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POST-TRIAL ENHANCED DEPLOYMENT AND TECHNICAL PERFORMANCE WITH THE MISTIE PROCEDURE PER LESSONS LEARNED

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Abstract

Objective: We hypothesize that procedure deployment rates and technical performance with minimally invasive surgery and thrombolysis for intracerebral hemorrhage (ICH) evacuation (MISTIE) can be enhanced in post-trial clinical practice, per Phase III trial results and lessons learned.

Methods: We identified ICH patients and those who underwent MISTIE procedure between 2017–2021 at a single site, after completed enrollments in the Phase III trial. Deployment rates, complications and technical outcomes were compared to those observed in the trial. Initial and final hematoma volume were compared between site measurements using ABC/2, MISTIE trial reading center utilizing manual segmentation, and a novel Artificial Intelligence (AI) based volume assessment.

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Conflict of Interest statements for all authors were completed and are available upon request.

Ethical approval/Informed consent

This study was approved by the University of Chicago Medicine (UCM) Institutional Review Board and ethics standards committee with a waiver of informed consent.

Results: Nineteen of 286 patients were eligible for MISTIE. All 19 received the procedure (6.6% enrollment to screening rate 6.6% compared to 1.6% at our center in the trial; p = 0.0018). Sixteen patients (84%) achieved evaculation target < 15 mL residual ICH or > 70% removal, compared to 59.7% in the trial surgical cohort (p = 0.034). No poor catheter placement occurred and no surgical protocol deviations. Limitations of ICH volume assessments using the ABC/2 method were shown, while AI based methodology of ICH volume assessments had excellent correlation with manual segmentation by experienced reading centers.

Conclusion: Greater procedure deployment and higher technical success rates can be achieved in post-trial clinical practice than in the MISTIE III trial. AI based measurements can be deployed to enhance clinician estimated ICH volume. Clinical outcome implications of this enhanced technical performance cannot be surmised, and will need assessment in future trials.

Keywords

Intracerebral hemorrhage; intracranial hemorrhage; MISTIE; artificial intelligence

Introduction

Intracerebral hemorrhage has greater morbidity and mortality than ischemic stroke (1–3). Despite its incidence approaching more than 5 million cases annually (4), there is to date no evidence-based effective treatment. Clinical injury from intracerebral hemorrhage (ICH) is directly associated with clot volume. With each 10 mL increase in ICH volume between 10 and 50 mL, there is an approximate 10% decrease in likelihood of good outcome. Large trials of craniotomy for ICH evacuation failed to improve functional outcome or mortality (5, 6). Non-surgical approaches aimed at early hemostasis and blood pressure control, while showing relative stabilization in hematoma growth, have also failed to significantly impact functional outcome or mortality (7–9).

More recently, a prospective randomized trial of minimally invasive surgery with thrombolysis and ICH evacuation (MISTIE III) demonstrated lower mortality without a net increase in the proportion of patients with severe disability in the surgical arm (10). More importantly, MISTIE identified thresholds of ≤15 mL residual ICH or ≥ 70% clot removal as portending significantly greater likelihood of favorable functional outcome (modified Rankin Scale 0–3) (11, 12). Greater surgeon and site experience were associated with better technical performance, and a number of modifiable factors to maximize ICH evacuation efficiency using this technique were identified (12). These included technical steps to optimize catheter placement and a strategy of pursuing aggressive dosing to achieve the desired ICH evacuation goals, while strictly adhering to the safety steps as articulated in the trial. However, it has remained unclear if the actual implementation of these lessons learned is feasible and/or would improve technical performance with the MISTIE procedure. Also, it remains uncertain whether the clinicians' assessment of extent of ICH removal is reliable to guide treatment goals.

Here we describe experience with treating eligible ICH patients per the MISTIE trial protocol in the period following completion of the trial. We assess rates of deployment of the procedure in MISTIE eligible cases, technical success rates per lessons learned in

the MISTIE III trial, and we determine if the site's own assessment of treatment goals are reliable.

Methods

Study Cohort

This is a retrospective analysis of consecutive cases with spontaneous ICH treated at a single tertiary care center from September 2017 to February 2021. Intracerebral hemorrhage cases had been identified prospectively in a Comprehensive Stroke Center database. Those with traumatic ICH etiology, hemorrhagic conversion of ischemic stokes, and primary extra-axial hematomas (subarachnoid hemorrhages, subdural hematomas or epidural hematomas) were excluded. Collected variables and data abstraction on remaining cases were verified by two team members (AL and FE). Ethics approval was obtained from the local institutional review board (IRB19–1339), and written consent was waived.

Data collection

For each patient, demographics, past medical history, best estimate of symptom onset and hospital location at the time of ICH detection were recorded. Demographics included patients' age and sex. Comorbid medical conditions including history of hypertension (HTN), diabetes mellitus (DM), cardiac disease (CAD), renal insufficiency, or cancer. Clinical presentation at the time of the event was noted, including Glasgow Coma Scale (GCS), intubation status, and ongoing use of antiplatelets or anticoagulants (therapeutic heparinoids, vitamin K inhibitor, or direct oral anticoagulants). Laboratory values were recorded, including platelet count, International Normalized Ratio (INR), partial thromboplastin time (PTT), and glomerular filtration rate (GFR). The very first computed tomography (CT) scan of the brain which corresponds to ICH detection as well as the follow-up CT (obtained on average 6 hours from the initial CT) were reviewed in all of our patients. From those images, hematoma volume, calculated using the ABC/2 formula(13), infratentorial location, and presence of intraventricular hemorrhage (IVH) were noted. ICH score was measured for each patient at the time of ICH detection. Eligibility for the MISTIE procedure was assessed, based on inclusion/exclusion criteria in the Phase III trial (10). Neurosurgical procedures, including placement of an external ventricular drain (EVD) and surgical hematoma evacuation were noted, including whether MSITIE procedure was performed. Thirty day mortality, and discharge disposition were recorded.

MISTIE patients

For patients who underwent MISTIE procedure, in addition to the aforementioned variables, the ICH volume after stability and before initiating surgery (designated as Vi), and hematoma volume on the first day after MISTIE catheter removal (designated as Vf) were calculated in milliliters (mL) using three different techniques. The first utilized the ABC/2 method (13). Two attending neurointensive care physicians (FG and AM) independently provided their volume assessment. For differences of ≤ 2 mL, the average was reported. For differences of > 2mL, a third senior study member (IAA) provided adjudication. These were recorded as site volumes (SV). The second method of volume measurement was the same used in the MISTIE III trial. CT scans were de-identified and sent as DICOM files to

the MISTIE III study imaging core at the Brain Injury Outcomes Section at Johns Hopkins Medical Institutions, where manual segmentation was performed by an experienced staff member using the OsiriX imaging software (OsiriX v. 4.1, Pixmeo; Geneva, Switzerland) as was performed in the Phase III trial (14). These were recorded as reading center volumes (RC), and used for primary reference analysis of technical outcome. Finally, a third novel method of volume measurements utilizing 3D deep neural network segmentation was calculated, and recorded as artificial intelligence (AI) measurements (15). In two cases Vf measurements were done on the last scan before catheter removal as no CT scan was acquired after catheter removal.

Catheter trajectory approaches and catheter position assessments were as described in the MISTIE III trial (12). Trajectory A represented anterior approach through a forehead burr hole. Trajectory B was a posterior approach with entry point through the parietal-occipital area, and Trajectory C was used for lobar hematomas, with entry point through the superficial area closest to the hematoma. Catheter position was designated as “good” if perforations were at the epicenter of hematoma, “suboptimal” if catheter perforations were eccentric within the hematoma, and “poor” if catheter perforations were outside the hematoma. The latter would have required catheter replacement. Complications and protocol deviations were assessed as previously defined and analyzed in the MISTIE III surgical cohort (11, 12).

All cases were performed by the senior investigator in the MISTIE trial (IAA), or under his direct supervision on site or via tele-mentoring of less experienced surgeons. Surgical experience was noted for the surgeon of record, as the number of prior MISTIE procedures performed by that surgeon, including the current case. All procedures were performed in the procedural CT scanner at our hospital, with intravenous sedation supervised by the neuro-critical care team. The protocol for real time CT scan image-guidance for ICH aspiration and catheter placement has been described in detail (11). No cases were performed in the operating room nor with navigational frameless stereotaxy.

The time from presumed symptom onset (or last recoded normal state) to initiation of the MISTIE procedure was calculated (this was available for 18 of the 19 cases).

Descriptive statistics were presented as means with standard deviations or medians with interquartile ranges (as appropriate) for continuous variables and as percentages for categorical variables. In univariate analyses, categorical variables were compared by Fisher exact test or chi-square test, and continuous variables were compared using t-test or Mann-Whitney U test, as appropriate. Pearson correlation and Bland-Altman plots were used to compare the different volumetric modalities. The significance level for all statistical analyses was set at $p < 0.05$. All analyses were performed with the use of R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Procedure deployment rate and patient characteristics

A total of 286 patients were included in the study. Of those, 267 were excluded for not meeting MISTIE III eligibility criteria (Supplemental Table 1). All remaining 19 patients who met eligibility criteria underwent the MISTIE procedure (enrollment to screening rate of 6.6 % post trial). The 19 patients represented a procedure volume of approximately 6 per year at our center, compared to 1 per year in MISTIE III trial, with 5 enrolled cases by our team over 5 years among 310 screened (enrollment to screening rate of 1.6% in the MISTIE III trial, $\chi^2(1) = 9.74$, $p = 0.0018$). The median age of the patients was 50 (47–65) compared to 62 (52–70) in the surgical arm of MISTIE III. Fifteen patients were male (63%) compared to 159 (63.6 %) of the surgical arm in MISTIE III. Eighteen of the nineteen patients were African American (95%) compared to 46 (18.4 %) in surgically treated MISTIE III surgical cases ($\chi^2(1) = 56.75$, $p < 0.01$). Median initial ICH volume (Vi) was 45.1 (36.3 – 52.3) in our cohort compared to 45.8 (35.4 – 59.6) in the surgical arm of MISTIE III. NIH stroke sale on presentation was 19 (16–22) in our cohort, identical to 19 (15–23) in the surgical arm of MISTIE III.

In our cohort, a medical history of hypertension, diabetes and cardiac disease was noted in 13 (68.4%), 8 (42.1%), and 4 (21.1%) patients respectively as compared to 241 (96.4 %), 72 (28.8%), and 38 (15.2%) of the surgical MISTIE III participants ($\chi^2(1) = 26$,1.5, and 0.5 respectively with $p < 0.01$, 0.2, and 0.5 respectively). Prior to presentation 5 of 19 (26.3%) patients were on antiplatelet therapy and none were on oral anticoagulants (0%) as compared to 67 (26.8 %) ($\chi^2(1) = 0$, p-value ~ 1) and 24 (9.6%) respectively in the surgical cohort of MISTIE III. The median days spent in the neuro-ICU in our cohort was 9.5 (6–14) days, versus 10 (7–17) in the MISTIE III surgical cohort. Table 1 summarizes the demographic, medical history, clinical characteristics and outcome surrogates of the 19 patients reported herein.

Technical performance

Table 2 presents individual patient performance metrics including time until intervention, catheter trajectory, position, surgeon experience at the time of placement and number of tissue plasminogen activator (t-pa) (Alteplase) doses administered before catheter removal. The median time from ictus to procedure initiation was 20 hours (16–42) compared to 47 hours (33–60) reported in the MISTIE III trial. The median total number of t-pa doses administered was 2 (1–4) compared to 4 (2–6) in the MISTIE III trial. Catheter trajectory was frontal (trajectory A) in 15 (79%) patients, followed by 3 (16%) lateral (trajectory C) and 1 (5%) parieto-occipital (trajectory B). This is in comparison to 115 (48%), 80 (33%) and 47 (19%) in MISTIE III. Initial catheter position was good in 14 (74%), suboptimal in 5 (26%) and poor in 0 (0%) patients in our cohort in comparison to 149 (61.6%), 76 (31.5%) and 17 (7%) respectively in the MISTIE III trial cohort.

End of procedure ICH volume (Vf) of <= 15 mL or >= 70% removal was achieved in 16 of our 19 cases (84%) (Figure 1), compared to 59.7% of surgical patients in MISTIE III trial ($\chi^2(1) = 4.51$, $p = 0.034$) . Mean Vf in this post trial series was 13 (SD 18) mL, compared

to 16 (SD13) mL in the MISTIE III trial, and mean ICH evacuated was 76 % (SD 18) in this post trial series, versus 69% (SD 20) in the MISTIE III trial. Figure 2 (case # 1) illustrates excellent removal in case with large irregular shaped hematoma with satellite bleeds, where less optimal results were encountered in the MISTIE trial (10, 11).

Three cases failed to achieve the desired extent of ICH removal by RC assessments. In one case (Figure 3, case #2), t-pa administration was held after the first dose in the setting of new onset coagulopathy (thrombocytopenia, elevated PT and PTT). The second case (case #8) failed to achieve the desired evacuation endpoint because of repeat bleeding and instability. Worsening IVH was noted after the sixth dose of t-pa. This, along with the patient's overall comorbid status, advanced age, and poor neurological exam prompted the team to re-approach the family about goals of care, electing to proceed with comfort measures and terminal extubation. In the third case (case#12), the site team determined the volume of the clot following the first dose of t-pa to be 13.9 mL and the catheter was removed accordingly, although subsequent RC volumes determined a Vf of 23 mL, and AI determined a Vf of 18.8 mL. Differences in measurements were attributed to irregular hematoma shape.

Other outcomes

Symptomatic brain bleed within 72 hours of the last dose was observed in 1 patient (5.3%) in our cohort (case detailed above), compared to 6 (2.4%) patients in the MISTIE III trial. In this cohort, five patients out of eighteen (one patient was lost in follow-up) expired within 30 days of ictus (27.8%) compared to a 9.4% reported 30-day mortality in the surgical cohort of MISTIE III trial ($\chi^2(1) = 6.0$, $p = 0.02$). Withdrawal of care as a mechanism of death was noted in 2 patients (10.5%) in this series compared to 26 patients (10.4%) in the MISTIE III trial.

Long term (6 and 12 months) follow-up was not available for our cohort, nor blinded outcome evaluations as per MISTIE III trial. As such, meaningful comparison to long term outcomes reported in MISTIE III is not possible. Of the 16 patients who did not expire in the hospital, one was discharge to hospice, three to a long-term acute care facility, one to subacute rehab and 11 patients were discharged to acute rehab.

There were no bacterial brain infections in our cohort. The 30-day rate of bacterial brain infections described in MISTIE III was 0.8%. Protocol deviations per previously described criteria (11) were limited to two cases where post catheter removal CT scan was not obtained. There were no instances of surgical task or other protocol deviations in our cohort, while 57 surgical task protocol deviations (126 total protocol deviations) were noted among 242 cases in the MISTIE III trial surgical cohort ($\chi^2(1) = 12.16$, $p < 0.01$) (11).

Methods of evaluating ICH removal

Table 3 demonstrates individual patient specific initial volume (Vi), end of treatment volume (Vf) and percent clot removal using all three volume measurement modalities. Site measurements were compared to the standard region of interest volume measurements acquired from the MISTIE III RC. Supplemental Figure 1 demonstrates the correlation and Bland-Altman plots for Vi and Vf respectively. For Vi Pearson correlation between the RC and the site measurements was 0.90, $p < 0.001$. Bland-Altman bias was −11.69 mL with

95% CI (−17.27 – −6.10), lower limit of agreement = −34.38, upper limit of agreement = 11.01. For End of treatment volume Vf, Pearson correlation was 0.97, $p < 0.001$. Bland-Altman bias was −1.60 mL with 95% CI (−4.29 – 1.08), lower limit of agreement = −12.52, upper limit of agreement = 9.31.

3D convolutional neutral network volume measurements were compared to the standard volume measurements acquired from the MISTIE III RC. Supplemental figure 2 demonstrates the correlation and Bland-Altman plots for Vi and Vf respectively. For Vi Pearson correlation between the reading center and the AI measurements was 0.99, $p < 0.001$, Bland-Altman bias was 1.51 mL with 95% CI (0.24 – 2.78), lower limit of agreement = −3.66, upper limit of agreement = 6.68. For End of treatment volume Vf, Pearson correlation was 0.99, $p < 0.001$. Bland-Altman bias was 2.2 mL with 95% CI (1.29–3.12), lower limit of agreement = −1.53, upper limit of agreement = 5.92.

There was overall better agreement of the new AI approach with the adjudicated RC measures, than between the site ABC/2 measurements compared to the adjudicated RC measures. Each of the measurement approaches identified 13 of 19 cases where target evacuations were reached, but there was one instance where Vf or evacuation % were at target by site measurements but not by the RC and AI measurements, and one instance vice versa. Both were due to false estimates of Vi by the site measurements.

Discussion

Following publication of the MISTIE III trial results, questions remained whether the procedure can be generalized in clinical practice and if technical performance can be enhanced per lessons learned (12). In this study we describe a single tertiary care center experience with minimally invasive surgery and thrombolysis for intracerebral hemorrhage evacuation (MISTIE) following completion of the MISTIE III trial. We examine procedure deployment rates in comparison to MISTIE III enrollment rate at our center. We also describe the demographic and clinical characteristics of the patients in comparison to those enrolled MISTIE III. We assess technical success rates per lessons learned in the MISTIE III trial and analyze procedural complications and protocol deviations. Finally, we compare the site's own assessment of ICH evacuation goals as determined by the ABC/2 method to measurements performed by the trial's imaging core as deployed in MISTIE III, and to a novel AI based volumetric assessment (15).

Procedure deployment rate and patient characteristics

We deployed the MISTIE procedure in all 19 eligible patients based on identical criteria as the MISTIE III trial. This represented 6.6 % of all ICH patients screened over approximately three years, more than 4 times greater than our site's enrollment rate during the actual MISTIE III trial. In each of the 19 patients, the procedure was presented to the family as a non-standard of care, with a thorough discussion of risks involved and potential benefit. Per trial results, we represented to the family the procedure's safety, likely benefit on mortality, easier management of intracranial pressure, and potential but not promised impact on functional outcome (10, 11). The availability of these results and the team's experience allowed greater confidence in offering the procedure, and potentially its acceptance by

families. Consent was also likely enhanced by the absence of potential randomization to non-surgical care or the prospects of research follow-ups.

Our patient cohort was predominantly African American (95%) compared to the 18.4% enrolled in MISTIE III. Our patients were younger, with a median age of 50 (47–65) compared to 62 (52–70) in the trial. Other demographic variables including gender were comparable. Medical history of essential hypertension was less frequent in our cohort, with otherwise similar rates of diabetes mellitus and other cardiac disease. Prior to admission, antiplatelet use in our cohort was comparable to that of patients enrolled in the surgical arm of MISTIE III. But, unlike the trial, none of the 19 patients in our current cohort were on oral anticoagulants. Median NIHSS on presentation was identical in our cohort to that in the MISTIE III cohort. Similarly, overall ICU length of stay in our cohort was comparable to that observed in MISTIE III.

Thirty-day mortality was available for 18 patients in our cohort. One patient was discharged to LTACH and lost to follow-up. The 30-day mortality was observed in 5/18 patients (27.8%) in comparison to 24 patients (9.4%) in the surgical arm of MISTIE III. Lower mortality had been previously reported in trial enrolled subjects (16–19), and may be attributed to more permissive deployment of the procedure in sicker patients outside a clinical trial (such as our case #8 herein). The rate of withdrawal of care as a mechanism of death was comparable in both cohorts. No unexpected complications or brain infections were noted in our cohort. Eleven patients (58%) were discharged to acute rehabilitation, and we note that most of patients who were discharged to acute rehabilitation achieved good functional outcomes (mRS 0–3) in the MISTIE trial (10). We cannot otherwise comment on long term outcomes in this cohort.

Procedural proficiency and protocol deviations

The median time from ictus to procedure was shorter in our cohort (20 hours compared to 47 hours in MISTIE III). This difference is likely attributable to the extensive time dedicated to consenting and explaining a research project during the trial period, and time taken by families to consent to a research project. Procedural consent was more expedient, and our team achieved greater efficiency by deploying the procedure in the CT scanner, rather than awaiting operating room availability. This faster procedural deployment was possible without modifications of the stability and etiology screens required in the protocol.

Catheter placement was predominantly via frontal approach consistent with what was described in the trial, followed by lateral and finally parieto-occipital approaches. All patients in our cohort had optimal or suboptimal catheter placement with none having poor catheter positioning. This is in comparison 7% rate of poor catheter position in MISTIE III. The use of a procedural CT scanner with real time verification of catheter placement, as well as the surgical experience accumulated in MISTIE III (12) are likely reasons for this difference. This optimized catheter placement also likely contributed to a lower median number of t-pa doses (2 in this series compared to 4 in the trial) used to reach endpoint of ICH evacuation.

ICH Volume reduction

The RC volumes were used for primary reference analysis of technical outcome as in the MISTIE III trial. Accordingly, initial hematoma volume in our cohort was like that in the surgical arm of MISTIE III (mean of 45.1 mL in our current cohort and 45.8 mL in the surgical arm of MISTIE III). Sixteen of 19 patients (84%) achieved the target goal of hematoma reduction to a final volume of <= 15 mL or >= 70% clot removal in comparison to approximately 60% the surgical cohort in the MISTIE III trial. The three cases that did not achieve target hematoma reduction were attributable to withholding further t-pa administration in the setting of new coagulopathy, local assessment of hematoma volume by the team as having achieved target, and rebleeding, respectively.

The procedure was performed with excellent technical outcomes despite limited experience by several surgeons of record, although all were mentored by the site's senior surgeon, and there was rigorous attention to deploying the approved and uniform procedure protocol (12). In the MISTIE III trial, surgeon experience was important in achieving superior technical performance (11), but we suggest here that individual surgeon learning curve may be mitigated at academic centers by team experience and hands-on mentoring. Our results confirm that lessons learned can be effectively reflected in improved team performance and improved surgical task performance; This should be relevant in future clinical trials.

Comparison of different volume assessments

It is important for surgeons to accurately assess extent of ICH removal, to maximize potential benefit from this procedure (11, 12). We compared our local site volume assessment as measured by utilizing ABC/2 method (13) to the standard volume measurements utilized in MISTIE III (RC measurements). Overall, the correlation for initial (Vi) and final (Vf) hematoma volumes was good. Of the three cases that failed to reach target Vf or percent hematoma evacuation as defined by the RC measurements, only one was erroneously misclassified by the site read as having achieved target. In reviewing the segmentation results from the RC (Supp. Figure 3), the irregular shape and multiple satellite bleeds within the final hematoma made it less amenable to measurement using the ABC/2 method and likely contributed to the observed discrepancy (14).

We also compared a novel method of volume measurements utilizing 3D deep neural network segmentation and compare those to the RC volume measurements (15) (Supp. Figure 2). Concordance between those two measurement modalities both by virtue of Pearson correlation and as demonstrated by Bland-Altman plot is highly consistent. All three cases that failed to reach target Vf or percent hematoma evacuation as defined by the RC measurements were accurately identified as such by the AI algorithm. No additional cases were identified by the AI algorithm as having failed to achieve goal. This new AI based approach may present a faster and consistent tool of ICH volume determination in future trials.

Limitations

Observations and conclusions in this study are limited by the post-hoc exploratory nature of our hypotheses. Formal statistical comparison of clinical outcomes (mortality and functional status) with MISTIE III or with opther treatments is not possible given the relatively small size of this cohort, and the lack of comparable follow-ups and blinded adjudicated outcome assessments. While statistical testing is significant as suggested by p-values for several comparisons throughout, the actual statistical power is low due to the sample size.

Conclusion

Deploying MISTIE in eligible patients presenting with spontaneous ICH is feasible. Lessons learned from the trial and post-trial data analyses were associated with enhanced procedural deployment rates, enhanced surgical task success rate, lower rates of technical complications and fewer protocol deviations, and higher likelihood of achieving target evacuation goals. As previously demonstrated, surgical expertise and a focus on team education, emphasizing technical nuances, and defining strict definitions of the task benchmark of success are fundamental. Volumetric measurements using the ABC/2 method are feasible but limited by irregular hematoma shapes and operator experience. Meanwhile AI based volumetric measurements perform very well and similar to manual segmentation by experienced reading centers. Clinical outcome implications of this enhanced procedure deployment and technical performance cannot be surmised, and will need to be addressed in future trials.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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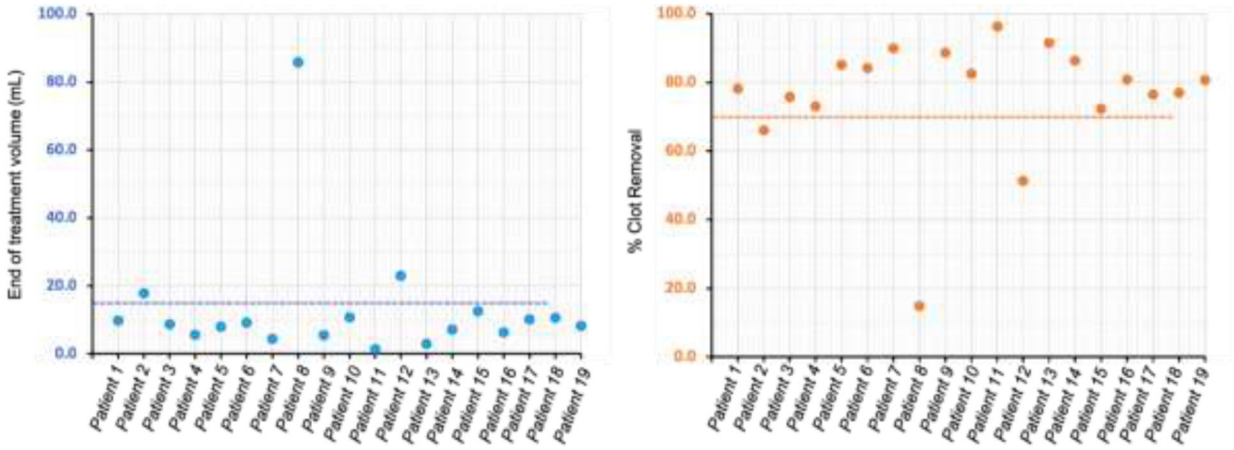

Figure 1.

End of treatment volume (blue) and percent clot removal (orange). Dashed blue lines represent the 15 mL cut-off. Dashed orange lines represent the 70% clot removal threshold. Three patients had a final clot volume of > 15 ml and concomitantly less than 70% clot removal.

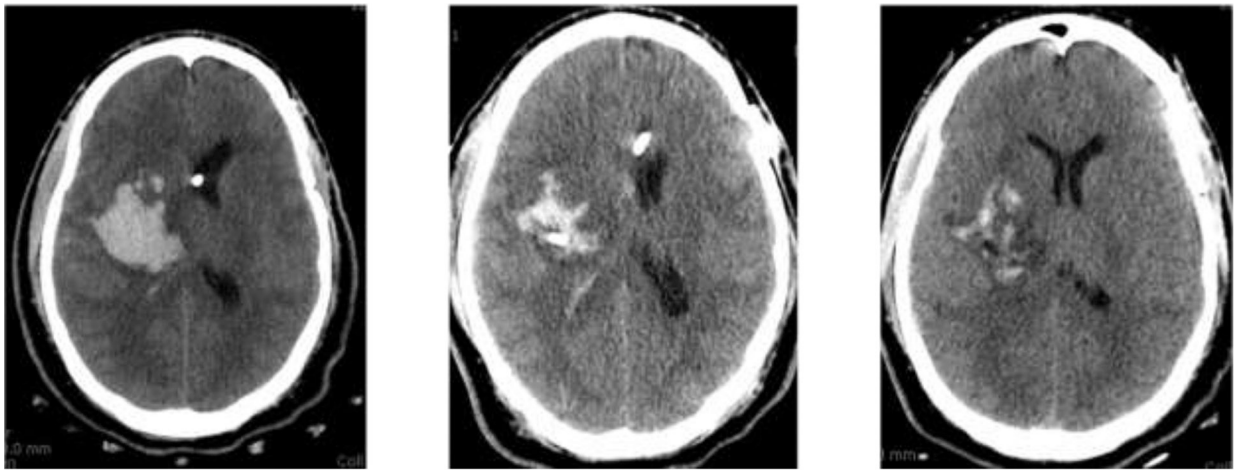

Figure 2.

Example of good evacuation (case #1) despite large irregular hematoma and trajectory C approach. Axial CT scans at ICH stability (left), post-initial aspiration and catheter placement (middle) and post-thrombolytic drainage and catheter removal (right).

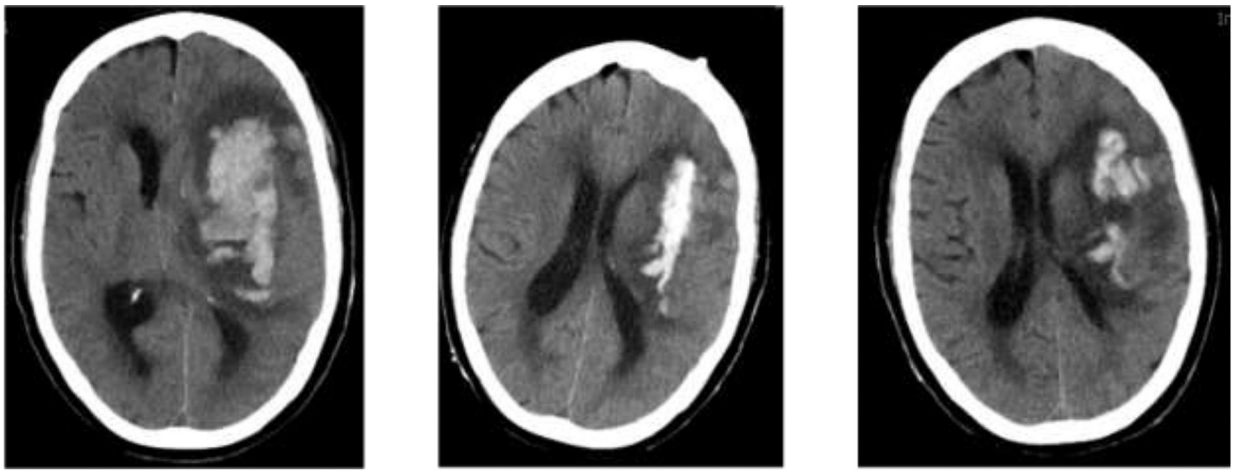

Figure 3.

Example of poor evacuation despite good catheter placement (case #2). Axial CT scans at ICH stability (left), post-initial aspiration and catheter placement (middle) and post-thrombolytic drainage and catheter removal (right), with evidence of rebleeding after development of new coagulopathy

Table 1.

Demographics, medical history, clinical characteristics, ICU complications, and outcome of 19 patients who underwent MISTIE procedure post-trial

Variable	
Demographics	
Age (IQR), y	50 (47 – 65)
Male (%)	15 (63)
Race	
African American (%)	18 (95)
White (%)	1 (5)
BMI (IQR)	32.3 (29 – 37.1)
History of HTN (%)	13 (68)
History of cardiac disease (%)	4 (21)
History of diabetes (%)	8 (42)
History of renal disfunction (%)	3 (16)
PTA antiplatelet therapy (%)	5 (26)
PTA anticoagulants (%)	0 (0)
Clinical Presentation	
GCS(IQR)	8 (7 – 12)
NIHSS(IQR)	19 (16 – 22)
ICH score(IQR)	2 (1 – 3)
Location	
Lobar (%)	5 (26)
Striatocapsular (%)	14 (74)
Thalamic (%)	0 (0)
Right hemisphere (%)	8 (42)
IVH (%)	9 (47)
ICU complications	
DVT/PE (%)	3 (16)
Chest infection (%)	7 (37)
UTI (%)	2 (10)
CNS infection (%)	0 (0)
Outcome surrogates	
Tracheostomy (%)	6 (32)
ICU LOS (IQR), d	9 (6 – 14)
Hospital LOS (IQR), d	16 (10 – 20)
Discharge disposition	
Acute rehab	11 (58)
Subacute rehab	1 (5)
LTACH	3 (16)

Variable	
Hospice	1 (5)
30-day mortality *	5 (28)

* One of the 19 patients was lost to follow-up.

Table 2.

Age, sex, hematoma location, total number of t-pa doses, trajectory, experience of surgeon of record, catheter position assessment, and time from ictus to procedure in 19 patients who underwent MISTIE procedure post-trial

Patient	Age	Sex	Location	t-PA dose(s)	Trajectory	Surgeon experience	Catheter position	Time Hours
1	36	M	Lobar	1	C	>12	suboptimal	20.1
2	74	F	Lobar	1	A	>12	good	42.7
3	50	M	Striatocapsular	1	A	>12	good	10.6
4	39	F	Striatocapsular	1	A	>12	suboptimal	16.0
5	50	M	Striatocapsular	3	A	>12	good	16.0
6	37	M	Lobar	6	A	1	good	8.8
7	47	M	Striatocapsular	2	C	1	good	63.9
8	80	M	Lobar	6	A	2	suboptimal	26.7
9	49	F	Striatocapsular	4	A	>12	good	12.7
10	49	M	Lobar	1	A	3	good	20.8
11	49	F	Striatocapsular	1	A	1	good	19.0
12	66	M	Striatocapsular	1	C	4	good	0.0
13	73	F	Striatocapsular	2	A	5	good	64.8
14	60	M	Striatocapsular	5	A	6	good	40.0
15	65	F	Striatocapsular	2	B	7	suboptimal	27.2
16	44	M	Striatocapsular	2	A	>12	good	14.5
17	61	F	Striatocapsular	3	A	8	good	21.4
18	56	M	Striatocapsular	2	A	>12	suboptimal	14.1
19	60	M	Striatocapsular	4	A	>12	good	6.0

Table 3.

Initial volume (Vi), final volume (Vf) and percent clot removal assessed by the trial Reading Center imaging core (RC), site measurements with ABC/2 method, and novel automated artificial intelligence (AI) methods.

Patient	RC Vi (mL)	RC Vf (mL)	RC percent removal	Site Vi (mL)	Site Vf (mL)	Site percent removal	AI Vi (mL)	AI Vf (mI)	AI percent removal
1	44.6	9.7	78.2	47.8	14.5	69.7	43.2	8.3	80.8
2*	52.3	17.8	66.0	70.4	21.0	70.2	49.1	16.1	67.2
3	35.9	8.7	75.7	52.3	14.2	72.8	34.2	8.2	76.1
4	20.9	5.6	73.1	32.2	7.2	77.6	21.7	5.4	75.1
5	53.7	8.0	85.2	61.2	17.4	71.6	58.1	6.8	88.3
6	58.1	9.2	84.1	85.3	10.9	87.2	62.0	9.0	85.5
7	43.7	4.4	89.9	53.8	7.9	85.3	38.3	2.1	94.5
8*	100.8	85.9	14.8	143.5	103.0	28.2	93.8	79.9	14.8
9	48.1	5.5	88.6	47.3	2.9	93.9	47.5	3.8	91.9
10	61.1	10.7	82.5	52.4	6.5	87.6	58.5	4.0	93.1
11	36.3	1.4	96.3	37.7	1.9	95.0	35.5	0.6	98.2
12*	47.2	23.0	51.3	60.1	13.9	76.9	45.6	18.8	58.9
13	34.4	2.9	91.5	60.0	2.0	96.7	33.1	1.9	94.3
14	52.2	7.1	86.4	58.7	5.1	91.3	49.2	3.0	94.0
15	45.1	12.5	72.3	58.9	9.9	83.2	43.6	9.4	78.5
16	32.7	6.3	80.8	39.6	6.6	83.3	30.4	4.2	86.2
17	43.09	10.11	76.5	56.6	14.6	74.3	40.4	9.7	76.1
18	46.31	10.65	77.0	47.0	12.3	73.9	45.3	9.5	79.1
19	42.39	8.16	80.8	56.1	6.3	88.8	40.7	5.0	87.6

*Patients 2, 8, and 12 did not achieve the evacuation goal of < 15ml final hematoma volume or > 70% removal per the reference RC assessment