

# Endoscopic Evacuation of Intracerebral Hematoma Utilizing a Side-Cutting Aspiration Device

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**BACKGROUND:** Intracerebral hemorrhage (ICH) is associated with a significant mortality of up to 50%, with almost all survivors suffering from debilitating functional compromise. In most cases, open craniotomy has failed to yield significant survival benefit. However, emerging evidence suggests that minimally invasive surgery (MIS) may yield clinically significant improvements in patient survival and quality of life in cases where open craniotomy has not shown benefit.

**CASE PRESENTATION:** We report the first documented usage of a side-cutting-aspiration device via an endoscopic approach for the evacuation of a 56cc hematoma, which was a technical modification on previous MIS techniques. The patient is a 50-yr-old female who was transferred emergently to our center with a National Institutes of Health Stroke Scale score of 27 and found to have a large hematoma involving her left basal ganglia. A minimally-invasive approach was elected due to evidence on the risks and suboptimal outcomes of open craniotomy in ICH evacuation. Neuronavigation was used to plan the surgical trajectory for ICH access. Evacuation took place in three main steps: 1) beginning at the center of the clot to remove bulk; 2) mobilizing clots from parenchymal walls to a safe zone via aspiration, followed by clot homogenization; and 3) re-expansion of the cavity via continuous irrigation to allow visualization of further clots. A final inspection was performed to ensure removal of all clots that could be safely removed. The dual functionalities of the device, namely, suction only and suction plus side-cutting functions, enabled key maneuvers, such as clot homogenization and controlled aspiration strength, to be safely performed. A near-total evacuation of the hematoma was achieved without damage to surrounding parenchyma. The patient experienced a rapid clinical course from comatose to discharge-ready in 5 d. At 30-d follow-up, the patient had residual expressive aphasia and was able to ambulate with the assistance of a quad cane. There are no radiographical signs of recurrent hemorrhage or parenchymal injury. Clinical follow-up with this patient is ongoing.

**CONCLUSION:** This is the first ICH evacuation with a side-cutting-aspiration device via an endoscopic approach. In our patient, this technique proved to be safe and efficacious, suggesting that this technique may be a promising addition to the armamentarium of MIS for ICH evacuation.

**KEY WORDS:** Intracerebral hemorrhage, Hemorrhagic stroke, Minimally invasive, Surgical evacuation, Supratentorial hematoma

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**ABBREVIATIONS:** **CT**, computed tomography; **ENRICH**, early Minimally-Invasive Removal of Intracerebral Hemorrhage; **ICH**, Intracerebral hemorrhage; **ICES**, intraoperative stereotactic computed tomography-guided endoscopic surgery; **IVH**, intraventricular hematoma; **MIND**, Prospective, Multicenter Study of Artemis, a Minimally Invasive Neuro Evacuation Device; **MIS**, minimally invasive surgery; **MISTIE**, minimally invasive surgery with thrombolysis in intracerebral haemorrhage evacuation; **mRS**, modified Rankin scale; **POD**, post-operative day; **SCUBA**, stereotactic intracerebral hemorrhage under water blood aspiration; **STITCH**, Surgical Trial In Traumatic Intracerebral Haemorrhage

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Intracerebral hemorrhage (ICH) occurs as a result of ruptured cerebral vessels and carries a devastating prognosis.<sup>1-4</sup> Although it only accounts for 10%-15% of all strokes, it is associated with a much higher risk of mortality and morbidity than its ischemic counterpart, resulting in death for approximately 50% of patients within the first 30 d and severe functional impairment in the majority of survivors.<sup>1-3</sup> While ICH has classically been described as a monophasic disease, there is increasing evidence to support a more dynamic course characterized by early hematoma expansion and corresponding clinical decline in nearly one-third of patients.<sup>2-4</sup> Given the rapid deterioration and grim prognosis associated with ICH patients, there has been significant interest in early intervention to optimize outcomes. Current ICH management is primarily medical, consisting of blood pressure stabilization, intracranial pressure monitoring, and coagulopathy reversal.

While medical management is standard of care, surgical evacuation may be necessary in patients with a large ICH to decrease mass effect and prevent hematoma expansion.<sup>2-4</sup> The American Stroke Association Stroke Council cites cerebellar hemorrhages and hematomas greater than 3 cm associated with clinical decline as indications for surgery.<sup>2-4</sup> The role of surgery for supratentorial hematomas, however, remains controversial. Prior studies including two randomized-controlled trials—Surgical Trial In Traumatic Intracerebral Haemorrhage (STITCH) I and STITCH II—have failed to demonstrate improved outcomes with surgery compared to conservative treatment.<sup>2-6</sup> Specifically, these trials demonstrated that complications associated with open craniotomy may outweigh the potential benefits of hematoma evacuation. It is important to note, however, that a key shortcoming of the STICH trials was the lack of surgical technique standardization, consisting primarily of open craniotomies. Interestingly, when the patients are stratified based on surgical approach, patients with minimally invasive surgery (MIS) demonstrated superior clinical outcomes to both the conventional craniotomy and medical management cohorts.<sup>7,8</sup> These results have sparked a renewed interest in surgery for ICH evacuation.<sup>9,10</sup> As such, clinical trials such as Early Minimally-Invasive Removal of Intracerebral Hemorrhage (ENRICH) and Prospective, Multicenter Study of Artemis, a Minimally Invasive Neuro Evacuation Device (MIND), in the removal of ICH) are currently investigating the usage of MIS to treat ICH, with results pending.<sup>11</sup> Recently, a multicenter randomized controlled trial, intraoperative stereotactic computed tomography-guided endoscopic surgery (ICES) with control cohort from minimally invasive surgery with thrombolysis in intracerebral haemorrhage evacuation (MISTIE) trial demonstrated that stereotactic endoscopic surgery with tomography guidance led to safe and effective evacuation of ICH.<sup>12</sup> This approach led to the immediate removal of over 67% of the hematoma and improved the likelihood of functional outcomes by 12% in comparison to the control group.<sup>12</sup> While our technique was similar to that used in MISTIE-ICES, we employed a side-cutting aspiration device for hematoma evacuation, in contrast to the aspiration-only



**FIGURE 1.** Preoperative axial head CT demonstrating 56cc left basal ganglia hemorrhage with associated brain herniation.

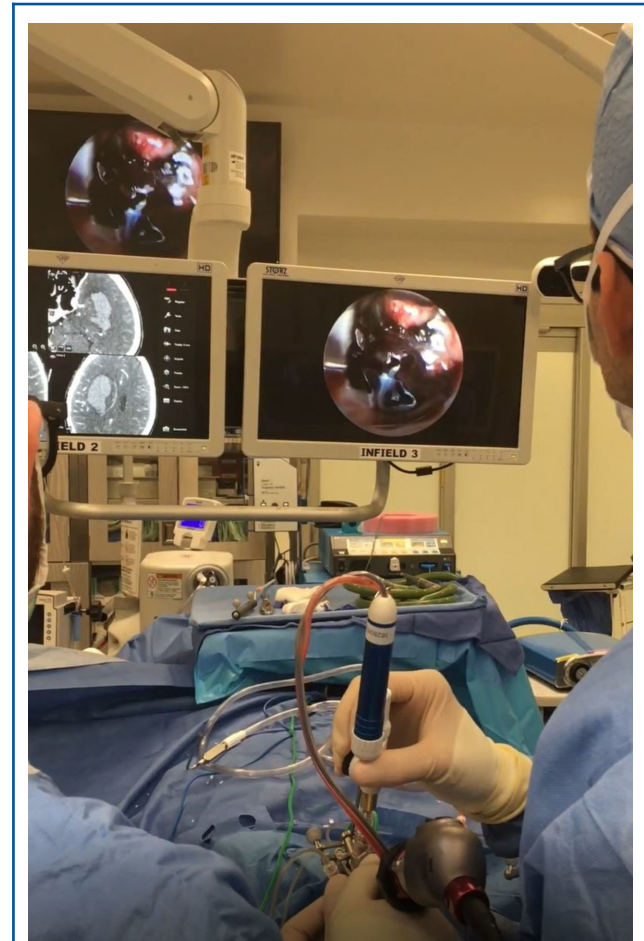
device utilized in MISTIE-ICES. With the background of ever evolving ICH treatment strategies, we present a modification to stereotactic intracerebral hemorrhage under water blood aspiration (SCUBA) technique by utilizing a side-cutting aspiration device via an endoscopic transcortical approach.<sup>10</sup> This is the first documented experience with this tool for ICH evacuation.

## CASE PRESENTATION

The patient is a 50-yr-old female with no significant past medical history who presented to an outside hospital emergency department and was diagnosed with an acute left ICH before she was transferred emergently to our center. Upon initial presentation, she was noted to have severe right-sided hemiplegia and aphasia, with a systolic blood pressure of 213 and a National Institutes of Health Stroke Scale score of 27. She was promptly intubated, started on nicardipine, and transferred to our center for further care; mannitol was administered during the transfer to reduce intracranial pressure. Head computed tomography (CT) revealed a 6.3 cm hematoma centered in the putamen of the left basal ganglia with an 8 mm midline shift to the right secondary to mass effect (Figure 1), and CTA demonstrated slight expansion of the parenchymal hematoma with intraventricular extension; spot sign was not present. CTA is routinely obtained prior to surgical intervention for ICH at our institution to rule out the

presence of a vascular lesion such as an aneurysm or arteriovenous malformation, which may alter the surgical approach. Indeed, obtaining CTA prior to surgical intervention is also a required component of several clinical trials, including MISTIE-III, ENRICH, and MIND. There was also a small intraventricular component noted, with blood in the ipsilateral ventricle. The notable size (56cc), expansion of the hematoma, presence of intraventricular hematoma (IVH), which is a negative prognostic factor in patients with ICH, and her declining clinical status were reasons for which surgical evacuation was considered. Given prior evidence showing lack of benefit with open craniotomy and emerging experience suggestive of benefits with minimally invasive approaches, we opted for an endoscopic, transcortical approach using a side-cutting aspiration device to rapidly access and evacuate the hematoma. Use of the side-cutting aspiration device was specifically selected given the experience of the senior author (P.F.R.) using this device for tumor removal and evacuation of intraventricular empyema.<sup>13</sup> The risks, benefits, and alternatives to surgery were thoroughly discussed with the husband of the patient, who provided informed consent for surgical evacuation. Although this technique is novel, one of the specific Food and Drug Administration approved indications of the side-cutting aspiration device is for the neurosurgical indication of hematoma evacuation and thus further Institutional Review Board review or ethics approval was not required.<sup>14</sup> A total of 15 h elapsed between when the patient was last seen well and initiation of surgical intervention. This was sufficient time to demonstrate radiographic clot stability after the initial expansion demonstrated on CTA but early enough to avoid the perihematomal edema that often leads to clinical decline in ICH patients.

The operation room selected is optimized for the performance of cerebrovascular and endoscopic neurosurgical procedures, specifically having ceiling mounted booms with endoscopic equipment consoles and screens for ease of setup. It is important to set up the screen opposite to the surgeons to work easily in the direct line of sight. The endoscopic equipment and side cutting-aspiration device were set up prior to the operation. The surgical trajectory was planned to approach the ICH along its long axis using neuronavigation (Brainlab, Munich, Germany). Figure 2 demonstrates the operative setup for this procedure. A horizontal incision was made on a forehead crease and monopolar cautery was used to dissect down to the cranium. A 13 mm burr hole was made at the entry point, followed by a duratomy and small corticectomy to allow endoscopic access (Figure 3). Subsequently, a 19-French peel-away sheath was inserted into the middle of the ICH using neuro-navigation, and the Lotta endoscope (Karl Storz, Tuttlingen, Germany) with a 15 gauge/26 cm side-cutting aspiration device handpiece (Myriad, NICO corporation, Indianapolis, Indiana) inserted through the sheath into the hematoma. The dual functionalities of the side-cutting plus aspiration and aspiration only were utilized to break up and evacuate clot. To avoid damage to eloquent areas, there were several important technical observations—the clot in the middle, which was furthest away from eloquent areas, was



**FIGURE 2.** Intraoperative view demonstrating side-cutting aspiration device utilized for ICH evacuation. Monitors showing the endoscopic view and navigation view are side-by-side to optimize ergonomics and visualization.

addressed first, for clot close to parenchymal walls, the clot was first mobilized away from the wall using the aspiration only setting and only broken up using the side-cutting function when it was confirmed to be safely away from critical structures, as the hematoma diminished in size, continuous irrigation was started through the endoscope to re-expand the cavity and improve visualization allowing further clot, particularly that next to parenchyma and the ventricle, to be visualized and safely mobilized. Furthermore, continuous irrigation was utilized as the primary method of achieving endoscopic hemostasis throughout the procedure. Hemostatic agents such as Floseal (hemostatic (Floleal, Baxter International Inc., Deerfield, Illinois) were also injected into the working cavity to maintain hemostasis. In this manner, near-total evacuation of the hematoma was performed. Highlights of this procedure can be seen in the accompanying operative video (**Video, Supplemental Digital Content**). After copious irrigation and confirmation of satisfactory evacuation,

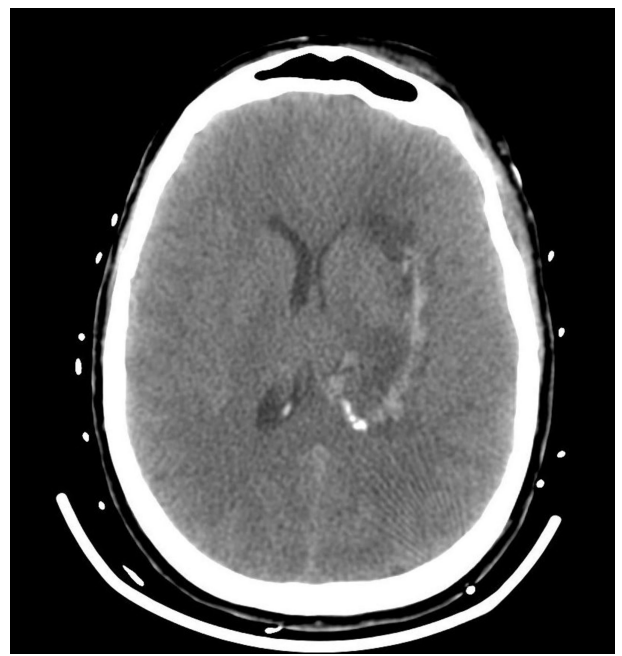




**FIGURE 3.** 13 mm burr hole craniectomy used for access.

injectable was administered into the cavity and subsequently irrigated out with warm irrigation. The burr hole was closed with a magnetic resonance imaging compatible burr hole plate and corresponding screws. The procedure took 2 h and 9 min to perform. Postoperatively, the patient was transferred to the intensive care unit in stable condition.

Immediate postoperative head CT showed clear recovery of midline without evidence of mass effect or acute intracranial findings (Figure 4). She was extubated on post-operative day (POD) 2, on which physical therapy was also initiated. The patient progressed well through her hospital stay and was medically ready for discharge on POD 5 and awaited placement at an appropriate acute rehabilitation facility, to which she was eventually discharged on POD 10. Neurological examination at the time of discharge indicated that the patient was alert and oriented to time, person, and place, with spontaneous eye movements. She was able to clearly follow commands, reply “yes”/“no” to questions, and state her name. She had full strength on her left side with continued right hemiplegia. On her 1-mo postoperative follow-up appointment, her exam was significant for residual expressive aphasia and right-sided weakness, though she was able to ambulate with a quad cane and moderate assistance. CT at this time again confirmed recovery of midline without any evidence of further hemorrhage or damage to the surrounding brain parenchyma (Figure 5). Per patient husband, the patient continues to improve



**FIGURE 4.** Immediate Postoperative Head CT.



**FIGURE 5.** Axial head CT at 1-month postoperative follow-up demonstrating resolution of brain shift and minimal evidence of surgical tract.

functionally with routine physical, occupational, and speech therapies.

## DISCUSSION

Uniformly acknowledged as the deadliest type of stroke, ICH is nevertheless the only subtype of stroke without a uniform treatment plan.<sup>15,16</sup> The current clinical management for ICH varies from exclusively supportive care to aggressive surgical intervention, with neither modality associated with a definitive survival benefit.<sup>15,16</sup> What is clear, however, is that the mechanism of neurological injury in ICH occurs in 2 phases: early destruction of parenchyma by the initial high-pressure hemorrhage and subsequent injury to adjacent viable structures from perihematomal inflammation and edema.<sup>16,17</sup> It is this second phase of injury that accounts for the delayed neurological deterioration in ICH patients, leading to increased recovery time and reduced likelihood of a functional outcome.<sup>16,17</sup> This understanding of the neurophysiological basis of ICH injury led to interest in surgical evacuation, which would putatively eliminate the second phase of injury, in the management of ICH.<sup>15-17</sup>

While conventional craniotomy has not been shown to have a survival benefit, emerging evidence suggests that surgical evacuation of ICH via a minimally invasive approach does offer benefit in terms of both survival and quality of life.<sup>15-17</sup> For instance, the MISTIE I and II trials, which investigated the safety and efficacy of hematoma drainage and concomitant tissue plasminogen activator (tPA) administration via a stereotactic catheter, reported 14% more patients in the surgical group who scored a 0 to 2 on the modified Rankin scale (mRS) compared to the medical group at 365 d.<sup>16,17</sup> Additionally, patients in the surgical arm also demonstrated greater improvements in mobility and “activities of daily living” on the Stroke Impact Scale, along with shorter hospital stay and reduced overall cost.<sup>16,17</sup> Importantly, these patients also had a significant decrease in perihematomal edema as a result of MIS, thereby further reinforcing the association between phase 2 ICH injury and clinical deterioration.<sup>16,17</sup> The recently published MISTIE III clinical trial found a statistically significant decrease of 6% to 8% in all-cause mortality in the MISTIE group (and thus had their ICH removed via MIS) compared to patients who received standard medical care ( $P = .037$ ).<sup>18</sup> Additionally, there was also a significant decrease in the number of serious adverse events in the first 30 days in the MISITE group ( $P = .012$ ).<sup>18</sup> Notably, while there were important differences in patient outcome between the MISTIE and control groups, MISTIE did not significantly improve the proportion of patients with large hematomas who achieved a good response, as defined by a mRS score of 0 to 3 at 365 d.<sup>18</sup> Thus, MISTIE III demonstrates that employment of a MIS technique for ICH evacuation may lead to benefit in certain arenas such as all-cause mortality, but that may not be correlated with improved functional outcomes across all patients, especially those with large hematomas.<sup>18</sup> However, the trial did demonstrate

a correlation between higher degree of hematoma evacuation and improved outcomes, which suggests that a technique capable of achieving a substantial degree of hematoma reduction may lead to improved clinical outcomes. This is an important observation since one important difference between our technique and MISTIE is the time to and extent of initial evacuation; while the MISTIE procedure requires several days for complete evacuation, our technique achieves immediate near-total evacuation of the hematoma, thereby reducing mass effect and secondary brain injury. This rapid operative course is especially important in patients with IVH, as this is associated with poor prognosis, thereby making rapid hematoma evacuation ever more pressing. Thus, we would recommend this procedure for patients with ventricular involvement, provided that the interval CT scan confirms hematoma stability. The studies by Wang WZ et al<sup>19</sup> and Kim YZ et al<sup>20</sup> have corroborated the results of the MISTIE trials, noting improved functional outcomes, lower mRS scores (1.2 after MIS vs 3.0 with medical treatment alone), and decreased dependence (40.9% vs 64% of patients) in ICH patients treated with MIS, compared to medical management.<sup>15,16,19,20</sup> Recently, our center demonstrated that minimally invasive hematoma evacuation with BrainPath (NICO corporation, Indianapolis, Indiana) in 18 patients was safe and efficacious, leading to 95.3% clot removal and median Glasgow Coma Score improvement from 10 (preoperative) to 14 (postoperative) and a 30-d mortality rate of 5.6%, a dramatic departure from the expected mortality rate of 50% based on ICH score.<sup>17</sup> While the role of surgical evacuation for ICH remains controversial, these reports indicate that MIS shows promise as a surgical option for ICH.

The encouraging results of MIS in ICH have motivated the development of several novel technologies to facilitate this process. The side-cutting-aspiration device utilized in our case provides a prime example; its dual functionalities allow for the homogenization and removal of clots while its blunt end reduces risk of parenchymal injury. Furthermore, the suction strength can be modulated by a foot pedal, allowing the surgeon to apply gentle suction near critical structures and stronger suction during clot aspiration. The endoscopic approach utilized also allows us to achieve hemostasis with continuous warm irrigation and injectable hemostatic agents like Floseal. Other possibilities to achieve hemostasis that were not employed in this specific case include small-diameter coagulation devices such as the take apart bipolar forceps (Karl Storz, Tuttlingen, Germany) that can be inserted through the working sheath of a ventriculoscope. Intravenous desmopressin use has also been reported as a method of achieving hemostasis in endoscopic procedures.<sup>12</sup> Since this patient's hematoma was stable at the time of surgical intervention, this case represented an ideal scenario for our endoscopic approach. If active bleeding is suspected, the physician should be comfortable with hemostatic tools such as bipolar before using this approach. In a similar vein, we would recommend performing a stability scan with interval CT prior to the operation to avoid possible intraoperative complications with hemostasis

achievement. Prior to utilizing this technology for ICH evacuation, we have previously shown the safety and efficacy of the same device for evacuation of an intraventricular empyema in 4 patients with pyogenic ventriculitis.<sup>13</sup> By allowing for source control and sufficient antibiotic penetrance, the endoscopic approach combined with the side-cutting-aspiration device led to control and eradication of infection in all four patients.<sup>13</sup> Additionally, this device has also been utilized for safe and effective resection of various neurological tumors, with particular proficiency in cases with narrow access corridors.<sup>21</sup> In one particular case series, this device allowed for successful tumor resection without injury to surrounding neurovascular structures in 30/31 cases.<sup>21</sup> These results support the safety of the side-cutting-aspiration device in minimally-invasive endoscopic surgery.

By combining a minimally-invasive approach with the side-cutting-aspiration device, we were able to achieve rapid access to the hematoma and elimination of risks (most notably decreased cortical disruption) associated with open craniotomy. A key consideration in surgical management of ICH is safe evacuation of the hematoma without damage to the surrounding parenchyma. As such, key decisions and steps in our approach were made to this end. For instance, the side cutting-aspiration device selected for evacuation provides control over the evacuation process; since the cutting function could be employed to break down clots, the surgeon does not need to rely on strong aspiration alone, which in excess could damage the surrounding tissue. Thus, our technique represents a key modification to the SCUBA technique, which relied primarily on aspiration and an agitation wand to break apart clots.<sup>10</sup> In SCUBA, large clots that adhere to the tip would require the removal of the entire endoscope and suction (Apollo Endosurgery, Austin, Texas) wand apparatus for clot disposal.<sup>10</sup> In contrast, our endoscopic approach allows mobilization of clots away from eloquent areas and onto the sheath prior to aspiration, thereby preventing damage to those structures and precluding repeated instrument withdrawal, which could also disturb the surrounding brain parenchyma. Lastly, compared to stereotactic clot aspiration techniques like SCUBA, our method provides improved clot and parenchyma visualization, therefore reducing the risks associated with unguided aspiration. Another important safety advantage of our approach can be found in the process by which clots are broken down, which entails inflating the cavity with irrigation to allow clear visualization of the remaining clot without injuring the surrounding parenchyma. As the patient's postoperative CT confirms, there is no evidence of parenchymal damage after a near-complete evacuation of the hematoma. In addition to minimizing cortical disruption, our technique also has important advantages over other minimally invasive modalities for ICH evacuation. For instance, aspiration devices such as the Artemis (Penumbra, Inc., Alameda, California) lack a cutting function for clot homogenization and rely on rotational disruption of the clot and extreme suction strength for evacuation.

Furthermore, this aspiration device has its functional opening at the end, instead of the side, thereby increasing the risk of parenchymal injury compared with our technique. Lastly, at our institution, the side-cutting-aspiration device accounts for 0.51 times the cost of the device utilized in SCUBA, though the exact numerical costs could not be reported due to the confidential nature of the negotiated costs between our institution and supplier.

This patient's remarkable clinical course paired with radiographic evidence of effective evacuation such as reestablishment of midline and lack of acute hemorrhage suggests that an endoscopic approach to ICH evacuation is a safer and more effective alternative to conventional open craniotomy. Its key strength lies in its ability to remove a large proportion of the hematoma, thereby preventing phase 2 neurological injury, without damaging the surrounding parenchyma. While an ideal outcome was achieved in this case, it is important to note that further experience is necessary to optimize the application of this side cutting-aspiration device for this purpose to consistently achieve optimal clinical outcomes, for which familiarization with its functions and usage is imperative. Nevertheless, the result of this case opens up exciting avenues for future research, including the standardization of an endoscopic protocol for ICH evacuation.

## CONCLUSION

An optimal outcome was achieved to evacuate a large ICH via a minimally invasive, endoscopic approach using a side-cutting-aspiration device and achieve near total evacuation of the hematoma without injury to the adjacent structures. This technique represents a promising modification to prior MIS approaches used for ICH evacuation.

## Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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**Supplemental Digital Content. Video.** Operative Video: Key Steps in Hematoma Evacuation with a Side-Cutting Aspiration Device.

## COMMENT

This is a comprehensive case illustration of the effectiveness of a side-cutting aspiration device to evacuate an intracerebral hemorrhage through a minimally invasive, endoscopic approach. This device has been FDA-approved for use in brain tumors, intraventricular tumors or cysts, and selected vascular abnormalities. The cutting-aspiration setting serves to achieve hematoma homogenization that facilitates the evacuation process, and the aspiration-only setting may be employed for gentle manipulation near brain parenchyma. Unlike previous aspiration techniques such as SCUBA, large clots can be handled without the need for complete device removal and re-insertion. Therefore, this device represents an incremental technical advance that may improve surgical performance in procedures for ICH evacuation.

Among the key findings of the recently completed MISTIE III trial was that clot size reduction to 15 ml or less can lead to improved functional outcomes when compared to optimal medical therapy. This finding highlighted that surgical technique and performance may be crucial in minimizing secondary injury from peri-hematoma inflammation and edema. Continued analysis of outcomes after more widespread adoption of this technique, along with comparisons to other minimally invasive techniques currently underway with the ENRICH and MIND trials, will be essential in the ongoing evaluation of safety and efficacy of surgery for ICH evacuation. Expanding our neurosurgical armamentarium to potentially improve outcomes in patients with devastating hemorrhagic strokes deserves further investigation.

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