Am J Transl Res 2025;17(10):8076-8086
www.ajtr.org /ISSN:1943-8141/AJTR0166929

Original Article

Clinical efficacy and safety analysis of minimally invasive tube placement, aspiration, liquefaction and drainage surgery for patients with cerebral hemorrhage

Weixin Zheng[1], Hong Lin[1], Zongliao Zheng[1], Yan Huang[1], Qikun Wang[1], Weiwei Wang[1], Yong Yang[2]

[1]Department of Neurosurgery, Zhangzhou Affiliated Hospital of FuJian Medical Unimersity, Zhangzhou 363000, Fujian, PR China; [2]Department of Pediatric Neurosurgery, Neurosurgery Center, Zhujiang Hospital, Southern Medical University, Guangzhou 510000, Guangdong, PR China

Received June 19, 2025; Accepted September 29, 2025; Epub October 15, 2025; Published October 30, 2025

Abstract: Objective: To evaluate the clinical efficacy and safety of minimally invasive tube placement combined with aspiration, liquefaction, and drainage in patients with cerebral hemorrhage. Methods: A total of 99 patients with cerebral hemorrhage admitted to our hospital between February 2022 to February 2024 were enrolled. Among them, 47 patients received traditional craniotomy (control group), and 52 patients underwent minimally invasive tube placement, aspiration, liquefaction, and drainage in addition to conservative treatment (research group). Clinical efficacy, safety (incidence of venous thrombosis, gastrointestinal bleeding, urinary tract infection, and pulmonary infection), surgery-related indicators (operative duration, hematoma clearance rate on postoperative day 1, edema volume on postoperative day 7), neurological function (National Institutes of Health Stroke Scale (NIHSS)), activities of daily living (Barthel Index), 30-day mortality risk (Intracerebral Hemorrhage Score (ICH)), 90-day functional outcome (Functional Outcome in Patients with Primary Intracerebral Hemorrhage Score (FUNC)), serum inflammatory factors (tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), C reactive protein (CRP)), oxidative stress indicators (superoxide dismutase (SOD), malondialdehyde (MDA)), cerebrovascular function-related indices (calcitonin gene-related peptide (CGRP), endothelin (ET)), rebleeding incidence, and morbidity and mortality were compared between the two groups. Results: The research group demonstrated significantly higher total effectiveness rates (96.15% VS. 76.60%, P=0.048) and hematoma clearance rate on postoperative day 1 in the research group compared with the control group (P<0.001). The incidence of venous thrombosis, gastrointestinal bleeding, urinary tract infection, and pulmonary infection, as well as the overall complication rate were comparable between groups (P>0.05). The research group exhibited shorter operative duration and lower edema volume on postoperative day 7 (P<0.001). Post-treatment NIHSS score, ICH score, FUNC score, TNF-α, IL-6, CRP, MDA, and ET levels were significantly lower, whereas Barthel Index, SOD, and CGRP levels were significantly higher compared with both pre-treatment and control group values (all P<0.05). No significant differences were observed in rebleeding, morbidity, and mortality rates between groups (P>0.05). Conclusion: Minimally invasive tube placement combined with aspiration, liquefaction and drainage demonstrates definite clinical efficacy and favorable safety in the treatment of cerebral hemorrhage.

Keywords: Minimally invasive tube placement, aspiration, liquefaction and drainage surgery, cerebral hemorrhage, clinical efficacy, safety

Introduction

Cerebral hemorrhage is the most prevalent hemorrhagic stroke, characterized by parenchymal bleeding, and is associated with high morbidity and mortality [1]. Epidemiological data suggest that its incidence is higher in men, shows seasonal variation with a peak in winter, and increases with age [2, 3]. The disease carries a poor prognosis, with a case-fatality rate of up to 40% at 1 month and as high as 54% at 1 year after onset; only 12-39% of patients achieve long-term functional independence [4]. Major risk factors include hypertension, cerebrovascular amyloidosis, anticoagulant use, vascular malformations, and hypercholesterolemia [5]. The pathological process involves blood-brain barrier disturbances, which causes oxidative stress, and an inflammatory cascade that exacerbates brain edema

https://doi.org/10.62347/QSTW6376

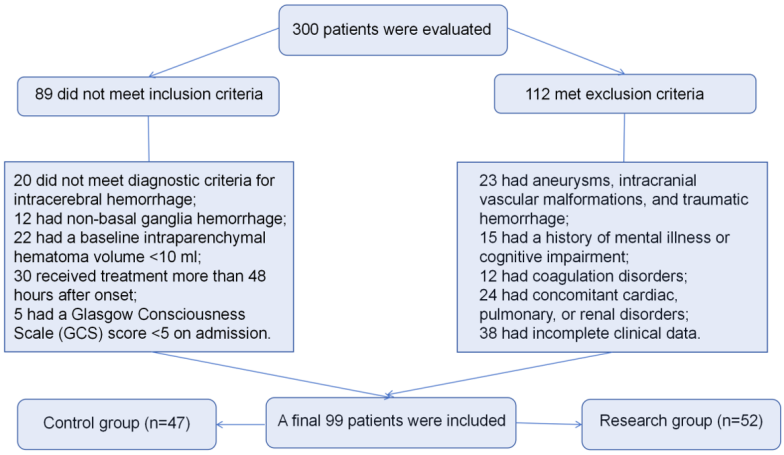

Figure 1. Patient selection flowchart.

and neurological injury, ultimately impairing activities of daily living (ADL) and quality of life [6, 7]. Timely and effective interventions are therefore essential.

Hematoma clearance remains the cornerstone of therapy, aiming to alleviate secondary brain damage; however, clinical outcomes remain unsatisfactory [8]. Numerous strategies have been investigated. For example, Wu L et al. [9] reported that NaoXueShu oral solution reduced hematoma volume, improved arousal, and partially preserved neurological function in patients with cerebral hemorrhage. Early intensive antihypertensive therapy has also been shown to lower the risk of rebleeding and peripheral hematoma events, contributing to the improvement in short-term quality of life [10]. Minimally invasive tube placement with aspiration, liquefaction, and drainage offers advantages such as reduced trauma, fewer complications, and technical feasibility, and has demonstrated therapeutic benefit in patients with large cerebral hemorrhage (50-80 mL) [11]. Moreover, this approach has shown efficacy in treating traumatic epidural hematoma across the transverse sinus, helping reduce the hematoma volume and promoting recovery [12].

This study focuses on evaluating the clinical efficacy and safety of minimally invasive tube placement, aspiration, liquefaction, and drainage in patients with cerebral hemorrhage. In addition, it examines the broader clinical benefits of this therapy, aiming to provide evidence-based guidance for optimizing patient management. The innovation of this study lies in its comprehensive assessment of the therapy from various dimensions, including clinical efficacy, safety, surgery-related indicators, neurological function, activities of daily living, serum inflammatory factors, oxidative stress parameters, cerebrovascular function indices, as well as rebleeding and mortality rates. Such multidimensional evaluation is expected to provide robust clinical evidence to inform treatment strategies and management decisions for patients with cerebral hemorrhage.

Materials and methods

Case selection

The current investigation utilized a retrospective methodology. A total of 99 patients with cerebral hemorrhage admitted to Zhangzhou Affiliated Hospital of Fujian Medical University between February 2022 and February 2024 were enrolled. Of these, 47 patients received traditional craniotomy (control group) and 52 patients underwent minimally invasive tube placement, aspiration, liquefaction and drainage (research group). The study protocol was approved by the Ethics Committee of Zhangzhou Affiliated Hospital of Fujian Medical University. Clinical data were retrieved from the hospital's electronic medical record system. The detailed patient inclusion process is shown in **Figure 1**.

Inclusion and exclusion criteria

Inclusion criteria: diagnosis of cerebral hemorrhage [13], with hematoma located in the basal ganglia confirmed by CT scan; baseline parenchymal hematoma volume ≥30 ml; treatment initiated within 48 h of onset; Glasgow Consciousness Scale (GCS) score ≥5 on admission; good compliance.

Exclusion criteria: presence of aneurysms, intracranial vascular malformations, or traumatic hemorrhage; history of psychiatric illness or cognitive impairment; coagulopathy; concomitant severe cardiac, pulmonary, or renal dysfunction; incomplete clinical data.

Treatment methods

The control regimen involved traditional craniotomy for hematoma clearance, conducted under general anesthesia with endotracheal intubation. Surgical planning utilized CT findings to position a horseshoe-shaped incision over the hematoma's surface projection, ensuring access through non-functional brain areas. Following craniotomy, the hemorrhagic site was exposed by gyrus separation along the cerebral sulci. A subsequent aspiration of roughly two-thirds of the hematoma was performed under direct visualization, with any instances of active hemorrhage being addressed using electrocautery. Upon verifying hemostasis, a closed drainage system was established. Then, 5,000 U of urokinase was administered into the hematoma cavity. The tube was clamped for 4-6 hours prior to being unclamped to facilitate drainage. This process was repeated daily for 3-5 days, with the tube being withdrawn after confirmation of significant hematoma resolution.

Patients in the research group underwent additional minimally invasive tube placement with aspiration, liquefaction and drainage based on the control group. Briefly, cranial CT was used to localize the hematoma and determine its size, puncture point and path. A small skull drill was used to create a burr hole, through which the puncture needle was advanced into the hematoma cavity. After removing the needle core and securing the drainage tube, approximately 1/3 of the hematoma volume was aspirated. Physiological saline and urokinase were then instilled into the hematoma cavity, the drainage tube was clamped for 3 hours, and subsequent drainage was monitored to evaluate hematoma clearance.

Standardized supportive therapy was provided postoperatively to each group. This regimen consisted of neurotrophic support, prophylactic antibiotics, hemodynamic optimization, and preventive strategies against potential complications. It should be noted that treatment allocation was not randomized; the final therapeutic approach was chosen by patients after receiving detailed information regarding the risks and benefits of each method.

Data collection, extraction, validation, and outcome measurements

All study data were sourced from the hospital's electronic medical records. The specific outcomes that were extracted, verified, and quantified are detailed below:

Clinical efficacy. Treatment efficacy was assessed post-treatment according to established criteria [14]. Cured: essential resolution of symptoms/signs, disability grade 0, and ≥90% NIHSS reduction; Markedly effective: significant symptom/sign alleviation, disability grades 1-3, and 46-89% NIHSS reduction; Effective: some symptom/sign improvement, disability grade >3, and 18-45% NIHSS reduction; Ineffective: absence of symptom/sign amelioration, unchanged unconsciousness, or mortality. The overall effective rate was calculated as: (number of cured + improved cases)/total cases × 100%.

Safety. Adverse events, including venous thrombosis, gastrointestinal bleeding, urinary tract infection, and pulmonary infection, were recorded, and the incidence rate was calculated. Venous thrombosis: deep vein thrombosis (DVT) or pulmonary embolism (PE) confirmed by venous ultrasound or venography; Gastrointestinal bleeding: hematemesis, melena, or coffee-ground aspirate from nasogastric tube, accompanied by a hemoglobin drop ≥20 g/L; Urinary tract infection: urinary symptoms (frequency, urgency, dysuria), urine microscopy >10 WBC/high-power field, or positive urine culture $\geq 10^5$ CFU/mL (any two of these are met); Pulmonary infection: diagnosis followed hospital-acquired pneumonia criteria, requiring a new or progressing pulmonary infiltrate on imaging, plus any two of the following: fever exceeding 38°C, leukocytosis or leukopenia, purulent respiratory secretions, or a decreased oxygenation index.

Surgery-related indicators. Operative duration (skin incision to wound dressing), hematoma clearance rate on postoperative day 1 ([preoperative volume - residual volume]/preoperative volume × 100%), and cerebral edema volume on postoperative day 7 (measured by CT) were compared between groups.

Neurological and functional evaluation. Neurological deficits: National Institutes of Health Stroke Scale (NIHSS) (range 0-45) [15]; with higher scores indicating more severe deficits. Activities of daily living: Barthel Index (BI; total score: 100) [16], with the score positively related to ADL. 30-day mortality risk: Intracerebral

Hemorrhage Score (ICH; range 0-6), where higher values correlate with increased mortality risk. 90-day functional outcome: Functional Outcome in Patients with Primary Intracerebral Hemorrhage Score (FUNC; range: 0-11), with lower scores indicating a more favorable prognosis.

Serum inflammatory factors. Fasting venous blood (5 mL) was collected from each patient before treatment and on day 7 post-treatment. After centrifugation, supernatants were stored at -30°C. Serum markers, including tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP) were quantified using ELISA kits (Nanjing Saihongrui Biotechnology Co., Ltd., Cat. No.: HEA133Hu03, SHR10291, SEA821Bo03), following the manufacturers' protocols.

Oxidative stress parameters. Serum superoxide dismutase (SOD) and malondialdehyde (MDA) were measured pre-treatment and at day 7 post-treatment using ELISA kits (Shanghai Fusheng Industrial Co., Ltd., Cat. No.: A126934, A126914).

Cerebrovascular function indices. Plasma calcitonin gene-related peptide (CGRP) and endothelin (ET) levels were determined by radioimmunoassay before treatment and on day 7 post-treatment (SenBeiJia Biological Technology Co., Ltd., Cat. No.: SBJ-H0977, SBJ-H1940).

Rebleeding, morbidity, and mortality. The incidence of rebleeding, overall morbidity and mortality was recorded for both groups.

Primary outcomes included clinical efficacy, safety profile, surgery-related indicators, neurological function, ADL, rebleeding, and mortality. Secondary outcomes included serum inflammatory factors, oxidative stress indicators, and cerebrovascular function indices.

Statistical analysis

SPSS 21.0 was utilized for data analysis. Measurement data, described by mean ± SEM, were assessed by t-tests (for comparisons between groups) or paired t-tests (for comparisons within groups pre- and post-treatment). Counting data were statistically described by frequency (percentage) and compared by χ^2 test. $P<0.05$ indicates the presence of statistical significance. In addition, this study employed a sample size estimation method for comparing two independent proportions. The calculation was based on the following preset parameters: an expected overall effective rate of 65% in the control group and 85% in the research group, with a minimum clinically important difference set at 20%. A two-sided test was adopted with a significance level (α) of 0.05 and a statistical power (1-β) of 80%. According to the computation performed in PASS software, the actual achieved power reached 84.6% with the final enrollment of 47 subjects in the control group and 52 in the research group.

Results

Baseline characteristics

No significant differences were observed between the two groups in terms of age, time from onset, hemorrhage volume, hematoma location, coma status, comorbid diabetes, or cerebral thrombosis ($P>0.05$) (**Table 1**).

Clinical efficacy

The research group showed a significantly higher overall effective rate compared with the control group (96.15% vs. 76.60%, $P<0.05$; **Table 2**).

Safety

Adverse events, including venous thrombosis, gastrointestinal bleeding, urinary tract infection, pulmonary infection, and the overall complication rate, did not differ significantly between groups ($P>0.05$) (**Table 3**).

Surgery-related indicators

The research group demonstrated superior surgical outcomes compared to the control group, with significantly reduced operative duration ($P<0.001$), improved hematoma clearance on postoperative day 1 ($P<0.001$), and decreased cerebral edema volume by day 7 ($P<0.001$; **Table 4**).

Neurological and functional outcomes

Pre-treatment NIHSS, ADL, ICH, and FUNC scores were comparable between groups (all $P>0.05$). After treatment, both groups demon-

Table 1. Baseline data

Data	Control group (n=47)	Research group (n=52)	χ^2 value	*P* value
Age (year)	59.19±6.87	60.38±6.46	0.888	0.377
Sex			0.066	0.797
Male	25 (53.19)	29 (55.77)		
Female	22 (46.81)	23 (44.23)		
Time from onset	2.68±1.11	2.21±1.26	1.960	0.053
Hemorrhage volume	64.09±8.63	61.35±10.91	1.376	0.172
Hematoma site			0.130	0.719
Left basal ganglia	20 (42.55)	24 (46.15)		
Right basal ganglia	27 (57.45)	28 (53.85)		
Comatose state			0.992	0.609
Sober	14 (29.79)	11 (21.15)		
Light coma	15 (31.91)	18 (34.62)		
Severe coma	18 (38.30)	23 (44.23)		
Combined diabetes			0.081	0.776
Yes	15 (31.91)	18 (34.62)		
No	32 (68.09)	34 (65.38)		
Combined cerebral thrombosis			0.749	0.387
Yes	10 (21.28)	15 (28.85)		
No	37 (78.72)	37 (71.15)		

Table 2. Clinical efficacy

Data	Control group (n=47)	Research group (n=52)	χ^2 value	*P* value
Cured	7 (14.89)	14 (26.92)		
Markedly effective	15 (31.91)	19 (36.54)		
Effective	14 (29.79)	17 (32.69)		
Ineffective	11 (23.40)	2 (3.85)		
Total efficiency	36 (76.60)	50 (96.15)	3.926	0.048

Table 3. Safety profiles

Safety assessment	Control group (n=47)	Research group (n=52)	χ^2 value	*P* value
Venous thrombosis	1 (2.13)	0 (0.00)	1.118	0.290
Gastrointestinal bleeding	1 (2.13)	3 (5.77)	0.844	0.358
Urinary tract infection	6 (12.77)	5 (9.62)	0.248	0.618
Pulmonary infection	4 (8.51)	6 (11.54)	0.249	0.618
Total	12 (25.53)	14 (26.92)	0.025	0.875

Table 4. Comparative analysis of surgical parameters

Surgery-related indicators	Control group (n=47)	Research group (n=52)	t value	*P* value
Operative duration (min)	56.55±13.87	23.17±4.47	16.443	<0.001
Hematoma clearance rate on postoperative day 1 (%)	60.91±6.42	85.98±7.90	17.214	<0.001
Cerebral edema volume on postoperative day (mL)	14.36±3.82	11.21±3.47	4.300	<0.001

strated improved neurological function and functional status: NIHSS, ICH, and FUNC scores decreased significantly (except ICH and FUNC in the control group), and BI scores increased.

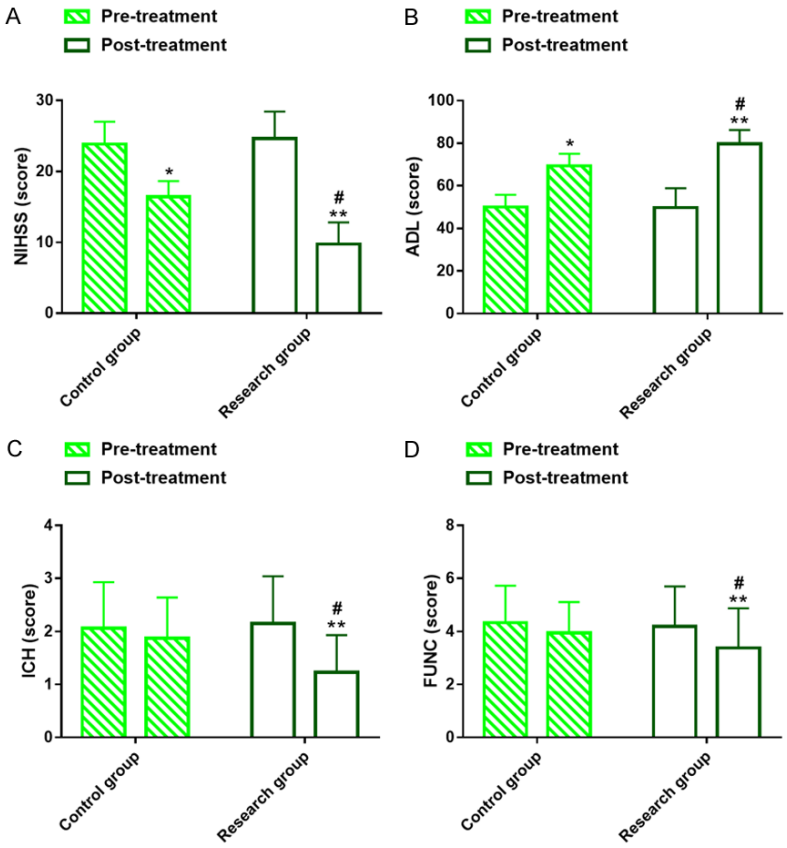

Figure 2. Neurological function and Activities of Daily Living (ADL). A. Pre- and post-treatment National Institutes of Health Stroke Scale (NIHSS) scores. B. Pre- and post-treatment Barthel Index scores. C. Pre- and post-treatment Intracerebral Hemorrhage (ICH) scores. D. Pre- and post-treatment Functional Outcome in Patients with Primary Intracerebral Hemorrhage (FUNC) scores. Note: *P<0.05, vs. pre-treatment; **P<0.01, vs. pre-treatment; #P<0.05, vs. control group.

The research group achieved greater improvements in all scales compared with the control group (P<0.05; **Figure 2**; **Table 5**).

Serum inflammatory factors

Baseline levels of TNF-α, IL-6, and CRP were comparable between groups (all P>0.05). After treatment, all three markers declined significantly in both groups (P<0.05), with lower post-treatment levels in the research group compared to the control group (P<0.05) (**Figure 3**; **Table 6**).

Oxidative stress parameters

Pretreatment SOD and MDA levels did not differ significantly between groups (P>0.05). After intervention, SOD increased and MDA reduced in both groups (P<0.05), with more pronounced changes observed in the research group (P<0.05; **Figure 4**; **Table 7**).

Cerebrovascular function indices

Baseline CGRP and ET levels were comparable between groups (P>0.05). After treatment, both groups exhibited therapeutic improvements, characterized by increased CGRP and decreased ET levels. Notably, the research group showed greater improvements, with higher CGRP and lower ET compared with controls (P< 0.05; **Figure 5**; **Table 8**).

Rebleeding, morbidity, and mortality

No marked differences were found between groups in terms of rebleeding incidence, morbidity, or mortality (P>0.05) (**Table 9**).

Discussion

Cerebral hemorrhage is often precipitated by factors such as overexertion and emotional stress, and is characterized by rapid onset, high risk of early mortality, and poor prognosis [17]. Conventional drug therapy mainly targets blood pressure control, cranial pressure reduction, and infection prevention, to achieve anti-inflammatory and hemostatic effects [18, 19]. However, the therapeutic efficacy of traditional therapy remains limited, underscoring the need for more effective treatment strategies.

In this study, patients who underwent minimally invasive tube placement with aspiration, liquefaction, and drainage demonstrated higher overall treatment efficacy compared with those who received conservative therapy. As a minimally invasive procedure, this technique facilitates rapid and effective hematoma evacuation, alleviates intracranial pressure, and reduces neurological injury, thereby improving

Table 5. Comparative analysis of NIHSS and ADL scores

Indicators	Control group (n=47)	Research group (n=52)	t value	*P* value
NIHSS (score)				
Pre-treatment	23.83±3.19	24.65±3.78	1.160	0.249
Post-treatment	16.43±2.22*	9.77±3.05**	12.308	<0.001
ADL (score)				
Pre-treatment	50.00±5.76	49.79±9.09	0.136	0.892
Post-treatment	69.40±5.67*	79.69±6.55**	8.315	<0.001

Note: NIHSS: National Institutes of Health Stroke Scale; ADL, Activities of Daily Living; *P<0.05, **P<0.01 vs. pre-treatment within the same group.

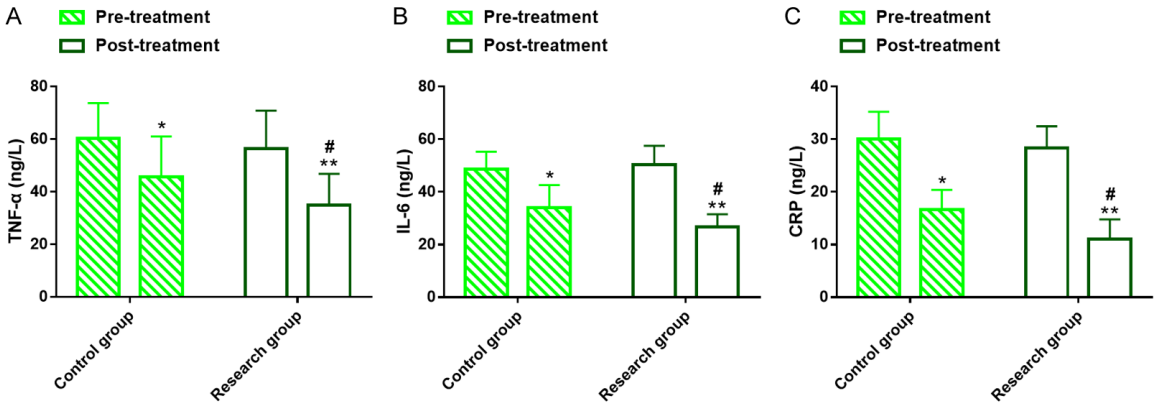

Figure 3. Serum inflammatory factors. A. Changes in tumor necrosis factor-α (TNF-α) before and after treatment. B. Pre- and post-treatment interleukin-6 (IL-6). C. Pre- and post-treatment C-reactive protein (CRP). Note: *P<0.05, vs. pre-treatment; **P<0.01, vs. pre-treatment; #P<0.05, vs. control group.

Table 6. Comparative analysis of TNF-α, IL-6, and CRP levels

Indicators	Control group (n=47)	Research group (n=52)	t value	*P* value
TNF-α (ng/L)				
Pre-treatment	60.34±13.38	56.50±14.32	1.374	0.173
Post-treatment	45.70±15.33*	34.88±11.97**	3.934	<0.001
IL-6 (ng/L)				
Pre-treatment	48.77±6.52	50.37±7.23	1.152	0.252
Post-treatment	34.09±8.51*	26.60±4.89**	5.433	<0.001
CRP (ng/L)				
Pre-treatment	30.06±5.19	28.38±4.11	1.794	0.076
Post-treatment	16.64±3.74*	11.06±3.72**	7.434	<0.001

Note: TNF-α: tumor necrosis factor-α; IL-6: interleukin-6; CRP: C-reactive protein; *P<0.05, **P<0.01 compared to pre-treatment values within each group.

clinical outcomes [20, 21]. By contrast, conservative treatment cannot directly remove the hematoma or relieve the compression on brain tissue, which likely explains the superior outcomes observed with minimally invasive intervention [22].

Importantly, the incidence of adverse events (e.g., venous thrombosis, gastrointestinal bleeding, urinary tract infection, and pulmonary infection) did not differ significantly between groups, suggesting that minimally invasive surgery does not increase the risk of adverse events. The favorable safety profile may be attributed to limited tissue damage during the procedure, improved oxygenation, accelerated hematoma absorption, and a shortened acute disease course [23, 24]. Furthermore, the

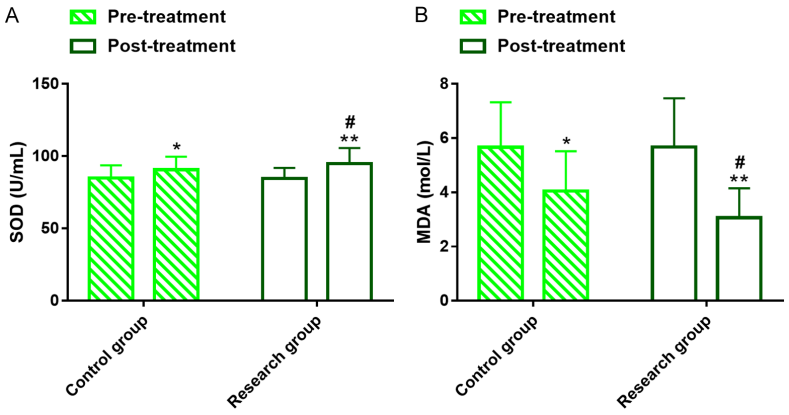

Figure 4. Oxidative stress marker profiles. A. Temporal changes in superoxide dismutase (SOD) levels. B. Temporal changes in malondialdehyde (MDA) levels. Note: *P<0.05, vs. pre-treatment; **P<0.01, vs. pre-treatment; #P<0.05, vs. control group.

Table 7. Comparative analysis of SOD and MDA activities

Indicators	Control group (n=47)	Research group (n=52)	t value	*P* value
SOD (U/mL)				
Pre-treatment	84.91±8.73	84.54±7.35	0.229	0.820
Post-treatment	90.70±8.98*	94.79±10.94**	2.020	0.046
MDA (mol/L)				
Pre-treatment	5.66±1.66	5.68±1.79	0.057	0.954
Post-treatment	4.05±1.47*	3.06±1.09**	3.830	<0.001

Note: SOD: superoxide dismutase; MDA: malondialdehyde; *P<0.05, **P<0.01 vs. pre-treatment within the same group.

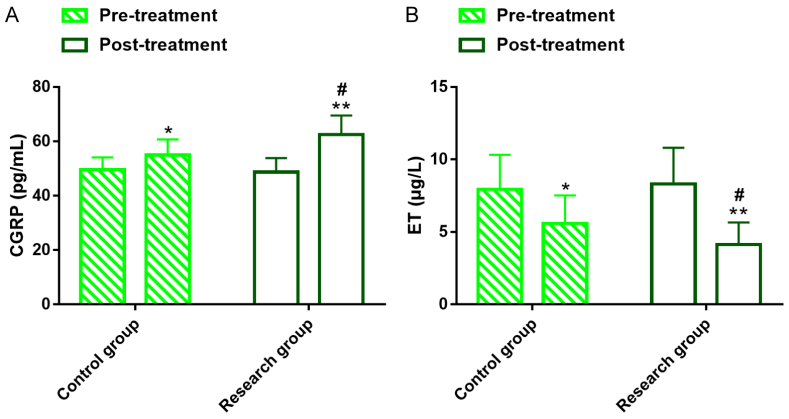

Figure 5. Cerebrovascular function marker dynamics. A. Calcitonin gene-related peptide (CGRP) level variations. B. Endothelin (ET) level variations. Note: *P<0.05, vs. pre-treatment; **P<0.01, vs. pre-treatment; #P<0.05, vs. control group.

research group showed surgical advantages, including shorter operative duration, higher hematoma clearance on postoperative day 1, and reduced cerebral edema volume at day 7.

On the other hand, this minimally invasive procedure also demonstrated neuroprotective effects, attenuating neurological deficits, improving activities of daily living, reducing 30-day mortality risk, and enhancing functional outcomes at 90 days post-treatment. These benefits can be attributed to effective removal of intracranial hematomas, which relieves the mass effect on brain tissue, reduces neurological impairment, and thereby supports functional recovery. Deng et al. [25] reported that minimally invasive tube placement with aspiration, liquefaction and drainage not only improved clinical efficacy and reduced complication in 39 patients with cerebral hemorrhage, but also enhanced neurological recovery, consistent with our findings. Similarly, Liang et al. [26] observed decreased NIHSS scores and improved neurological function in patients with hypertensive basal ganglia hemorrhage treated with this technique, further corroborating our results.

Further analysis revealed that the minimally invasive procedure also ameliorated inflammatory imbalance, oxidative stress, and cerebrovascular dysfunction. In the pathophysiology of cerebral hemorrhage, abnormal activation of inflammatory cytokines, oxidative stress, and disruption of vasoactive factor balance exacerbate hemodynamic instability, increase vascular permeability, promote hematoma expansion, and aggravate neuronal

Table 8. Comparative analysis of CGRP and ET

Indicators	Control group (n=47)	Research group (n=52)	t value	*P* value
CGRP (pg/mL)				
Pre-treatment	49.57±4.52	48.69±5.14	0.900	0.370
Post-treatment	54.98±5.69*	62.50±6.98**	5.837	<0.001
ET (μg/L)				
Pre-treatment	7.93±2.39	8.32±2.48	0.795	0.429
Post-treatment	5.60±1.92*	4.12±1.53**	4.261	1.53

Note: CGRP: calcitonin gene-related peptide; ET: endothelin; *P<0.05, **P<0.01 (within-group comparison to pre-treatment).

Table 9. Rebleeding incidences and death rates

Project	Control group (n=47)	Research group (n=52)	χ^2 value	*P* value
Rebleeding	2 (4.26)	4 (7.69)	0.512	0.474
Death from illness	5 (10.64)	1 (1.92)	3.294	0.070

injury [27]. By rapidly removing the hematoma, this technique reduces the accumulation of toxic metabolites, while the liquefaction effect of urokinase interrupts the inflammation - oxidative stress cascade. Together, these mechanisms help restore the balance of vasoactive mediators such as ET-1 and CGRP, optimize the cerebral microenvironment, and promote neurological restoration. Wu J et al. [28] concluded that minimally invasive tube placement with aspiration, liquefaction and drainage significantly down-regulated serum TNF-α, IL-6, and CRP levels at 3 and 7 days postoperatively, highlighting its role in maintaining cytokine balance, which aligns with our findings. Finally, the minimally invasive technique demonstrated comparable efficacy to conventional surgery with regard to rates of rebleeding and mortality.

Several limitations of this study should be noted. First, the relatively small sample size (n=99) may limit the generalizability of the findings; larger, multi-center studies are needed for external validation. Second, this study did not include a cost-effectiveness analysis, which may provide critical evidence for broader clinical adoption. Third, outcomes related to quality of life, sleep quality, and psychological well-being were not assessed. Incorporating these dimensions in future studies could further elucidate the comprehensive benefits of minimally invasive tube placement, aspiration, liquefaction, and drainage surgery for cerebral hemorrhage.

Conclusion

Minimally invasive tube placement with aspiration, liquefaction and drainage represents an effective and safe therapeutic option for patients with cerebral hemorrhage. Beyond alleviating neurological deficits and improving activities of daily living, it contributes to better overall prognosis by attenuating excessive inflammation, mitigating oxidative stress, optimizing cerebrovascular function, and reducing the risks of rebleeding and mortality.

Acknowledgements

This project is supported by the Natural Science Foundation of Fujian Province (2020J011305).

Disclosure of conflict of interest

None.

Address correspondence to: Yong Yang, Department of Pediatric Neurosurgery, Neurosurgery Center, Zhujiang Hospital, Southern Medical University, Guangzhou 510000, Guangdong, PR China. Tel: +86-020-61643888; E-mail: southenmedical@163.com

References

[1] Montano A, Hanley DF and Hemphill JC 3rd. Hemorrhagic stroke. Handb Clin Neurol 2021; 176: 229-248.

[2] Poon MT, Bell SM and Al-Shahi Salman R. Epidemiology of intracerebral haemorrhage. Front Neurol Neurosci 2015; 37: 1-12.

[3] Magid-Bernstein J, Girard R, Polster S, Srinath A, Romanos S, Awad IA and Sansing LH. Cerebral hemorrhage: pathophysiology, treatment, and future directions. Circ Res 2022; 130: 1204-1229.
[4] An SJ, Kim TJ and Yoon BW. Epidemiology, risk factors, and clinical features of intracerebral hemorrhage: an update. J Stroke 2017; 19: 3-10.
[5] Zille M, Farr TD, Keep RF, Romer C, Xi G and Boltze J. Novel targets, treatments, and advanced models for intracerebral haemorrhage. EBioMedicine 2022; 76: 103880.
[6] Chen S, Li L, Peng C, Bian C, Ocak PE, Zhang JH, Yang Y, Zhou D, Chen G and Luo Y. Targeting oxidative stress and inflammatory response for blood-brain barrier protection in intracerebral hemorrhage. Antioxid Redox Signal 2022; 37: 115-134.
[7] Qi R, Liu H, Liu C, Xu Y and Liu C. Expression and short-term prognostic value of miR-126 and miR-182 in patients with acute stroke. Exp Ther Med 2020; 19: 527-534.
[8] Wang J, Wang G, Yi J, Xu Y, Duan S, Li T, Sun XG and Dong L. The effect of monascin on hematoma clearance and edema after intracerebral hemorrhage in rats. Brain Res Bull 2017; 134: 24-29.
[9] Wu L, Li Y, Wang X, Ren X, Zhu H, Sun Y, Xing Y, Zhu L, Gao Y and Shang H. A systematic review and meta-analysis on the treatment of cerebral hemorrhage with NaoXueShu oral liquid. Biomed Res Int 2017; 2017: 8542576.
[10] Zang Y, Zhang C, Song Q, Zhang J, Li H, Zhang C, Feng S and Gu F. Therapeutic effect of early intensive antihypertensive treatment on rebleeding and perihematomal edema in acute intracerebral hemorrhage. J Clin Hypertens (Greenwich) 2019; 21: 1325-1331.
[11] Li G, Qin X, Pen G, Wu W, Yang J and Yang Q. Effect of minimally invasive aspiration in treatment of massive intracerebral hemorrhage. Acta Neurochir Suppl 2011; 111: 381-382.
[12] Lu Z, Zhu G, Qiu Y and Cheng X. Minimally-invasive aspiration and drainage for management of traumatic epidural hematoma straddling transverse sinus. Neurol India 2013; 61: 111-116.
[13] Freeman WD and Aguilar MI. Intracranial hemorrhage: diagnosis and management. Neurol Clin 2012; 30: 211-240, ix.
[14] Connolly SJ, Sharma M, Cohen AT, Demchuk AM, Czlonkowska A, Lindgren AG, Molina CA, Bereczki D, Toni D, Seiffge DJ, Tanne D, Sandset EC, Tsivgoulis G, Christensen H, Beyer-Westendorf J, Coutinho JM, Crowther M, Verhamme P, Amarenco P, Roine RO, Mikulik R, Lemmens R, Veltkamp R, Middeldorp S, Robinson TG, Milling TJ Jr, Tedim-Cruz V, Lang W, Himmelmann A, Ladenvall P, Knutsson M, Ekholm E, Law A, Taylor A, Karyakina T, Xu L, Tsiplova K, Poli S, Kallmunzer B, Gumbinger C and Shoamanesh A; ANNEXA-I Investigators. Andexanet for factor Xa inhibitor-associated acute intracerebral hemorrhage. N Engl J Med 2024; 390: 1745-1755.
[15] Strbian D, Sairanen T, Meretoja A, Pitkaniemi J, Putaala J, Salonen O, Silvennoinen H, Kaste M and Tatlisumak T; Helsinki Stroke Thrombolysis Registry Group. Patient outcomes from symptomatic intracerebral hemorrhage after stroke thrombolysis. Neurology 2011; 77: 341-348.
[16] Li W, Gao J, Wei S and Wang D. Application values of clinical nursing pathway in patients with acute cerebral hemorrhage. Exp Ther Med 2016; 11: 490-494.
[17] Etminan N and Macdonald RL. Neurovascular disease, diagnosis, and therapy: subarachnoid hemorrhage and cerebral vasospasm. Handb Clin Neurol 2021; 176: 135-169.
[18] Chen HS, Cui Y, Zhou ZH, Zhang H, Wang LX, Wang WZ, Shen LY, Guo LY, Wang EQ, Wang RX, Han J, Dong YL, Li J, Lin YZ, Yang QC, Zhang L, Li JY, Wang J, Xia L, Ma GB, Lu J, Jiang CH, Huang SM, Wan LS, Piao XY, Li Z, Li YS, Yang KH, Wang DL and Nguyen TN; ARAMIS Investigators. Dual antiplatelet therapy vs alteplase for patients with minor nondisabling acute ischemic stroke: the ARAMIS randomized clinical trial. JAMA 2023; 329: 2135-2144.
[19] Saldana S, Breslin J 2nd, Hanify J, Heierman T, Larizadeh K, Sanchez M and Phipps W. Comparison of clevidipine and nicardipine for acute blood pressure reduction in hemorrhagic stroke. Neurocrit Care 2022; 36: 983-992.
[20] Darrivere L, Lapidus N, Colignon N, Chafai N, Chaput U, Verdonk F, Paye F and Lescot T. Minimally invasive drainage in critically ill patients with severe necrotizing pancreatitis is associated with better outcomes: an observational study. Crit Care 2018; 22: 321.
[21] Mahmoud A, Abuelazm M, Ahmed AAS, Elshinawy M, Abdelwahab OA, Abdalshafy H and Abdelazeem B. Percutaneous catheter drainage versus needle aspiration for liver abscess management: an updated systematic review, meta-analysis, and meta-regression of randomized controlled trials. Ann Transl Med 2023; 11: 190.
[22] Al-Khaled M and Eggers J; QugSS2 Study. Prognosis of intracerebral hemorrhage after conservative treatment. J Stroke Cerebrovasc Dis 2014; 23: 230-234.
[23] Kim CH, Choi JH and Park HS. Safety and efficacy of minimally invasive stereotactic aspiration with multicatheter insertion compared

with conventional craniotomy for large spontaneous intracerebral hemorrhage (≥50 mL). World Neurosurg 2019; 128: e787-e795.
[24] Rho S, Kim TS, Joo SP, Gong TS, Kim HJ and Park M. A study on the proper catheter position in minimally invasive surgery using stereotactic aspiration plus urokinase for intracerebral hemorrhage. J Cerebrovasc Endovasc Neurosurg 2022; 24: 121-128.
[25] Deng C, Ji Y, Song W and Bi J. Clinical effect of minimally invasive aspiration and drainage of intracranial hematoma in the treatment of cerebral hemorrhage. Pak J Med Sci 2022; 38: 95-99.
[26] Liang KS, Ding J, Yin CB, Peng LJ, Liu ZC, Guo X, Liang SY, Zhang Y and Zhou SN. Clinical study on minimally invasive liquefaction and drainage of intracerebral hematoma in the treatment of hypertensive putamen hemorrhage. Technol Health Care 2017; 25: 1061-1071.
[27] Yoshimoto M, Takeda N, Yoshimoto T and Matsumoto S. Hypertensive cerebral hemorrhage with undetectable plasma vascular endothelial growth factor levels in a patient receiving intravitreal injection of aflibercept for bilateral diabetic macular edema: a case report. J Med Case Rep 2021; 15: 403.
[28] Wu J and Zhang S. Analysis of the therapeutic effect and prognostic factors of 126 patients with hypertensive cerebral hemorrhage treated by soft-channel minimally invasive puncture and drainage. Front Surg 2022; 9: 885580.