluation revealed mildly decreased central vision of 20/20-3 with each eye, inferior temporal visual field defect in the right eye, and inferior temporal and nasal visual field defects in the left eye, abduction deficits in both eyes with intermittent esotropia and grade 4 optic disc edema in both eyes. She was referred to our neurosurgery team for emergent evaluation given suspicion for IH as a cause of her symptoms. Medical therapy with acetazolamide 1000mg twice daily was initiated with minimal change in symptoms.

Neuroimaging

CT scans obtained demonstrate a depressed skull fracture in the parieto-occipital skull overlying the distal third of the SSS (Fig. 1A, B) consistent with the history of GSW. Digital subtraction angiography demonstrated compromised venous flow in the posterior one-third of the superior sagittal sinus (Fig. 2A, B) and volumetric flow analysis measured via Q-MRV and Q-MRA (NOVA, VasSol Inc., River Forest, IL) showed reduced flow through the SSS of 214 mL/min, total jugular venous outflow of 397 mL/min (Fig. 3A, B), and a large difference between large vessel arterial inflow and large vessel venous outflow (301 mL/min).

Operation

To decompress the SSS and decrease ICP the patient underwent bilateral occipital craniectomy (Fig. 4) and cranioplasty with titanium mesh (Fig. 1C). The patient was placed in a prone position and, following skin incision, four burr holes (two burr holes on each side of the SSS, were made). The craniectomy was completed using high-speed power drill (diamond tip) at which time the depressed bone fragments were removed. However, due to the risk of venous sinus bleeding, the bone fragments penetrating the sinus were not completely removed and a small fragment of bone was left in place drilled to an eggshell

thickness (Fig. 1C). No sinus bleeding was encountered during the decompression. Dural matrix was then placed in the boney defect and was covered with a piece of GelFoam followed by a preformed titanium mesh and the incision was closed.

Postoperative Course

The procedure was performed without complications and the patient woke up with improvement in many symptoms including headaches and double vision. Follow up Q-MRV 1 day postoperatively showed improvement in the flow through the SSS measured at 380 mL/min with total venous outflow to 541 mL/min (Fig. 3C, D). Acetazolamide was discontinued due to rash. She was discharged the day after surgery and at 2 weeks postoperatively had improvement in headaches but persistence of transient visual obscurations and papilledema (Fig. 5A). Visual field showed inferior loss in both eyes, sparing part of the inferotemporal field in the left eye. She was started on topiramate and by one month postoperatively had improvement in visual fields in both eyes as well as resolution of papilledema (Fig 5B). Q-MRV and Q-MRA 2 weeks post operatively showed additional improvement in total venous outflow to 599 mL/min and decrease in the difference between arterial inflow and venous outflow to 185mL/min.

Discussion

Signs and symptoms of IH often include headache, diplopia, loss of peripheral vision, blurred central vision, and nonspecific symptoms including nausea, vomiting, and dizziness.¹¹ IH caused by impaired cerebral venous outflow due to compression of the SSS is a very rare event with few reports in the literature.^{5,7,9,10,20,23,25} The presentations are heterogeneous, some with acute symptoms within 48 hours, and others with delayed symptoms often several weeks after the initial traumatic injury.¹² In the reported cases, compression of the SSS occurred across various parts of the sinus from anterior to posterior. Overall morbidity and mortality is affected by the location of sinus compression, where injury across the anterior one-third of the sinus is associated with the lowest mortality while injury to the posterior one-third is associated with the highest.¹⁸ While this study by Meier et al¹⁸ reported death in all of their patients with compression of the posterior one-third of the SSS, demonstrating the significant amount of difficulty in managing these injuries, our patient and previous reports^{5,7,9,10,23,25} of similar injuries illustrate successful operative management of posterior SSS compression in the setting of depressed skull fractures.

Typically, conservative management of depressed skull fractures overlying venous sinuses is advocated rather than a surgical approach due to the high risk of hemorrhage associated with operation around a venous sinus.^{16,19,27} However, in those patients in which evidence of elevated ICP is present, as was the case with our patient, surgery to elevate the depressed skull fractures and remove the cause of sinus compression can be safely performed to restore blood flow in the sinus. Furthermore, when deciding whether surgical intervention is appropriate one must distinguish between SSS thrombosis causing a flow obstruction or SSS stenosis causing IH. While surgical intervention and elevation of the depressed fracture is often curative in patients with SSS stenosis, surgery alone will not cure SSS thrombosis unless the thrombus is removed. This approach, however, drastically increases the risk of

major hemorrhage and is not normally considered.^{9,21} In cases of non-thrombotic SSS stenosis, significant injuries and neurological deficits are unlikely to resolve without surgical intervention, especially when the posterior one-third of the sinus is involved. Therefore, elevation of the depressed fracture must be considered in management of these patients. While this has been the method most commonly utilized in the literature^{5,7,9,10,20,23} one report demonstrates the use of repeated lumbar puncture to reduce ICP while collateral venous drainage develops.²⁵

One of the most important aspects of management of IH is appropriate and adequate imaging studies. These studies not only help guide treatment strategies but help to delineate things like SSS thrombosis versus SSS stenosis as discussed above. Traditional imaging done in patients presenting with signs and symptoms of IH includes contrast MR studies and cerebral angiography. Studies not traditionally done, and not previously reported for SSS compression due to depressed skull fracture, include quantitative Q-MRA/MRV with volumetric flow analysis as we report here. The role of Q-MRA in assessment of intracranial flow have been validated in animal models⁶ and established in ischemic stroke, following intracranial stenting or carotid endarterectomy or in the diagnosis subclavian steal syndrome.^{2-4,13} We demonstrate quantitative improvement in cerebral venous outflow following surgical intervention and further improvement with additional medical management. In addition, we demonstrate a narrowing of the gap between measured arterial inflows and venous outflows following treatment, similar to Q-MRV findings in dural arterial venous fistula associated IH¹⁷ and idiopathic IH.¹ These Q-MRV results provide an objective measure of short and long term patient outcomes and could be a potential method with which to track progress in patient recovery over extended periods of time.

In closed depressed skull fractures, surgery is often only recommended for one of three reasons: repair of lacerated dura, evacuation of hematoma, or for the correction of cosmetic deformity.^{8,9,22,24,26} While this and previous case reports illustrate the efficacy of surgical intervention in depressed skull fractures overlying venous sinuses, most texts and current recommendations do not list venous sinus injury as an indication for surgical intervention. The most commonly cited reason for not operating is the associated risk of hemorrhage by operating near a venous sinus. The risk of hemorrhage is most often correlated with the complete removal of depressed bone fragments. Rather than remove the bone fragments we decided that drilling them down with a high speed drill to an eggshell thickness would not only decompress the SSS but would help avoid this dreaded complication. Furthermore, it is very possible that even with decompression of the sinus, hemorrhage could still occur and thorough planning and preparation must take place in order to assure adequate response should this happen. While the risk of hemorrhage is very real and is not one to rebuff, the long-term risk for permanent neurological deficit by not operating in these patients far outweighs the risk of hemorrhage associated with operation near venous sinuses. It is clear, though, that the best approach for management of depressed skull fractures overlying venous sinuses must consider imaging studies (including quantitative venous flow studies), the patient's overall clinical condition, and the risks and benefits of different treatment modalities. However, surgical intervention, as successfully demonstrated by our patient, should always been considered an option in similar cases as this.

Conclusions

Patients with venous sinus injury may present with various signs and symptoms due to IH, typically including visual disturbances and headache. They may present shortly after initial injury or may not develop symptoms for days to weeks after the injury. Patients presenting with signs of IH and possible venous sinus injury should be evaluated with Q-MRV when available and cerebral angiography and should be treated promptly to minimize IH related morbidity. While conservative management is often advocated for closed depressed skull fractures, surgical intervention should always be considered in patients with symptomatic venous sinus injury especially when the posterior aspect of the sinus is involved. We demonstrate here that successful surgical decompression of the injured sinus results in hemodynamic and clinical improvement, with complete resolution of headaches and significant improvement in visual deficits and papilledema.

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Figure 1.

A. Preoperative axial CT scan demonstrating the depressed skull fracture following a gunshot wound. B. Preoperative sagittal CT scan showing the fracture in the parietal bone. C. Postoperative axial CT scan revealing the decompressive craniectomy and cranioplasty.

Figure 2.

Left. Left internal carotid artery angiogram, lateral view, demonstrating no contrast opacification of the posterior one-third of the superior sagittal sinus (*arrows*). *Right.* Left internal carotid artery angiogram, oblique view, demonstrating compression of the posterior one-third of the superior sagittal sinus without complete occlusion (*arrows*).

Figure 3.

A. Preoperative Q-MRV NOVA 3D reconstruction of volumetric flow analysis demonstrating reduced flow through the superior sagittal sinus as well as the compression of the sinus (arrows). B. Preoperative Q-MRV venous map demonstrating flow through the venous sinuses. C. Postoperative Q-MRV NOVA 3D reconstruction of volumetric flow analysis demonstrating the increased flow through the superior sagittal sinus following decompression as well as the absence of any noticeable postoperative compression (arrows). D. Postoperative Q-MRV venous map demonstrating flow through the venous sinuses following decompression.

Figure 4.
Intraoperative photo following bilateral occipital craniectomy before cranioplasty with titanium mesh.

Figure 5.

A. Optic disc photo at 2 weeks post operatively with persistent papilledema. B. Optic disc photo at 6 weeks post operatively with resolution of papilledema.