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Surgical Management of Intracerebral Hemorrhage

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Abstract

Intracerebral hemorrhage (ICH), defined as bleeding within the brain parenchyma, remains a challenging and controversial neurosurgical entity to treat. ICH has a broad range of etiology—stemming from complications associated with traumatic head injury to complications of hemorrhagic stroke. The role of medical management lies in optimizing blood pressure and intracerebral pressure, preventing secondary injury from complications of the hematoma such as seizures, and correcting coagulopathy. Given the mass effect of a hematoma and the possibility of expansion, surgical interventions attempt to evacuate the clot to restore normal intracerebral pressure and prevent worsening neurologic injury. This chapter reviews the recent controversy associated with surgical evacuation of intracerebral hemorrhage placing particular emphasis on the size and location of the hemorrhage and the methods used to evacuate the expanding ICH. Moreover, this chapter reviews considerations and therapeutic goals of the preoperative and postoperative window to minimize complications and optimize patient care.

Keywords: intracerebral hemorrhage, hemorrhagic stroke, surgical intracerebral hemorrhage, neurosurgical interventions

1. Introduction

Intracerebral hemorrhage (ICH) is defined as bleeding that takes place within the brain parenchyma and impacts 63,000 people annually within the United States [1, 2]. ICH is a major complication of traumatic brain injury and contributes to 15% of strokes [3]. Many etiologies are implicated in ICH, including hypertension, vascular anomalies, amyloid angiopathy,

coagulopathy, brain malignancies, pregnancies, and substance abuse. Depending on the extent of hemorrhage and additional risk factors, ICH prognosis can be highly variable. Extensive hemorrhage has been associated with greater than 30% mortality rate within one month of injury with only 30% of patients returning to independent functioning by 6 months [4].

Medical management aims to optimize blood pressure, intracerebral pressure (ICP), coagulopathy, seizure control, fever control, and deep vein thrombosis prophylaxis. Additionally, surgical management aims to prevent neurologic decline through surgical decompression of the skull and evacuation of expanding hematoma [5]. However, the role of surgery in management for ICH remains controversial, and numerous trials have been conducted examining the indications and efficacy of prompt surgical intervention. This chapter will explore the current scientific literature regarding the indications and efficacy of neurosurgical intervention in the management of patients with ICH.

2. Preoperative diagnostics and workup

ICH presents with acute-onset focal neurologic deficits, headache (approximately 40% of patients), elevated systolic blood pressure (50%), nausea, and vomiting (50%) [5–7]. Common deficits include, in order of decreasing incidence, paresis, sensory deficits, speech deficits, vision changes, and gait disturbances [6]. Symptoms are often progressive due to hematoma expansion, which tends to occur within the first several hours following ICH. However, patients without hemorrhage growth may still experience substantial neurological deterioration within the first 24 hours [8]. Electrographic seizures may occur in up to a third of patients with ICH, although only half of these are clinically significant [9]. Seizures are more likely to occur with cortical involvement of ICH and may be associated with neurological deterioration and increased midline shift [10, 11]. Patients commonly have altered mental status, and those with large or growing hematomas may experience rapid worsening in Glasgow Coma Scale (GCS) [12].

Non-contrast computed tomography (CT) scan is considered to be the "gold standard" for diagnosis of new ICH and detection of other forms of intracranial bleeding that may present concomitantly [13]. Magnetic resonance imaging (MRI) may also be beneficial in identifying microhemorrhages, and CT angiogram is sensitive in identifying secondary causes of intraparenchymal bleeding such as aneurysm rupture, vasculitis, intracranial malignancy, or arteriovenous malformations [14, 15].

In an emergency setting, ensuring adequate airway, breathing, and cerebral perfusion is essential. For patients with a GCS < 8, transtentorial herniation, intraventricular hemorrhage, or hydrocephalus, an ICP monitor should be placed to dynamically monitor cerebral perfusion pressure [16]. Management of elevated ICPs in the acute setting includes elevating the head of bed to 30°, sedation, intubation, and hyperventilation of the patient to a $PaCO_2$ of 25–30 and rapidly infusing hypertonic saline or mannitol while preparing the operating room for surgical decompression or clot evacuation [9, 17]. Management of hemorrhagic mass effect and acute hydrocephalus via external ventricular drain is beneficial for ICP measurement and cerebrospinal fluid (CSF) diversion in these patients and has been shown to significantly reduce mortality in the setting of intraventricular hemorrhage [18, 19].

3. Surgical management

The role of surgery in the treatment of intracerebral hemorrhage remains a matter of debate. Though many clinical trials have attempted to better characterize the role of surgical evacuation in ICH, variability in factors such as location and volume of the bleed and method of surgical intervention have long limited extrapolation to guidelines. Much less controversy surrounds the surgical management of infratentorial ICH due to proximity to the brain stem and the possibility of catastrophic injury and complications [20, 21]. For this reason, posterior fossa hematomas greater than 3 cm are evacuated due to the significant risk of brain stem compression and hydrocephalus [22].

Regardless of the cause of ICH, close monitoring of complications such as hypertension, hematoma expansion, perihematomal edema, seizures, intraventricular hemorrhage leading to hydrocephalus, and venous thromboembolism is vital to patient survival and prevention of functional deficits [23]. In addition to reducing intracranial pressure, surgical evacuation reduces clot volume, which contributes to both mechanical compression of the brain and neurotoxic edema [24]. Despite these perceived benefits, clinical trials prior to 2004 failed to demonstrate a clear survival difference in patients offered surgical intervention and medical treatment compared to conservative medical management. For example, a multicenter randomized controlled trial utilizing minimally invasive, stereotactic approaches with low-dose tissue plasminogen activator (tPA) for liquefaction and aspiration of clot (SICHPA trial) demonstrated effective reduction of clot size compared to conservative treatment, but no differences were found in 180-day mortality rates [25].

Five trials from 1989 to 2003 demonstrated equivocal outcomes following surgical intervention. Encouraging functional outcomes were demonstrated in a small study of stereotactic evacuation of putaminal hemorrhages in 2004 [26]. The International Surgical Trial in Intracerebral Hemorrhage (STICH) randomized over 1000 patients with spontaneous basal ganglia and/or lobar hemorrhages to surgery within 24 hours of presentation versus early conservative management with possible surgical evacuation after 24 hours in the setting of neurological deterioration to examine the efficacy of early surgical clot evacuation. Though the trial found only 26% of surgical patients had favorable outcomes at 6 months compared to 24% in the medical management group, subgroup analysis demonstrated that patients with supratentorial ICH with hematomas 1 cm or less from the cortical surface had improved outcomes with surgical evacuation compared with patients with deep hematomas and conservative management [27].

To follow up on this finding, over 600 patients with 10–100 mL superficial lobar hemorrhages and no intraventricular hemorrhage (IVH) were randomized to evacuation within 12 hours plus medical treatment compared to medical management alone with the option for subsequent surgical intervention for neurological deterioration in the STICH II trial in 2013 [28]. This trial demonstrated similarly statistically insignificant findings. Mortality at 6 months was 18% in the early surgery group compared to 24% in the medical management group, with an absolute difference of 5.6%. Though the surgery group demonstrated no vegetative survivors through 6 months and the distribution of Extended Glasgow Outcome Scale (GOS-E) scores was more favorable in the surgery group, neither of these findings was statistically

significant. However, subgroup analysis of patients with poor prognosis before treatment defined as GCS 9–12 demonstrated more favorable outcome with surgery (odds ratio of poor outcome: 0.49, 95% confidence interval 0.26–0.92, p = 0.02). Based upon the results of the STICH II trial, the investigators concluded that patients with higher GCS of 13–15 do not demonstrate survival advantage with early surgery if given the option of delayed surgery if deterioration occurs.

The CLEAR IVH trial and MISTIE trial are ongoing investigations that use minimally invasive technique with assistance of low-dose tPA [29]. Preliminary results from the MISTIE II trial demonstrated minimally invasive aspiration with low-dose tPA reduced clots to 50% of the stabilized volume within the first week, compared to a 6% reduction with medical management alone. Though statistically significant increases in symptomatic bleeding were not seen with the use of tPA (2.4% in the minimally invasive plus tPA group versus 9.3% in the medical management group), the authors did caution that the use of minimally invasive techniques with tPA did increase asymptomatic hemorrhages (22.2% versus 7.1%, p = 0.051). These results demonstrate the safety and efficacy of these interventions compared with conservative management alone [30]. Furthermore, hematoma evacuation has been shown to significantly reduce perihematomal edema, even when combined with tPA delivered to the clot [31]. The MISTIE Intraoperative Stereotactic Computed Tomography-Guided Endoscopic Surgery (MISTIE ICES) trial [32] was recently completed and demonstrated 42.9% of surgical patients had functional neurological outcomes defined as a modified Rankin scale score (mRS) of 0–3, compared to 23.7% in the medical management group at 180 and 365 days (p = 0.19). These results demonstrate the safety and efficacy of CT-guided endoscopic surgery to remove acute ICH. Examples of endoscopic hemorrhage evacuation can be found below (**Figures 1**–**3**).
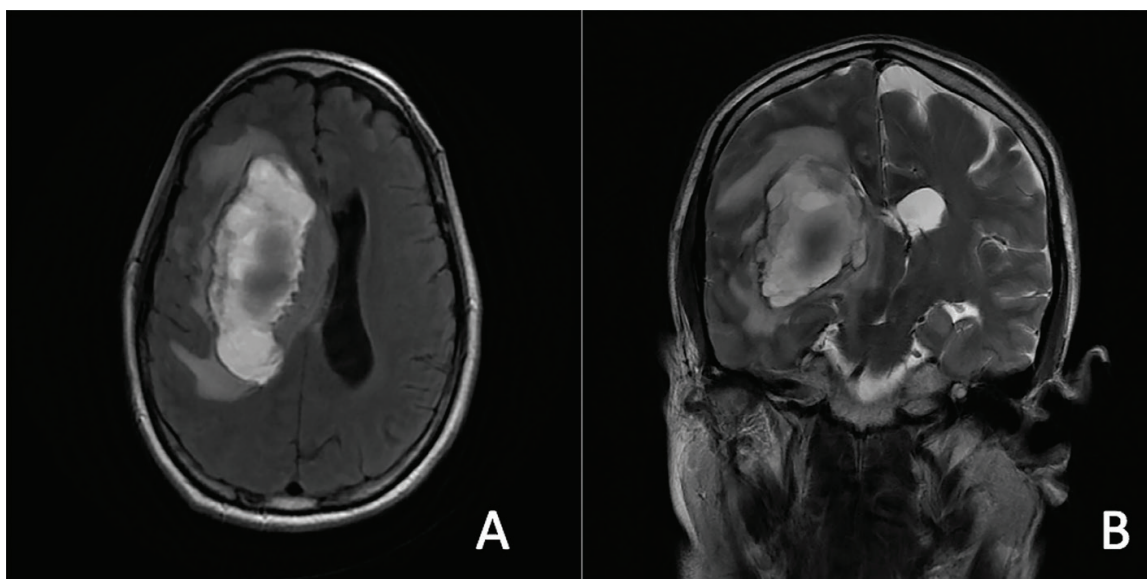

Figure 1. (A and B): Axial and coronal MRI demonstrating right-sided preoperative intracerebral hemorrhage involving the right ventricle.
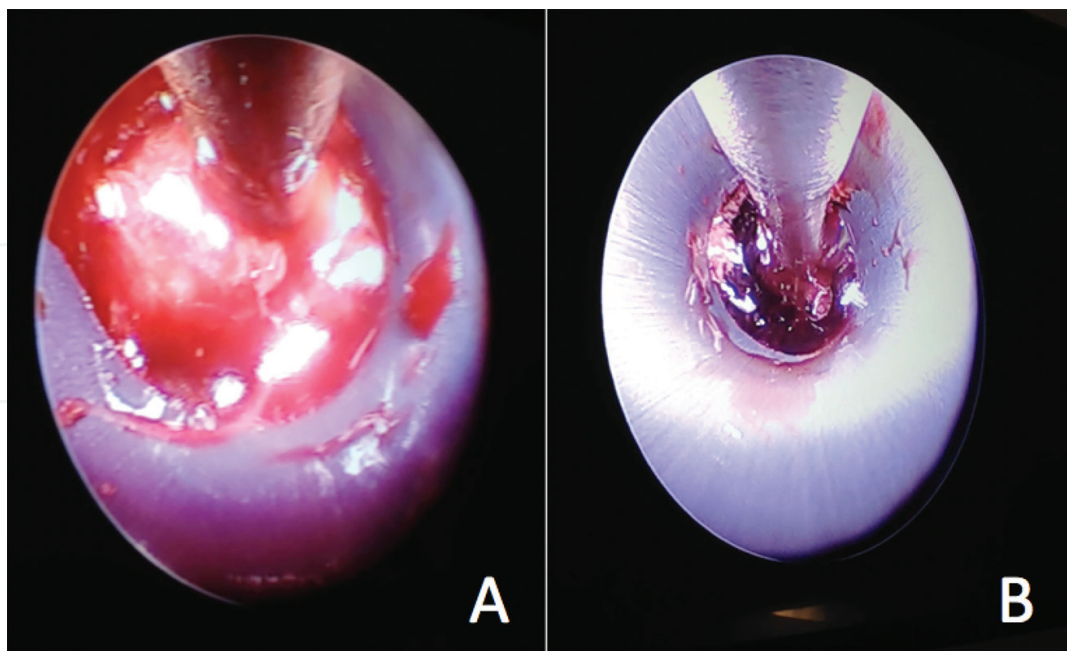
Figure 2. (A and B): Intraoperative endoscopic clot evacuation using minimally invasive technique.

Figure 3. Follow-up axial CT scan after endoscopic hemorrhagic evacuation demonstrating resolution of clot.

4. Endoscopic hemorrhage evacuation example

Taken together, the results of these trials demonstrate the difficulties in producing guidelines for the surgical management of ICH (**Figures 1–3**). Though surgical intervention demonstrates better outcomes in early trials, these findings do not reach statistical significance. Like many neurosurgical studies, many of these trials suffer from significant patient crossover and highly variable patient characteristics. It has been argued that the subjectively better outcomes in early trials are of clinical relevance, especially when patients are projected to have poor outcomes as a result of the location or volume of their bleed. More recent trials have demonstrated the safety and efficacy of endoscopic measures combined with low-dose tPA in dissolving clots, reducing edema, and improving outcomes to a statistically significant degree. Endoscopic approaches to ICH will likely become more widely utilized as more data from clinical trials becomes available.

5. Postoperative management

Postoperative management of ICH includes ensuring appropriate blood pressure control, frequent neurologic examinations, deep vein thrombosis prophylaxis, and gastric ulcer prophylaxis. Subsequent physical therapy and rehabilitation especially in the first month after ICH has been shown to be more effective in increasing independence with activities of daily life and motor function when compared to controls [33].

Despite limited evidence of long-term postoperative management of ICH, studies suggest that ICH patients would benefit from a systolic blood pressure of <130 mmHg. Patients, notably, with established small vessel disease see a 60% risk reduction in recurrent ICH with these blood pressure guidelines [9]. Furthermore, studies have shown that in patients with poor clinical grade or coexisting cardiopulmonary complications, early hemodynamic stabilization is associated with lower rates of delayed cerebral ischemia, lower 90-day mRS, and lower length of intensive care unit stay [34].

Deep vein thrombosis (DVT) prophylaxis after ICH is a current area of uncertainty. Various studies, including the CLOTS3 trial, show reduction in asymptomatic DVT with the use of intermittent pneumatic compression devices in ICH patients. Similarly, low molecular weight heparin or unfractionated heparin can be used for DVT prophylaxis in patients with stable hematomas or 24 hours after craniotomy [35]. There is little current evidence to suggest positive or negative outcomes of mortality with gastric ulcer prophylaxis for ICH patients. A randomized controlled trial comparing ranitidine, sucralfate, and placebo for gastric hemorrhage prophylaxis in ICH patients showed no significant difference in mortality or pneumonia. However, given the increased prevalence of gastric ulcers in these patients, prophylaxis should be initiated based on current data [36].

6. Conclusion

Intracerebral hemorrhage remains a serious complication associated with head trauma and a consequence of hemorrhagic stroke. Appropriate diagnosis and management of intracerebral

pressures and ventilation preoperatively remains an important opportunity to improve patient outcomes. While surgical intervention for large infratentorial ICH is clearly beneficial, the role of supratentorial ICH remains controversial given the diversity of ICH locations, depth of bleed, and technique used to evacuate the hemorrhagic clot. Superficial cortical ICH can have improved outcomes with surgical evacuation compared to medical management alone, and image-guided endoscopic evacuation of clot also shows promise. ICH patients can have a host of complications in the postoperative window and require close follow-up to prevent subsequent surgical and medical complications. Further prospective trials elucidating whether surgical intervention compared to medical management alone is optimal given an ICH location, presentation, or volume of hemorrhage will continue to guide the management of this diverse population.

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