Original research

Minimally invasive surgery for evacuation of intracerebral hematoma by neurointerventionalists: initial experience

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ABSTRACT

Background There is growing interest and evidence in spontaneous intracerebral hemorrhage (ICH) evacuation with minimally invasive surgery (MIS). If early ICH evacuation becomes the standard of care, training neurointerventionalists to perform MIS would expand global access to treatment. We present a retrospective analysis of patients who underwent MIS–ICH evacuation performed by interventional neurologists in collaboration with neurosurgeons.

Method Patients meeting prespecified criteria underwent MIS–ICH evacuation using the Artemis (Penumbra) by an interventional neurologist–neurosurgeon team. Baseline demographic, clinical, and radiographic characteristics were collected. Procedure location was recorded. The primary outcome of interest was the rate of symptomatic rebleeding. Secondary outcomes included hematoma reduction, serious adverse events, length of stay, disposition, and discharge and 6 month functional status.

Results 19 patients were included in this analysis. One third of cases were performed in the neuroangiography suite using intraprocedural flat panel CT and the rest were performed in the operating room. All were performed under neuronavigation using AxiEM (Medtronic-Stealth-Station). There was a median 80% hematoma reduction from a median preoperative ICH volume of 31.1 mL (IQR 26.2–56.4). A post-procedural hematoma volume of <15 mL was achieved in 67% of cases, comparable with that seen in the ENRICH (Early Minimally Invasive Removal of Intracerebral Hemorrhage) trial (72.7%). No patients developed symptomatic post-procedural hematoma expansion.

Conclusion This study suggests that MIS–ICH evacuation can be performed safely and effectively by trained neurointerventionalists. Our experience also supports the ability to perform MIS–ICH evacuation in the neuroangiography suite. We advocate for the development of a standardized neurointerventional training protocol and certification pathway for the performance of MIS–ICH evacuation with the goal of improving global access to care.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Intracerebral hemorrhage has a higher incidence in developing countries, and carries a high risk of mortality and long term disability, while lacking evidence based effective treatment.

⇒ Theoretically, prompt surgical intervention could substantially change the natural history of the disease by reducing hematoma and perihematomal edema.

WHAT THIS STUDY ADDS

⇒ Minimally invasive surgery for intracerebral hematoma evacuation can be safely and effectively performed in the angiography suite, by interventional neurologist–neurosurgeon teams using the Artemis neuro evacuation device with no perioperative complications.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE, OR POLICY

⇒ The present study requires further research to expand our knowledge, include neurointerventionalists in this technique, and improve global access to patient care.

INTRODUCTION

Intracerebral hemorrhage (ICH) comprises 10–15% of all strokes in high income countries and 25–50% in developing countries. It carries a high risk of mortality and long term disability but lacks evidence based effective treatment.[1 2] Hematoma volume >60 mL is the biggest predictor of mortality (91%) in the first 30 days.[3] Rebleeding occurs in approximately 33% of patients during the first 3 hours and in an additional 11% of patients up to 24 hours with accompanying neurological deterioration. ICH causes continuous time related brain damage due to mass effect, blood products toxicity, and hematoma expansion.[4] Theoretically, prompt surgical intervention could substantially change the natural history of the disease by reducing hematoma and perihematomal edema.[4–6]

However, similar to early thrombectomy trials for acute ischemic stroke, the results of randomized controlled trials evaluating the surgical treatment of ICH have failed to reach statistical significance.[7–12] As devices evolve and surgical techniques improve, we can expect a decrease in intraoperative injury to eloquent cortex and subcortical white matter tracts, making surgical intervention safer. Additionally, patient subgroups that may derive greater benefit from MIS–ICH evacuation have been identified. Notably, the impact of time from ictus to intervention has come under scrutiny as a modifiable factor

in the race to improve ICH outcomes. A study by Kellner *et al* suggests that for each additional hour from ictus to treatment, there is a 5% reduction in the odds of achieving a favorable postoperative outcome (modified Rankin Scale (mRS) score of 0–3).[13] As stated by Li *et al*, we may be on track for a second code stroke, or rather a 'code ICH'.[14]

If emergent MIS hematoma evacuation achieves level 1 evidence for the treatment of spontaneous ICH, we wonder how we can best position ourselves to meet the global demands of patient care. In 2019, the annual global incidence of hemorrhagic stroke was 44/100 000 people.[15] Meanwhile, there is an estimated median of 0.44 neurosurgeons per 100 000 people, which drops to 0.12/100 000 in low income countries. The lack of access to neurosurgical care disproportionately affects low and middle income countries and rural areas.[16]

Patients with spontaneous ICH, commonly categorized as a code stroke in prehospital triage systems, present to thrombectomy capable centers. Thrombectomy capable centers are not required to have neurosurgical coverage. Those patients requiring neurosurgical care may have to be transferred out. Even when transferring to another medical center is possible, the delay in care can be devastating in the setting of acute neurological injury.[17]

Training of non-neurosurgical healthcare workers to perform basic and emergent neurosurgical procedures has been effectively implemented to increase access to care in low income countries and rural areas.[18 19] Image guided external ventricular drainage (EVD) placement in the neuroangiography suite by interventional neuroradiologists has been successfully performed in the US.[20] Neurointerventionalists encounter these patients as code strokes, are involved in their management in the neurocritical care unit, and are comfortable performing high precision image guided intracranial procedures, such as aneurysm coiling and mechanical thrombectomy. Training neurointerventionalists to perform MIS–ICH hematoma evacuation should be considered as a means to increase global patient access to care.[18]

Different approaches to MIS hematoma evacuation are briefly summarized in table 1. Stereotactic aspiration with thrombolysis and craniopuncture both involve the placement of a catheter in the hematoma bed followed by local thrombolytic clot irrigation and passive hematoma drainage over the following days. These two approaches benefit from the use of smaller diameter catheters but it comes at the cost of visualization and the ability to address active bleeding. The other approaches favor active removal of the hematoma with varying combinations of optics and instruments, used either in tandem (endoscope, Surgiscope) or in parallel (endoscope assisted, endoport mediated). Larger devices allow for greater visualization and instrumentation but sacrifice some degree of minimally invasiveness (table 1).[21–23]

METHODS

This was a retrospective analysis of a prospectively maintained database at a comprehensive stroke center in south Texas, USA. Included patients underwent minimally invasive endoscopic evacuation for spontaneous supratentorial ICH using the Artemis Neuro Evacuation Device (Penumbra, Alameda, California, USA) between June 2018 and 2023. Procedures were performed by an interventional neurologist–neurosurgeon team in either the neuroangiography suite (Cath lab) or the operating room. We included patients aged ≥18 years and ≤80 years with a supratentorial ICH of volume ≥20 and ≤80 mL (measured using A×B×C/2 method). More detailed inclusion and exclusion criteria used are available in online supplemental data.

MIS technique

Cerebral angiography was performed before evacuation to exclude underlying vascular lesions, including aneurysms and arteriovenous malformations. All patients were intubated and sedated before initiation of the procedure. Sheath trajectory was preplanned based on neuroimaging. Access was obtained using standard burr hole opening. The endoscope sheath that comes with the Artemis was advanced into the mid to distal hematoma bed under neuronavigation using Medtronic Stealth Station AxiEM (Medtronic, Minneapolis, Minnesota, USA). Subsequently, the endoscope (Stortz, El Segundo, California, USA) and Artemis, which were placed inside one of the ports of the endoscope, were carefully advanced together through the sheath into the hematoma. Using aspiration and irrigation, the hematoma was removed, addressing any active bleeding as needed using irrigation, adjunct hemostatic agents, electrocautery, and/or temporarily docking the endoscope on the bleeder for hemostasis. Once completed, the sheath and devices were backed out 1 cm and the process of irrigation and aspiration was repeated.

Table 1 Approaches to minimally invasive surgery for intracerebral hemorrhage hematoma evacuation[21 23]

	Name	Description	Size (mm)	Access	Studies
Thrombolytic	Craniopuncture	YL-1 craniopuncture needle* placed with electric drill -> ±manual aspiration ->catheter placement -> thrombolytic clot irrigation	3		PubMed: 19236490[29]
	Stereotactic aspiration with thrombolysis	Stereotactic cannula placement -> manual aspiration -> catheter placement -> thrombolytic clot irrigation	4.8	Burr hole	MISTIE II,[9] MISTIE III[11]
Non-thrombolytic	Endoscope	Apollo/Artemis Neuro Evacuation device: stereotactic sheath placement -> endoscope through which multifunctional wand is inserted (device used in the current study)	6.3	1 cm craniectomy	ICES,[7] INVEST,[30] MIND,[25] DIST[12]
	Endoscope assisted	Stereotactic sheath placement -> endoscope and multifunctional cannula working side by side	10	1.5–2 cm craniectomy	
	Surgiscope	Aurora Surgiscope and Evacuator system: stereotactic sheath placement -> like endoscopic evacuation but with a larger working channel and cautery capability	11.5	Burr hole or microcraniotomy	MIRROR,[31] EVACUATE[32]
	Endoport mediated	NICO BrainPath and NICO Myriad system: stereotactic endoport placement -> microscope or exoscope and suction or Myriad device working side by side	15.8	2.5–3 cm craniotomy	ENRICH[33 34]

*Inner diameter 2.5 mm, outer diameter 3 mm (Beijing WanTeFu Medical Apparatus, Beijing, China).
DIST, the Dutch Intracerebral haemorrhage Surgery Trial pilot study; ENRICH, Early Minimally Invasive Removal of Intracerebral Hemorrhage; EVACUATE, Ultra-Early, Minimally inVAsive intraCerebral Haemorrhage evacUATion vs Standard trEatment; ICES, Intraoperative Stereotactic Computed Tomography-Guided Endoscopic Surgery; INVEST, Minimally Invasive Endoscopic Surgery With Apollo vs Best Medical Management for Supratentorial Intracerebral Hemorrhage; MIND, Artemis in the Removal of Intracerebral Hemorrhage; MIRROR, Minimally Invasive IntRaceRebral HemORrhage Evacuation; MISTIE, Minimally Invasive Surgery Plus Alteplase for Intracerebral Hemorrhage Evacuation.

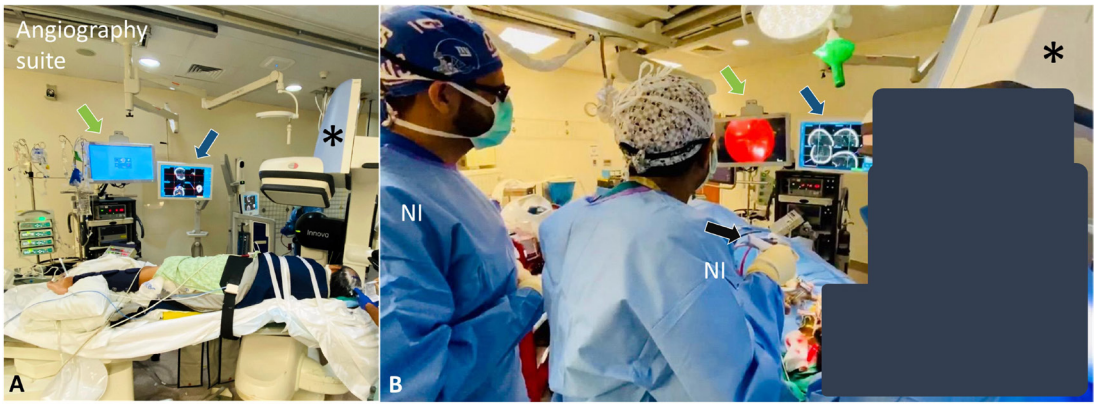

Figure 1 (A) Angiography suite set-up and patient preparation for minimally invasive surgery (MIS). (B) A proctored MIS procedure taking place using neuronavigation system (blue arrow) and Artemis device (black arrow). Light green arrow=endoscopic visualization screen; black asterixis=frontal image intensifier used obtain flat panel CT images. Proctoring neurosurgeon not pictured. NI, neurointerventionalist.

This continued until the endoscope was at the proximal end of the hematoma. At this point the Artemis device was removed, and the hematoma bed was irrigated under endoscopic visualization, addressing any active bleeding or residual hematoma as needed.

In the neuroangiography suite, a flat panel CT was then performed to ensure adequate hematoma removal before removal of the endoscope (figure 1). The scalp and skin were closed in a routine manner. An intraoperative flat panel CT control was taken to see if there was significant residual hematoma that needed further evacuation during the same session. It should be noted that burr hole access and closure were performed by the neurosurgeon while MIS hematoma evacuation was performed by the interventional neurologist under neurosurgical proctoring with graduated independence reflecting mastery of skills. This approach was taken to foster collaboration and allow the interventional neurologists to focus on the MIS procedure even if they had already mastered burr hole access and closure from routine EVD placements.

Data collection

Baseline demographic, clinical, and radiographic information was collected. The primary outcome of interest was symptomatic post-procedural hematoma expansion, defined as an increase in hematoma volume between initial CT and follow-up imaging accompanied by a deterioration in neurological examination, defined as either an increase in the National Institutes of Health Stroke Scale (NIHSS) score ≥4 or a decrease in the Glasgow Coma Scale (GCS) score ≥2. Secondary outcomes of interest included median post-evacuation hematoma volume, median percentage hematoma reduction, post-procedural hematoma volume <15 mL, median duration of hospitalization, median duration of ICU stay, asymptomatic post-procedural hematoma expansion, defined as an increase in hematoma volume between initial CT and follow-up imaging of ≥5 mL without a change in neurological examination, mortality within 72 hours, 7 days, and hospitalization, other serious adverse events, and discharge mRS and 6 month mRS scores. Pre- and post-procedural hematoma volume for each patient was independently measured using the ABC/2 method by three physicians, including one neurosurgeon, one interventional neurologist, and one vascular neurologist. An average of the three measurements was used. Serious adverse events included postoperative infection and cerebral edema requiring decompressive hemicraniectomy within 72 hours. The 6 month mRS score was not available in seven patients, in which case the last measured value was carried forward for analysis.

Analysis

As there was no control group in this study, outcomes were compared with results presented from the recent randomized controlled trials ENRICH (Early Minimally Invasive Removal of Intracerebral Hemorrhage) and ICES (Intraoperative Stereotactic Computed Tomography-Guided Endoscopic Surgery). Efficacy outcomes were additionally analyzed based on procedure location (operating room vs neuroangiography suite) and were compared using the Mann–Whitney U test for continuous variables and the χ^2 test for categorical variables. Analysis was performed with JASP statistical software (V.0.17.3, University of Amsterdam, Netherlands).

RESULTS

A total of 19 patients, 47% women and 95% Hispanic with a median age of 62 years (IQR 53–73) were included in this analysis. Median NIHSS score on presentation was 12 (IQR 7–18) and median ICH score was 1 (IQR 1–3). Hematoma location was near evenly split between lobar (47%) and the basal ganglia (53%). Baseline demographic, clinical, and radiologic data are presented in table 2.

Initial hematoma volume was median 31.1 mL (IQR 26.2–56.4) (table 3). Average time to hematoma evacuation was 2.14 days (range 0–5) after symptoms onset. Seventeen patients (89%) underwent diagnostic angiography before MIS hematoma evacuation to evaluate for underlying vascular abnormalities. In seven patients (37%), MIS hematoma evacuation was performed in the neuroangiography suite and the rest were performed in the operating room. Additional steps to obtain hemostasis were undertaken in 60% of cases, mostly using irrigation with or without an adjunct hemostatic agent and one requiring additional use of electrocautery. All procedures performed in the neuroangiography suite used intraoperative flat panel CT to ensure adequate hematoma removal before closing.

No patients had symptomatic or asymptomatic post-procedural hematoma expansion. One patient required decompressive craniectomy for symptomatic cerebral edema within 72 hours postoperatively. No patient died within 72 hours of the hematoma evacuation, but three patients died within 7 days. One patient underwent craniectomy >72 hours post-MIS for symptomatic cerebral edema immediately after which he developed

Table 2 Baseline demographic, clinical, and radiographic features of patients included in the study

No of patients	19
Age (years) (median (IQR))	62 (53–73)
Women	9 (47)
Ethnicity	
Hispanic	18 (95)
Black	1 (5)
GCS at discharge (median (IQR))	13 (10–15)
NIHSS (median (IQR))	12 (7–18)
ICH score (median (IQR))	1 (1–3)
ICH location	
Basal ganglia	10 (53)
Lobar	9 (47)
ICH laterality	
Left	10 (53)
Right	9 (47)
Associated findings	
Intraventricular hemorrhage	9 (47)
Hydrocephalus	7 (37)

Values are number (%) unless indicated otherwise.
Patients' clinical features are listed in the online supplemental data.
GCS, Glasgow Coma Scale; ICH, intracerebral hemorrhage; NIHSS, National Institutes of Health Stroke Scale.

Table 4 Outcome data

Hematoma reduction (%) (median (IQR))	80 (52–87)
Operating room (n=12)	80 (43–86)
Neuroangiography suite (n=7)	70 (58–87)
Postoperative hematoma volume <15 mL (n (%))	13 (68)
Operating room (n=12)	8 (67)
Neuroangiography suite (n=7)	5 (71)
Safety outcomes (n (%))	
Symptomatic rebleeding	0
Asymptomatic rebleeding	0
Decompressive craniotomy	1 (5)
Inpatient mortality (n (%))	3 (16)
Within 72 hours	0
Within 7 days	2 (11)
Length of stay (days) (median (IQR))	
Hospital length of stay	16 (12.5–22.5)
ICU length of stay	12 (7–20)
Discharge mRS (median (IQR))	5 (4–5)
Discharge GCS (n=16) (median (IQR))	13 (10–15)
mRS at 6 months (n=9) (median (IQR))	3 (2–5)

Per cent postoperative hematoma volume <15 mL was not significantly different in procedures performed in the neuroangiography suite versus the operating room (P=0.85).
Per cent hematoma reduction also did not significantly differ (P=0.93).
GCS, Glasgow Coma Scale; mRS, modified Rankin Scale.

massive ICH with intraventricular extension, hydrocephalus, and midline shift, and progressed to brain death. The second patient died from multiorgan failure in the setting of sepsis. The third patient died later during hospitalization from cardiac arrest in the setting of hypoxic respiratory failure due to COVID-19 pneumonia. No other serious adverse events were recorded.

Median postoperative hematoma volume was 8.2 mL (IQR 4.7–18.5) from a median preoperative hematoma volume of 31.1 mL (IQR 26.2–56.4). Median postoperative hematoma reduction was 80% (IQR 52–87). A postoperative hematoma volume of <15 mL was achieved in 13 patients (68%). Patients managed in the angiography suite had a median preoperative hematoma volume of 26.5 mL (IQR 23–41.7), postoperative volume of 5.1 mL (IQR 3.9–16.5), and reduction of 70% (IQR 58–87). Postoperative hematoma volume of <15 mL was achieved in five patients (71%). Patient managed in the operating room (n=12) had a median preoperative hematoma volume of 46.5 mL (IQR 29.8–66.6), postoperative volume of 9.1 mL (IQR 4.9–20) and reduction of 80% (IQR 43–86). Postoperative hematoma reduction did not significantly differ between procedure locations (P=0.93). Postoperative hematoma volume of <15 mL was achieved in eight patients (67%). This also did not significantly differ between procedure locations (P=0.85) (table 4).

Median length of inpatient hospitalization was 16 days (IQR 12.5–22.5) and median ICU stay was 12 days (IQR 7–20). Median discharge mRS was 5 (IQR 4–5), median discharge GCS was 13 (IQR 10–15), and median 6 month mRS was 3 (IQR 2–5).

Table 3 Management data

Time to treatment (days) (mean (range))	2.14 (0–5)
Procedure location (n (%))	
Operating room	12 (63)
Neuroangiography suite	7 (37)
Angiogram before MIS (n (%))	17 (89)
Required control of bleeding (n (%))	11 (60)
Irrigation	10 (53)
Adjunct hemostatic agent	6 (32)
Electrocautery	1 (5)
Intraoperative soft tissue CT (n (%))	7 (37)
Hematoma volume (mL) (median (IQR))	
Preoperative hematoma volume	31.1 (26.2–56.4)
Operating room (n=12)	46.5 (29.8–66.6)
Neuroangiography suite (n=7)	26.5 (23–41.7)
Postoperative hematoma volume	8.2 (4.7–18.5)
Operating room (n=12)	9.1 (4.9–20)
Neuroangiography suite (n=7)	5.1 (3.9–16.5)

MIS, minimally invasive surgery.

DISCUSSION

This is the first description of interventional neurologists performing MIS for spontaneous ICH. Our main goal was to investigate safety and efficacy of MIS–ICH evacuation when performed by interventional neurologists.

Safety

We observed no cases of post-procedural symptomatic or asymptomatic hematoma expansion. The main serious adverse event encountered was symptomatic cerebral edema within 72 hours of the procedure requiring hemi-craniectomy which occurred in one patient. There were three mortalities during the post-procedural hospitalization that were not directly attributable to complications of the MIS–ICH hematoma evacuation. These

Table 5 Efficacy outcomes compared with high quality trials

	Current study (n=19)	ICES (n=14)	ENRICH (n=150)
Median hematoma reduction (%)	80	71.2	87.7
Postoperative hematoma volume <15 mL (%)	68	68	72.7

ENRICH, Early Minimally Invasive Removal of Intracerebral Hemorrhage; ICES, Intraoperative Stereotactic Computed Tomography-Guided Endoscopic Surgery.

results support that interventional neurologists can perform MIS–ICH hematoma evacuation safely.

This is the first study that has compared performing MIS in different locations and showed that there was no statistically significant difference between outcomes in hematoma reduction achieved in the operating room versus the angiography suite (P=0.85). Additionally, there were no complications attributed to performing MIS in either location.

Efficacy

We observed a median hematoma reduction of 80%, comparable with the mean 73.2% and median 87.7% hematoma reduction reported in the ENRICH trial (table 5). Additionally, a postoperative hematoma volume of <15 mL, associated with functional improvement in MISTIE (Minimally Invasive Surgery Plus Alteplase for Intracerebral Hemorrhage Evacuation) III, was achieved in 68% of patients, comparable with 72.7% reported in the ENRICH trial. We compared our results with the ENRICH trial data as it is the most recently published multicenter, randomized controlled trial of MIS–ICH hematoma evacuation, but it is worth noting that an endoport mediated approach was used in ENRICH whereas we used an endoscope approach.

The ICES trial, a multicenter, randomized controlled trial published in 2016, used an endoscope approach and reported a median 71.2% hematoma reduction, with 68% achieving a postoperative hematoma volume of <15 mL, similar to our results. When comparing these outcomes with open surgical hematoma evacuation, the Swiss Trial of Decompressive Craniectomy Versus Best Medical Treatment of Spontaneous Supratentorial Intracerebral Hemorrhage (SWITCH) [24] showed 12% hematoma reduction, which suggests a better achievement with MIS. Other studies, such as the Intertnational Surgical Trials in Intracerebral Hemorrhage (STICH)[8] and STICH II,[10] do not mention this variable in their analysis.

We acknowledge the challenges in ascertaining long term follow-up for all cases due to several patient related factors, including insurance status, migration, mortality from unrelated conditions, and changes in contact information. As a result, we were unable to assess the 6 month mRS score for approximately 44% of patients, which notably included a significant portion of lobar hemorrhages treated. While our results demonstrated a significant improvement in mRS scores at 6 months, exceeding those observed in the ENRICH trial, the significant loss of patient follow-up introduces potential bias, and our sample size was too small to show any significant outcomes differences. We observed that patients achieving lower mRS scores generally had fewer associated conditions. To address this bias in future research, we recommend studies involving larger, stratified, and randomized cohorts with extended follow-up periods.

Time to treatment

Although our mean 2.14 day interval until MIS performance may seem lengthy for immediate hematoma evacuation, it did not exceed the average time to operation outlined in the inclusion criteria of the MIND (Artemis in the Removal of Intracerebral Hemorrhage) trial[25] and other studies.[26] As more studies show benefit of MIS and it becomes the standard of care, we believe that the optimal time to treatment will also be determined.

Neuroangiography suite

Flat panel detector CT based neuronavigation systems can be used in the neuroangiography suite to acquire pre-intervention, intra-intervention, and post-intervention imaging, aiding in evaluating hematoma behavior and evacuation, obtaining three-dimensional imaging, assessing catheter introduction, and evaluating navigational accuracy.[27] We experienced these advantages with the seven cases performed in the neuroangiography suite with no difference in procedural efficacy compared with those performed in the operating room. We are hardly the first to note the benefits of performing MIS hematoma evacuation in the neuroangiography suite, but we wanted to confirm clinical equipoise.[28]

Future direction

Our results suggest that interventional neurologists can perform MIS hematoma evacuation in the neuroangiography suite without compromising safety or efficacy compared with data from high quality, multicenter, randomized controlled trials. This invites a larger multidisciplinary discussion of the role of neurointerventionalists in the surgical management of these patients, especially in parts of the world lacking adequate neurosurgical coverage. If MIS is confirmed effective and instituted as standard of care in US hospitals and worldwide, we suggest including neurointerventionalists in the work force by creating a credentialing pathway for the performance of emergent MIS–ICH hematoma evacuation. In the absence of positive clinical trials, one could argue that this discussion is premature. It is worth remembering that while mechanical thrombectomy has been the first line therapy for large vessel occlusion stroke since 2015, eligible patients continue to lack access to treatment globally, disproportionately so in low and middle income countries and rural areas.[28] Having these discussions now will allow us to more rapidly expand patient access to MIS hematoma evacuation if it becomes the standard of care for acute spontaneous ICH.

Neurointerventionalist training pathway

One possible training pathway would have neurointerventionalists first learn to perform burr holes for routine procedures such as EVD placement and subdural hematoma evacuation, followed by a cadaveric course to learn endoscopic and aspiration techniques and to enhance precise hand–eye coordination when repeatedly performing these procedures. We believe that for operators already proficient in burr hole access and closure, proper cadaveric training followed by 5–10 proctored MIS–ICH procedures may be sufficient to begin solo practice, with a gradual increase in case volume. For operators new to burr hole techniques, we recommend first learning and performing 5–10 burr hole procedures, followed by at least 10 proctored MIS–ICH cases before transitioning to independent practice. When neurosurgeons are present in a healthcare center, performing burr hole should be their primary responsibility.

Limitations

The present study had several limitations. The small sample size and single center nature, along with the lack of randomization, reduces the generalizability of the results. Incomplete

long term follow-up data was addressed using the last observed measure carried forward, which can introduce bias. As this is a proof of concept study in the multidisciplinary approach to ICH management, we cannot recommend the implementation of our protocol in other centers until more data from trials and new studies are available.

CONCLUSION

This single center experience showed that minimally invasive intracerebral hematoma evacuation with the Artemis device could be successfully performed by interventional neurologists. We advocate for collaboration with our neurosurgical colleagues to create a path for neurointerventionalists to become credentialed in emergent MIS–ICH hematoma evacuation with the goal of improving global access to patient care.

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Contributors All of the authors contributed to the elaboration of the present work, with significant participation to the steps of study design and conceptualization (WT and AEH), data collection and analysis (WT, GB, SM, AB, and AEH), writing and drafting (WT, GB, and SM), reviewing and editing (WT, GB, SM, AB, and AEH), and supervision and oversight (WT). WT is the guarantor and has accepted responsibility for all aspects of the study, ensuring that any questions related to its accuracy or integrity will be appropriately addressed. We used Chat GPT AI in some sections for guiding redaction and writing. AI generated content was ultimately edited and paraphrased by the authors.

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