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Original Article

Outcomes, neurological function, and inflammation indices following minimally invasive hematoma removal in hypertensive cerebral hemorrhage patients

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Abstract: Objective: To evaluate the clinical efficacy of minimally invasive removal of intracranial hematoma (MIRICH) in the treatment of patients with hypertensive intracranial hemorrhage (HICH) and its effect on brain nerve function and body inflammation index. Methods: This retrospective study involved 150 HICH patients treated at Shanghai Blue Cross Brain Hospital from January 2019 to March 2024. Patients were assigned into two groups according to the surgical approach they received: the control group (n = 75), treated with traditional craniotomy, and the observation group (n = 75), treated with MIRICH. The two groups were compared in terms of operative parameters, hematoma clearance rate, clinical efficacy, neurological function recovery, inflammatory markers, and postoperative complications. Risk factors affecting clinical efficacy were also analyzed. Results: Compared to the control group, the observation group had significantly shorter operation and hospitalization times, less intraoperative blood loss, and a higher hematoma clearance rate ($P < 0.05$). The total effective rate was significantly higher in observation group than that in control group (94.67% vs. 84.00%; $\chi^2 = 4.478$, $P = 0.034$). Three months after operation, compared to the control group, the neurological deficit score and NIH Stroke Assessment Scale (NIHSS) scale score were significantly lower in the observation group. The Activity of Daily Living Scale (ADL) scale score was significantly higher in the observation group. Serum levels of tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6) and high sensitivity C-reactive protein (hs-CRP) were significantly lower in the observation group ($P < 0.05$). The mean velocity (Vm), peak systolic velocity (PSV) and pulsatility index (PI) in the observation group were significantly higher ($P < 0.05$). The cognitive function score of observation group was significantly higher than that of control group (24.65±3.13 vs. 18.43±2.76; $t = 12.919$, $P < 0.05$). The incidence of postoperative complications was 12.00% in the observation group and 17.33% in the control group, with no significant difference ($P > 0.05$). Multivariate Logistic regression analysis identified age, surgical method, and operation time as significant risk factors affecting clinical efficacy. Conclusion: MIRICH surgery can improve the hematoma clearance rate in HICH patients, with better clinical efficacy, and less trauma. Additionally, it promotes neurological function recovery, improves the prognosis and living ability of patients, and reduces the level of serum inflammatory factors. It is a promising treatment option worthy of wider adoption.

Keywords: Minimally invasive removal of intracranial hematoma, hypertensive intracranial hemorrhage, clinical effect, brain nerve function, inflammation indicators

Introduction

Hypertensive intracranial hemorrhage (HICH) is a severe cerebrovascular disease caused by long-term hypertension, leading to pathological changes in the small arteries of the brain, such as degeneration, necrosis, and ischemia [1]. It primarily affects middle-aged and elderly individuals, typically between 50 and 70 years old. With the aggravation of aging population, the incidence of HICH is rising annually, drawing significant attention from various sectors [2]. HICH can severely impair brain nerve function and cause brain tissue edema, necessitating prompt treatment.

In the clinical management of HICH, treatment options include not only intracranial hematoma removal surgery but also medical interventions, such as dehydration to reduce intracranial pres-

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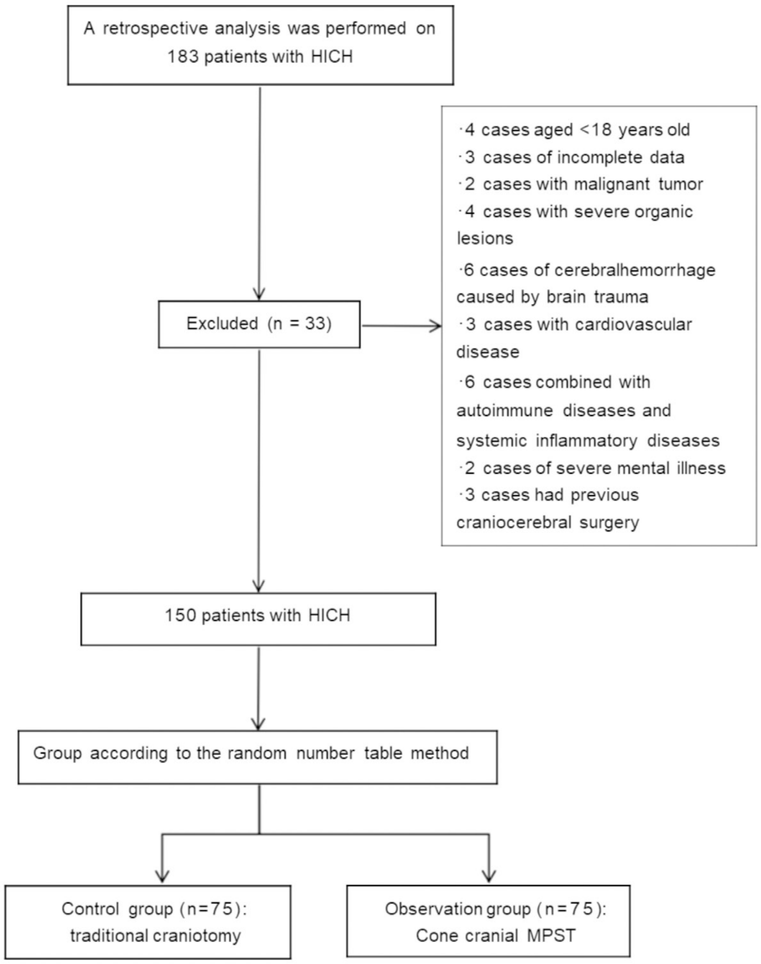

Figure 1. Patient screening flow chart. HICH: Hypertensive Intracranial Hemorrhage; MPST: Minimally Invasive Removal of Intracranial Hematoma.

sure and cerebral edema, adjust blood pressure, prevent continued bleeding, and protect nerve function to promote recovery, along with intensive care to prevent complications. Although traditional craniotomy for hematoma removal is effective, it has drawbacks, such as significant surgical trauma and slow patient recovery, which limit its wide use in clinical practice [3].

In contrast, minimally invasive removal of intracranial hematoma (MIRICH) is a surgical technique developed based on the principles of minimally invasive medicine. It enters the brain through a small incision or drilling, using specialized surgical instruments to remove hematoma and relieve the space-occupying effect, thereby minimizing damage to brain tissue [4]. This technique has shown positive outcomes in treating cerebral hemorrhage by significantly increasing patient survival rates, promoting neurological function recovery, reducing complications, and improving prognosis. In clinical practice, MIRICH is regarded as a feasible and safe minimally invasive treatment for large basal ganglia hemorrhage. This method also enables hospitals with only CT machines to treat basal ganglia cerebral hemorrhages. However, HICH is associated with high disability rates, mortality, and severe complications. Therefore, the clinical efficacy, impact on neurological function, and safety of conical skull MIRICH surgery in HICH patients require further exploration to confirm. This study aims to evaluate the therapeutic value of MIRICH in the treatment of HICH.

Objects and methods

Research object

A retrospective analysis was conducted on 150 HICH patients who were treated at Shanghai Blue Cross Brain Hospital from January 2019 to March 2024. This study was approved by the Ethics Committee of Shanghai Blue Cross Brain Hospital. The patient screening process is shown in **Figure 1**.

Inclusion criteria [5]: (1) Patients with cerebral hemorrhage confirmed by computed tomography (CT) and a clear history of hypertension; (2) Patients who met the surgical indications and received surgical treatment within 24 hours of onset, with a bleeding volume between 20-40 mL; (3) Patients without cerebral hernia.

Exclusion criteria: (1) Patients with severe organic lesions; (2) Patients with tumor; (3) Patients with cerebral hemorrhage caused by other factors (e.g., traumatic brain injury); (4) Patients with severe mental disorders, autoimmune diseases, etc.; (5) Patients who had previously undergone brain surgery.

Methods

Grouping method: According to the treatment method, the patients were divided into a control group (n = 75) and an observation group (n = 75).

Operative method: The control group was treated with traditional craniotomy. The location of the hematoma was determined using head CT, and the surgical incision was designed accordingly. After general anesthesia and tracheal intubation, a scalp incision was made, the periosteum was separated, and the skull was fully exposed. A drill was used to create a bone window (2.5 cm × 3.0 cm), and the window was expanded using bite forceps as needed to expose the dura mater. The hematoma was then aspirated using a micro-aspirator, and the hematoma cavity was treated and hemostasis achieved. A catheter was placed for drainage, and the drainage tube was removed 3-5 days post-surgery.

The observation group was treated with skull MIRICH. The hematoma focus was accurately located using head CT. After local anesthesia, routine disinfection, and positioning, an approximately 3 cm incision was made. A drill was used to create a small hole in the skull, and a milling cutter was used to form the bone flap. A puncture needle was inserted into the hematoma cavity. Once successful, the inner core of the cannula was removed, and the hematoma was evacuated under endoscopic monitoring. The hematoma cavity was then rinsed with normal saline, and a drainage tube was placed.

Data collection

Standardized data collection methods were employed, with data extracted by two independent researchers to ensure consistency and accuracy.

Data on general information, perioperative basic indicators, clinical efficacy, neurological function, inflammatory markers, hemodynamic indicators, cognitive function, and postoperative complications were collected. Additionally, risk factors affecting the clinical efficacy of HICH were analyzed.

(1) General information. Age, gender, degree of coma, bleeding site, pupil response, and Glasgow Coma Scale (GCS) score were recorded.

(2) Perioperative basic indicators. The operation time, hospitalization time, intraoperative blood loss, and hematoma clearance rate were compared between the two groups. Hematoma clearance rate = (preoperative hematoma volume-postoperative hematoma volume)/preoperative hematoma volume × 100%.

(3) Efficacy evaluation. Evaluation criteria [6]: Recovery: Disability grade 0, with a 91-100% decrease in preoperative neurological deficit score; Markedly effective: Disability grade 1-3, with a 46-90% decrease in neurological deficit score. Improvement: An 18-45% decrease in the neurological deficit score compared to preoperative values. Ineffective: A decrease in the neurological deficit score of < 17% compared to preoperative levels. Total effective rate = (basic recovery + significant progress + progress)/total number of cases × 100%.

(4) Neurological function evaluation. The neurological deficit score, Activity of Daily Living Scale (ADL) [7], and NIH Stroke Assessment Scale (NIHSS) [8] were used to assess functional recovery before surgery and 3 months post-surgery. The ADL scale, with a total score of 100 points, assesses walking, transfer, and other items, with higher scores indicating better independent living ability. The NIHSS scale, with a total score of 42 points, assesses sensory, motor, and consciousness items, with lower scores indicating less pronounced neurological deficits.

(5) Evaluation of inflammatory factor levels. The levels of tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and high-sensitivity C-reactive protein (hs-CRP) were compared between the two groups. Detection method: 3 mL of fasting venous blood was collected from patients before and 3 months after surgery. After centrifugation at 3000 rpm for 10 minutes, the supernatant was stored at -20°C for testing. TNF-α was detected by radioimmunoassay (Ruier Biotechnology Co., Ltd.), IL-6 by enzyme-linked immunosorbent assay (Shanghai Hengyuan Biochemical Reagent Co., Ltd.), and hs-CRP by latex-enhanced immunoturbidimetric assay (Shanghai Fuxing Changzheng Medical Company).

Table 1. Comparison of baseline data between the two groups of HICH patients

Index	Observation group (n = 75)	Control group (n = 75)	χ^2/t	*P*
Age/years	62.36±3.24	62.19±3.28	0.326	0.745
Gender			0.243	0.622
Male	43 (57.33)	40 (53.33)		
Female	32 (42.67)	35 (46.67)		
Coma degree			0.269	0.874
Shallow coma	25 (33.33)	24 (32.00)		
Moderate coma	27 (36.00)	30 (40.00)		
Deep coma	23 (30.67)	21 (28.00)		
Bleeding part			0.108	0.743
Cerebral lobes	33 (44.00)	35 (46.67)		
Basal nuclei	42 (56.00)	40 (53.33)		
Pupil situation			0.167	0.683
Unilateral pupil enlargement	61 (81.33)	59 (78.67)		
Bilateral pupil dilation	14 (18.67)	16 (21.33)		
GCS score			0.139	0.933
> 12	21 (28.00)	19 (25.33)		
8-11	34 (45.33)	35 (46.67)		
< 8	20 (26.67)	21 (28.00)		

Note: GCS, Glasgow Coma Scale; HICH, Hypertensive Intracranial Hemorrhage.

(6) Hemodynamic evaluation. A blood flow analyzer (model EMS-9WA, Delikai) was used to monitor hemodynamic indicators before surgery and 3 months post-surgery. These included mean velocity (Vm), peak systolic velocity (PSV), and pulsatility index (PI), with three measurements taken for each parameter.

(7) Cognitive function evaluation. Cognitive function was assessed before surgery and 3 months after surgery using the Montreal Cognitive Assessment (MoCA). The scale includes assessments of orientation, memory, calculation, attention, and language ability, with a total score ranging from 0 to 30 points. Higher scores indicate better cognitive function.

(8) Evaluation of postoperative complications. Postoperative complications were monitored, including intracranial infection, pulmonary infection, lower extremity venous thrombosis, and postoperative secondary bleeding.

(9) Multivariate analysis. Based on the effects of surgical treatment, patients were divided into two groups. The effects of age, gender, surgical method, operation time, and intraoperative blood loss on treatment outcomes were analyzed.

Statistical analysis

SPSS 27.0 statistical software was used for data analysis. Chi-square test (χ^2) was used to compare the distribution of categorical data (n, %) between the two groups. The measurement data were presented as mean ± standard deviation (SD), and comparisons were made using the t-test. Multivariate Logistic regression analysis was conducted to identify the risk factors affecting the clinical efficacy of MIRICH in the treatment of HICH. $P < 0.05$ was considered statistically significant.

Results

Comparison of general data between the two groups

There were no significant differences in age, sex, degree of coma, or other baseline characteristics between the two groups (all $P > 0.05$), indicating comparability, as shown in **Table 1**.

Comparison of surgical indicators between the two groups

Compared to the control group, the observation group had significantly shorter operation time and hospitalization times, less intraoperative

Table 2. Comparison of surgical indicators between the two groups of HICH patients

Group	Operation time (min)	Hospitalization time (d)	Intraoperative blood loss (mL)	Hematoma clearance rate (%)
Observation group (n = 75)	74.34±11.36	14.32±2.98	63.22±9.34	80.41±5.38
Control group (n = 75)	102.43±18.53	19.56±3.72	115.25±13.49	70.95±7.71
χ^2/t	11.192	9.523	27.461	8.708
P	< 0.001	< 0.001	< 0.001	< 0.001

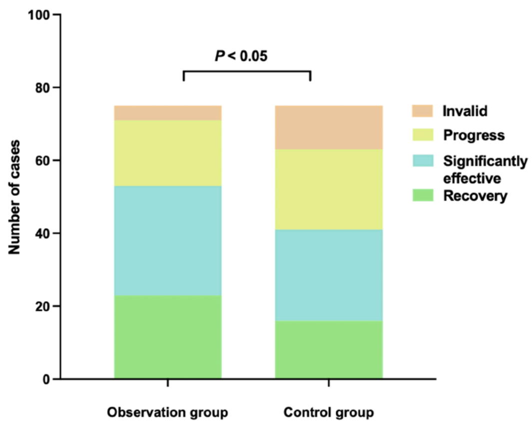

Figure 2. Comparison of clinical efficacy between the two groups.

blood loss, and a higher hematoma clearance rate (all $P < 0.05$). See **Table 2**.

Comparison of clinical efficacy between the two groups

The total effective rate was 94.67% in observation group, significantly higher than 84.00% in control group (x^2 = 4.478, P = 0.034). See **Figure 2**.

Comparison of neurological function between the two groups

Before operation, there were no significant differences in neurological deficit score, ADL, or NIHSS scale scores between the two groups (all $P > 0.05$). Three months after operation, the neurological deficit score and NIHSS score in the observation group were significantly lower than those in the control group, while the ADL score was significantly higher (all $P < 0.05$). See **Table 3**.

Comparison of inflammatory factor levels between the two groups

Before operation, there were no significant differences in the levels of inflammatory factors between observation group and control group ($P > 0.05$). Three months after operation, the serum levels of TNF-α, IL-6 and hs-CRP were significantly lower in the observation group than those in the control group (all $P < 0.05$). See **Table 4**.

Comparison of hemodynamic parameters between the two groups

There were no significant differences in Vm, PSV, or PI between the two groups before operation (all $P > 0.05$). Three months after operation, Vm, PSV and PI increased in both groups, with the observation group showing significantly higher values than the control group (all $P < 0.05$). See **Table 5**.

Comparison of cognitive function score between the two groups

Before surgery, the cognitive function score of patients in the observation group was 11.88±1.98 points, and that in the control group was 11.61±1.89 points (t = 0.843, $P > 0.05$). Three months after operation, the cognitive function score of the observation group was 24.65±3.13 points, significantly higher than 18.43±2.76 points in the control group (t = 12.919, $P < 0.05$). See **Figure 3**.

Comparison of postoperative complications between the two groups

During the postoperative observation period, the total incidence of complications was 12.00% in the observation group and 17.33% in the control group. Although the observation group had fewer complications, there was no significant difference in the total incidence of postoperative complications between the two groups ($P > 0.05$). See **Table 6**.

Multivariate Logistic regression analysis of factors affecting the clinical efficacy of HICH

Based on the surgical treatment effect, the 150 patients were divided into a recovery gr-

Table 3. Comparison of neurological function between the two groups of HICH patients before and after treatment

Group	Neurological deficit score/point		ADL score/point		NIHSS score/point	
	Before operation	3 months after operation	Before operation	3 months after operation	Before operation	3 months after operation
Observation group (n = 75)	24.64±4.28	13.45±1.67	42.52±5.38	69.36±6.25	24.85±3.64	11.43±1.21
Control group (n = 75)	25.57±4.32	19.12±2.25	42.41±5.27	56.31±5.68	25.11±3.53	14.25±2.17
t	1.329	17.521	0.123	13.394	0.433	9.856
P	0.186	< 0.001	0.903	< 0.001	0.666	< 0.001

Note: ADL, Activity of Daily Living Scale; NIHSS, NIH Stroke Assessment Scale.

Table 4. Comparison of inflammatory factors between the two groups of HICH patients before and after treatment

Group	TNF-α (μg/L)		IL-6 (ng/L)		hs-CRP (mg/L)	
	Before operation	3 months after operation	Before operation	3 months after operation	Before operation	3 months after operation
Observation group (n = 75)	63.27±4.72	41.44±3.56	45.68±4.83	14.35±2.74	15.86±3.55	7.43±2.28
Control group (n = 75)	63.16±4.68	56.30±3.87	45.22±4.64	30.14±3.52	15.75±3.63	11.34±2.86
t	0.144	24.495	0.595	30.652	0.198	9.251
P	0.886	< 0.001	0.553	< 0.001	0.843	< 0.001

Note: TNF-α, tumor necrosis factor-α; IL-6, interleukin-6; hs-CRP, high sensitivity c-reactive protein.

Table 5. Comparison of hemodynamic parameters between the two groups of HICH patients before and after treatment

Group	Vm (cm/s)		PSV (cm/s)		PI	
	Before operation	3 months after operation	Before operation	3 months after operation	Before operation	3 months after operation
Observation group (n = 75)	52.67±5.27	72.64±6.78	66.55±6.48	83.92±6.67	1.17±0.13	2.84±0.22
Control group (n = 75)	52.84±5.46	65.21±5.87	66.19±6.54	80.22±7.14	1.19±0.13	1.75±0.18
t	0.204	7.178	0.342	3.280	1.006	33.129
P	0.839	< 0.001	0.733	0.001	0.316	< 0.001

Note: Vm, mean velocity; PSV, peak systolic velocity; PI, pulsitility index.

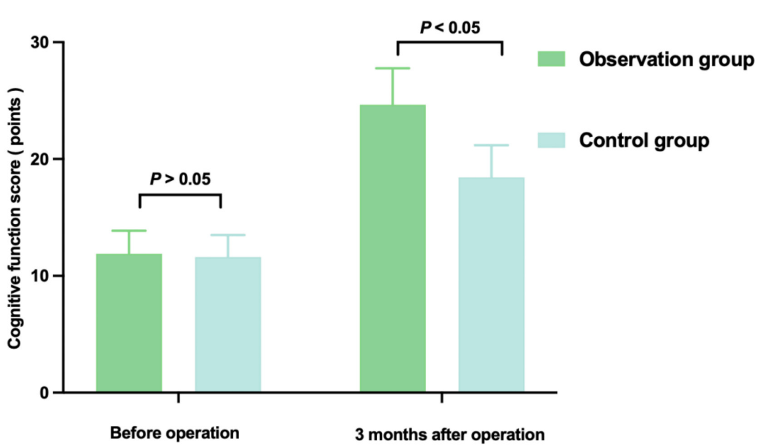

Figure 3. Comparison of cognitive function scores between the two groups.

oup (39 cases) and a non-recovery group (111 cases). Univariate analysis showed significant differences in age, surgical method, and operation time between the recovery group and the non-recovery group (all $P < 0.05$). See **Table 7**.

With recovery (yes = 0, no = 1) as the dependent variable, and age, surgical method, and operation time as independent variables, multivariate Logistic regression model was

Table 6. Comparison of total incidence of postoperative complications between the two groups of patients

Group	n	Intracranial infection	Pulmonary infection	Lower extremity venous thrombosis	Postoperative secondary bleeding	Total rate
Observation group	75	3 (4.00)	2 (2.67)	2 (2.67)	2 (2.66)	9 (12.00)
Control group	75	4 (5.44)	3 (4.00)	3 (4.00)	3 (4.00)	13 (17.33)
Z/χ^2				-0.104		3.888
P				0.917		0.049

Table 7. Single factor analysis

Index	Healing group (n = 39)	Unhealed group (n = 111)	t/χ^2	P
Age/years	62.10±2.95	63.92±2.99	3.275	< 0.001
Gender			0.350	0.554
Male	20 (51.28)	63 (56.76)		
Female	19 (48.72)	48 (43.24)		
Coma degree			3.278	0.194
Shallow coma	17 (43.59)	32 (28.83)		
Moderate coma	11 (28.21)	46 (41.44)		
Deep coma	11 (28.20)	33 (29.73)		
Bleeding part			0.065	0.799
Basal nuclei	22 (56.41)	60 (54.05)		
Cerebral lobes	17 (43.59)	51 (45.95)		
Pupil situation			0.139	0.710
Unilateral pupil enlargement	32 (82.05)	88 (79.28)		
Bilateral pupil dilation	7 (17.95)	23 (20.72)		
GCS score			0.755	0.686
> 12	14 (35.89)	32 (28.83)		
8-11	16 (41.03)	53 (47.75)		
< 8	9 (23.08)	26 (23.42)		
Modus operandi			11.294	< 0.001
Traditional craniotomy	16 (41.03)	79 (71.17)		
Cone cranial MPST	23 (58.97)	32 (28.83)		
Operation time	78.41±11.28	89.18±20.84	4.021	< 0.001
Intraoperative blood loss	85.66±27.08	90.49±29.06	0.907	0.366

Note: GCS, Glasgow Coma Scale; MPST, Minimally Invasive Removal of Intracranial Hematoma.

Table 8. Multivariate Logistic regression analysis

danger indexes	*B*	*S.E.*	*Wald* χ^2	*P*	*OR (95% CI)*
Age	0.192	0.071	7.239	0.007	1.212 (1.054-1.394)
Modus operandi	1.332	0.418	10.165	0.001	3.789 (1.671-8.592)
Operation time	0.033	0.013	6.488	0.011	1.034 (1.008-1.060)

used to analyze their impact on the therapeutic effect. The results indicated that age, surgical method, and operation time were significant risk factors affecting the clinical efficacy of HICH ($P < 0.05$). See **Table 8**.

Discussions

In recent years, the incidence of hypertension has steadily increased, leading to a rise in the occurrence of hypertensive cerebral hemorrhage (HICH) [9]. Cerebral hemorrhage in cerebral lobes and basal ganglia is common in HICH [10]. Most HICH cases result from long-term high blood pressure, which causes atherosclerosis in the small arteries of the brain. This leads to a weakening of blood vessel walls. Factors such as limited expansion of small aneurysms, fatigue, emotional changes, and blood pressure surges can cause these aneurysms to rupture and result in bleeding [11, 12]. Currently, the clinical treatment of HICH primarily focuses on reducing intracranial pressure, alleviating edema, and preventing cerebral herniation. Therefore, the main treatment strategy is to remove intracranial hematomas and reduce inflammatory response.

At present, according to the treatment guidelines of HICH both domestically and internationally, surgical treatment is not routinely recommended [13-15]. This is particularly true for patients with cerebral hemorrhage in the basal ganglia, where the decision to choose surgery and the type of surgery to perform remains unclear. However, with the continuous advancement of medical imaging technology, surgical treatment for patients with cerebral hemorrhage has gained broader acceptance and recognition [16]. Despite this, the choice of the optimal treatment remains a challenging issue for clinicians. Traditional craniotomy hematoma removal is a classic method for treating HICH, effectively removing the hematoma and improving neurological symptoms. However, it is associated with significant trauma and a higher incidence of complications [17, 18]. In recent years, many reports suggest that patients with cerebral hemorrhage treated with minimally invasive hematoma removal can achieve better prognosis [19, 20]. MIRICH surgery has the advantages of less trauma, faster postoperative recovery, and fewer complications. Direct vision during surgery not only ensures effective hematoma removal but also prevents excessive traction that could worsen brain tissue damage. Studies have shown that for HICH in the basal ganglia, MIRICH surgery significantly improves hematoma clearance rate, reduces intraoperative bleeding and postoperative brain tissue edema, and enhances surgical outcomes [21]. The results of this study showed that compared with control group, patients in observation group had shorter operation time and hospital stay, and less intraoperative blood loss. The reason is that the cone skull MIRICH surgery is faster, uses a smaller surgical incision, is less invasive, and causes less tissue damage, leading to reduced intraoperative blood loss and a lower risk of complications, along with a quicker postoperative recovery. In addition, hematoma clearance rate is one of the most intuitive indicators for evaluating the effectiveness of surgical treatment [22]. In this study, the hematoma clearance rate in the observation group was 80.41±5.38%, and the total effective rate was 94.67%, both significantly higher than those in the control group (70.95±7.71%; 84.00%). The difference in treatment outcomes between the two groups can be attributed to the ability of MIRICH surgery to more accurately locate and remove the hematoma, thereby reducing the postoperative hematoma volume. This method is safer and more reliable, and it improves the overall efficacy of the treatment. Thanks to the clear surgical field of vision that MIRICH provides, deep hematomas can be completely removed, leading to better clinical outcomes [23].

The neurological deficit score usually includes assessments of the patient's level of consciousness, motor function, sensory function, language function, and other relevant parameters. The ADL (Activity of Daily Living) scale serves as a reference for evaluating a patient's ability to perform daily activities such as eating, bathing, and dressing, which is crucial for assessing the prognosis and recovery of HICH patients. The higher the ADL scale score, the greater the patient's self-care ability [24]. The NIHSS scale is widely used to evaluate the neurological function in stroke patients and is also the most common reference index to evaluate the degree of neurological impairment in patients with cerebral hemorrhage [25]. NIHSS can directly reflect the level of brain nerve function in patients with HICH after surgical treatment, incorporating scores of consciousness, eye movement, facial paralysis, limb movement, language, and sensation. The higher the total score, the more serious the neurological impairment [26]. In this study, the neurological deficit score and NIHSS scale score in the observation group were significantly lower than those in the control group three months post-surgery, indicating that MIRICH surgery led to better recovery of neurological function. This may be attributed to the minimally invasive nature of skull surgery, which involves a smaller incision, resulting in reduced brain tissue damage and promoting faster neurological recovery. Additionally, the ADL score for the observation group was significantly higher than that for the control group, indicating that patients undergoing minimally invasive surgery had better self-care abilities and improved quality of life. These findings further emphasize the advantages of minimally invasive surgery in enhancing patients' daily living activities and overall recovery. Studies have shown that, compared with small bone window craniotomy and microsurgery, neuroendoscopic surgery for paroxysmal hypertensive intracerebral hemorrhage leads to higher hematoma clearance rate, less intraoperative bleeding, shorter operation time, fewer hospitalization days, lower incidence of postoperative complications, lower NIHSS score and higher ADL score three months after surgery [27]. This finding of study is basically consistent with the above research.

Inflammatory factors such as TNF-α, IL-6 and hs-CRP play an important role in the occurrence, development, and prognosis of HICH. These factors are involved in the formation of cerebral hemorrhage and are significant in a series of inflammatory reactions and prognosis after cerebral hemorrhage [28]. After intracerebral hemorrhage, rapid inflammatory cascades occur in the tissues surrounding the hematoma, including the activation of microglia and astrocytes, and the infiltration of white blood cells [29]. These cells will release pro-inflammatory cytokines such as TNF-α and IL-6 after activation, which can further amplify the inflammatory response [30, 31]. Studies have shown that the levels of serum hs-CRP and IL-6 in patients with cerebral hemorrhage are closely related to the amount of cerebral hemorrhage and neurological impairment [32]. These inflammatory markers can serve as key indicators for diagnosing the severity of cerebral hemorrhage and predicting patient prognosis. Elevated levels of inflammatory biomarkers are associated with poor prognosis, including higher in-hospital mortality. The results of this study showed that the levels of serum TNF-α, IL-6 and hs-CRP in the observation group decreased significantly three months after surgery and were significantly lower than those in the control group. This indicates that conical skull MIRICH surgery may be more effective in reducing the level of inflammation-related biomarkers. MIRICH surgery plays a key role in reducing the body's inflammatory response and the levels of inflammatory factors by reducing surgical trauma and faster postoperative recovery [33]. The effectiveness of MIRICH surgery is also reflected in its promotion of neurological function recovery. By reducing the level of inflammatory factors, MIRICH surgery may provide a more favorable environment for recovery, which is helpful to improving the neurological function and quality of life of patients [34]. This was evidenced in the improvement of neurological function scores in the study. The neurological function score of the observation group was significantly decreased, indicating better recovery. Zhang et al. [35] showed that compared with craniotomy, minimally invasive surgery was more effective in the treatment of hypertensive cerebral hemorrhage, which was more conducive to the recovery of neurological function, improvement of prognosis and reduction of serum inflammatory factors.

As key cerebral hemodynamic parameters, Vm, PSV and PI are essential for evaluating changes in the cerebral vascular wall [36]. This study showed that, three months after surgery, the hemodynamic parameters (Vm, PSV and PI) in the observation group were significantly improved compared to those in the control group. This reflects the advantages of MPST surgery in improving the efficiency of hematoma removal, thereby improving the hemodynamic status of patients. For HICH patients, brain tissue compression, vasculopathy and cerebral hematoma are common factors leading to abnormal cerebral hemodynamics. These abnormalities are typically characterized by decreases in Vm, PSV and PI, indicating that MPST surgery helps restore cerebral blood supply by reducing vascular compression. The resulting increase in cerebral blood flow creates a favorable environment for the recovery of damaged neurological function, which is a key reason why MPST surgery accelerates the recovery of neurological function in patients [37]. Therefore, in this study, the cognitive function score in observation group was significantly better than that in control group. This result reveals the significant effect of MPST surgery in improving cerebral hemodynamics and promoting neurological recovery. In addition, during the postoperative observation period, the total incidence of postoperative complications was 12.00% in the observation group and 17.33% in the control group. The incidence of postoperative complications in the observation group was lower than that in the control group, indicating that conical skull MIRICH surgery can reduce the incidence of postoperative complications.

To identify factors affecting the clinical efficacy of HICH, this study divided patients into a recovery group (39 cases) and a non-recovery group (111 cases) according to the effect of surgical treatment. With recovery (yes = 0, no = 1) as the dependent variable and age, surgical method, and operation time as independent variables, a multivariate Logistic regression model was used to analyze their influence on therapeutic effect. The results showed that age, surgical method and operation time were significant risk factors affecting the clinical efficacy of MPS in the treatment of HICH. As age increases, physiological function changes, including a decline in immune function and metabolism, which may influence postoperative recovery and treatment outcomes. Older patients may also have poor tolerance to surgery due to decreased physiological reserves, increasing the risk of surgery [38]. Therefore, treatment plans should be adjusted according to the patient's age and other relevant factors to achieve optimal outcomes. The choice of surgical method also significantly affects treatment efficacy. Some studies [39, 40] have shown that surgical methods selection influences patient recovery and outcomes. For example, traditional craniotomy exposes brain tissue by cutting the skull and scalp, providing an open surgical field but resulting in large trauma. In contrast, minimally invasive surgery, performed through a small incision or a natural cavity, has less trauma, faster postoperative recovery, and fewer complications. In many cases, it may yield better efficacy than traditional craniotomy. However, the choice of surgical methods should be determined by professional doctors according to the specific conditions of patients and the characteristics of lesions. The length of operation time may also affect the therapeutic effect. Prolonged operation times can lead to various adverse events, increasing the risk of surgical failure, escalating health care costs, and even threatening the patient's life [41]. There is a certain correlation between the prolonged operation time and the increased risk of postoperative complications [42]. Therefore, efforts should be made to minimize the operation time to reduce the physiological burden on patients and lower the risk of postoperative complications.

The limitation of this study include the fact that all samples were sourced from a single center, and the relatively small sample size may introduce bias in the results. Future studies should aim to expand the sample size for further validation to reduce potential errors. The study participants were all middle-aged and elderly people, whose physical condition may have been relatively poor. Some patients experienced a prolonged recovery period after surgery, and future studies could benefit from extended follow-up periods. With the development of minimally invasive and endoscopic techniques, conical skull MIRICH surgery is expected to become more widely used in clinical practice, and prospective randomized controlled trials are needed to confirm its effectiveness.

In conclusion, a comprehensive analysis indicates that compared with traditional craniotomy, MIRICH surgery can improve the hematoma clearance rate in HICH patients, with better clinical efficacy and less trauma, which is conducive to the recovery of neurological function and patient prognosis. It also reduces the level of serum inflammatory factors, which is worthy of further promotion.

Disclosure of conflict of interest

None.

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