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Successful Administration of Minimally Invasive Decompressive Surgery in Treatment of Malignant Middle Cerebral Artery Infarction

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Abstract

Background: Malignant middle cerebral artery infarction (MMI) is the most devastating stroke. Decompressive hemicraniectomy (DHC) has been recommended as the first-line treatment for MMI for decades. Considering the limitations for DHC, such as aging impacting outcome, highly invasive procedure, delayed complications, we developed minimally invasive decompressive (MID) surgery as an alternative therapy for MMI.

Case summary: Here, we reported three cases of life-threatening MMI who accepted MID surgery and got good outcomes. The first was a 70-year-old male patient who developed acute MMI 17 hours after intravenous thrombolytic therapy. He underwent MID and a standard external ventricular drainage due to worsening consciousness. Another 58-year-old man who received endovascular therapy accepted MID 36 hours after attack. Due to increased exudation and large volume of aspiration, this patient developed postoperative hemorrhagic transformation. The third patient with a previous history of multime strokes quickly turned into herniation caused by a severe hemispheric infarction. Application of MID in the third patient was a little difficult due to a high suctioning resistance.

Conclusion: MID surgery is a feasible, safe and effective alternative treatment for some patients with MMI, and deserves fur-

ther clinical study and application.

Keywords: Malignant Middle Cerebral Artery Infarction; Minimally Invasive Decompression Surgery; Strokectomy; Stereotactic Aspiration; Decompressive Hemicraniectomy

Introduction

Malignant middle cerebral artery infarction (MMI) is associated with a rate of 68% of life-threatening edema [1] and a mortality of 78% ~79% without accurate diagnosis in the first few hours after the initial attack [2,3]. Most MMI patients died of refractory increased intracranial pressure (ICP) within 3-4 days of symptom onset [4,5]. Compared with conservative management, decompressive hemicraniectomy (DHC) with bone flap removal significantly reduced the mortality of MMI and improved the prognosis where a good outcome was defined as Modified Rankin Scale (mRS) ≤ 3[6,7]. European randomized controlled trials, including the French DECIMAL trial [8], the German DESTINY trial[9], and the Dutch trial HAMLET[10] had confirmed a reduce of 50% mortality in MMI patients who received DHC surgery. About 47% to 50% of the DHC-treated patients had a good outcome at 12 months after stroke compared with a rate of 22.2% to 27% in patients who received conservative treatment [8-10].

However, DHC was employed as a salvage surgery with a complication rate of 13% [11]. Early complications include hemorrhage, dysfunction of the CSF compartment, postoperative infection; and delayed complications include subdural hygroma, hydrocephalus, and syndrome of the trephined [12]. In addition, secondary cranioplasty is often required several months after DHC surgery, which increases the inherent risks and complications of the surgery as well as the additional medical costs of the operation [13]. To reduce ICP and save patients' lives who refused to accept DHC surgery, Dr Yang had developed an innovative operated method for MMI, minimally invasive decompressive (MID) surgery, that worked with small incisions, simple bedside procedures, low risk of general anesthesia, less blood loss, no need for a transplant, shorter surgery time and fewer complications

Methods

Surgical procedure

The goal of MID surgery is to relieve increased intracranial pressure caused by space-occupying cerebral edema in patients with MMI. To start MID, the surgeons need to make a small (5mm) incision on the scalp after local anesthesia, which causes less tissue disruption and blood loss than DHC. Then the surgeons used a high-speed dental drill to make a small cranial window (approximately 3~5 mm in diameter) in the frontal skull and cut open the dura mater. A sterile silicone tube was implanted into the infarct core under the guidance of CT imaging. Then a particular volume of infarct tissue was artificially suctioned using a 10 ml syringe (Fgiure1 a and l). The first aspiration volume was between 15~60 ml depending on the clinical symptoms and the degree of midline shift on CT imaging. Then the aspiration tube was ligated on the scalp and connected to an external sterile bag for continuous external drainage. Postoperative brain CT scan was routinely conducted to evaluate the changes of brain edema, and intermittent aspiration by using 10 ml syringe was required subsequently to achieve effectively decompressive effects by adjusting the position of the drainage tube. Generally, the drainage tube was removed after 5~7 days.

Results

Case 1

A 70-year-old right-handed male patient with a history of hypertension was admitted due to acute left hemiparesis and speech impairment for 2.5 hours in February 2021. The initial National Institute of Health Stroke Score (NIHSS) score was 14. There was no significant abnormality in the blood profiles and no signs of hemorrhage on brain CT. Recombinant tissue plasminogen activator, alteplase, was administered intravenously within one hour. Approximately 17 hours after thrombolysis, his condition dete-

riorated to unconscious with dilated pupils and slowed pupillary light reflex response, adding a Glasgow Coma Scale (GCS) of 5. A repeat brain CT scan (Figure 1 b) showed space-occupying infarction that caused mid-line shift and compression of the lateral ventricle. Time-of-flight brain MR angiography (MRA) and Doppler ultrasonography did not disclose visible stenosis or occlusion of the right carotid artery, MCA or anterior cerebral artery (ACA, Figyre 1 f). While, routine holter monitoring had detected paroxysmal atrial fibrillation suggesting cardioembolism and successful thrombolytic therapy for this patient. Although adequate osmotherapy had been administered, the patient's condition progressively deteriorated. However, his family refused to take DHC surgery. Then we performed MID at the bedside with the written informed consent. The first aspiration volume after operation was 20 ml. Postoperative brain CT scan at 12 hours indicated exacerbation of brainstem compression. Then the patient underwent a standard external ventricular drainage (EVD) on the contralateral hemisphere for temporally controlling ICP (Figure1 c). We subsequently carried out intermittent aspiration according to clinical manifestation and CT imaging (Figure 1 d). The aspiration volume in the following days was 52ml on day two and 7ml on day four after MID. Then we removed the MID drainage system after five days' reservation with a total aspiration volume of 79 ml, and the EVD system was kept for ten days with a total drainage volume of 1385ml.

Adequate postoperative management was added to avoid incision and shunt infection. On day eight after MID, he could open eyes occasionally with GCS score increasing to 7; cerebral edema tended to alleviate on CT imaging at this time. On the 14th day, the lesion on diffusion-weighted imaging (DWI) shrank (Figure 1 e), and the cerebral edema had almost disappeared. His consciousness improved significantly with autonomic activities in the right limbs. However, this patient developed sever pulmonary infection with bilateral pleural effusion, thus we performed a tracheotomy to alleviate hypoxia on day three after MID. Meanwhile, we used a tube thoracostomy drainage to relieve pleural effusion on day eight after MID under consecutive administration of antibiotics with Cefperazone--Sulbactam and meropenem according to sputum culture and drug-sensitive test. The patient's mRS was up to 4 through 2 months' medical treatment and 4 months of rehabilitation. Radiological iamges showed encephalomalacia on CT scan and better morphology of cerebral vasculartur on MRA (Figure 1 j).

Case 2

A 58-year-old right-handed man without medical history was diagnosed with acute cerebral infarction with acute speech deficit and left hemiparesis for an hour in August 2020 (Figure 1 h). The initial NIHSS score was 12 with a blood pressure of 166/94 mmHg. Due to the concern of hemorrhage risk, his family refused intravenous thrombolysis but agreed to take cerebral angiography, which confirmed the occlusion of the M1 segment of the right MCA (Figure 1 q). Then intra-arterial thrombolysis with urokinase at a dosage of 200,000 UI was performed 3 hours after the attack, followed by mechanical thrombectomy at 6.5 hours. Brain CT scan after thrombectomy showed high density in the right frontal and temporal lobe (Figure 1 i), which was considered to be caused by contrast medium extravasation rather than hemorrhagic transformation. At 36 hours after thrombectomy, the patient became progressively obtunded with a NHISS score of 20, GCS of 8, and brain CT scan showed MMI with ipsilateral ventricular compression and midline shift (Figure 1 j), which was probably caused by hyperperfusion injury. Then the MID was operated under the guidance of CT imaging. Multiple aspiration was performed according to the clinical manifestation and CT imaging (Figure 1 k and m), and most of the suctioned content was liquefaction tissue. The first aspiration volume was 60 ml, then 43 ml on day two, 60 ml on day three, 10 ml on day four, and 10 ml on day six when the patient's symptoms improved with a GCS of 13(Figure 1 n).

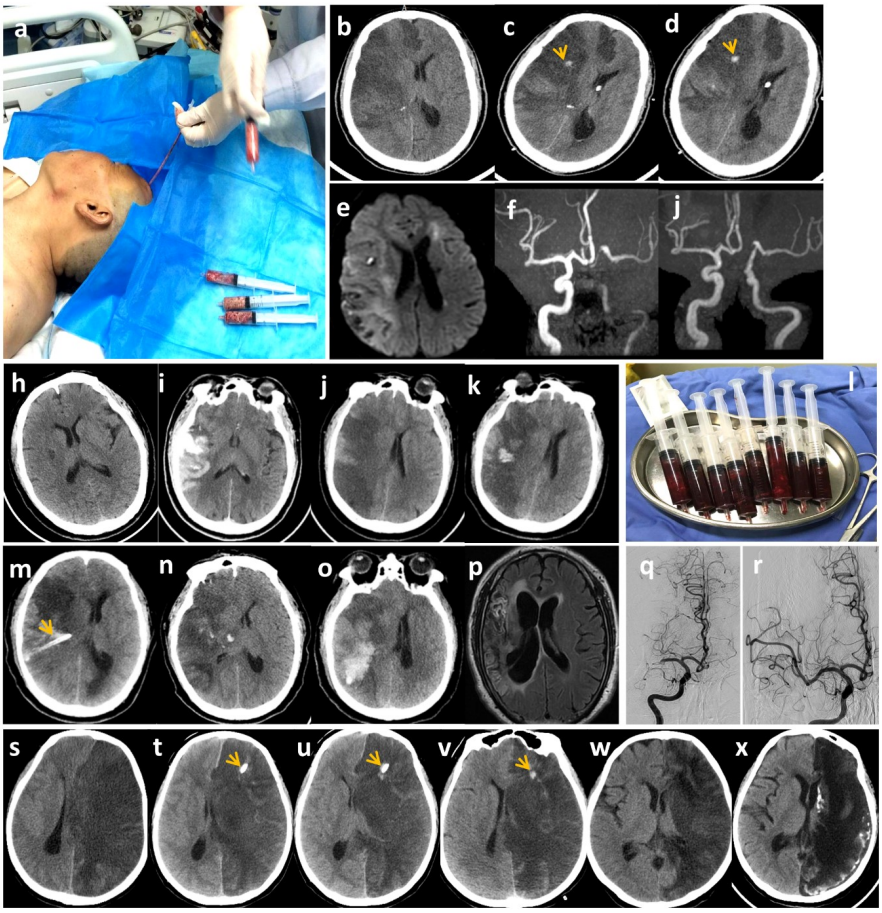

Figure 1: Operation procedure and radiological findings in patient 1. Radiological findings in Patient 2 (h~r) and 3 (s~x)

The drainage system was removed on day seven after MID surgery when the CT scan alleviation of cerebral edema was visible, and the total drained volume was 183 ml for necrotic brain tissue and liquefaction. Conservative medical management was continued throughout the treatment. However, his consciousness deteriorated, companied by vomiting and left mydriasis 8 hours after removal of the drainage tube, and GCS dropped to 8. Brain CT scan showed hemorrhagic transformation in the ipsilateral infarction area (Figure 1 o). Then we operated minimally invasive puncture and drainage (MIPD) to suction the hematoma; and the drainage was kept for seven days. After medical management and rehabilitation of 4 months (Figure 1 p and r), his NIHSS score decreased to 6, and mRS score was 2 for independent movement.

Case 3

A 58-year-old right-handed female was found to be in coma for 8 hours in March 2019. Her blood pressure was 170/100 mmHg on admission. During the past two months, she had been attacked twice by ischemic stroke with definite neurological deficits under regular oral aspirin administration due to right internal carotid artery stenosis. The ultimate NIHSS score was 14, and mRS was 4 with grade 0 myodynamia of right extremities prior to this admission. Neurological examination on admission showed coma, GCS of 7, NIHSS of 32, anisocoria with mydriasis, and no pupillary light reflex response on the left side. An emergent brain CT scan revealed an extensive left-hemispheric infarction with malignant space-occupying brain edema and bilateral ventricular compression (Figure 1 s), indicating supratentorial herniation and a life-threatening situation in this patient. MID surgery was performed immediately with written consent from her family. Meanwhile, hyperventilation and mannitol were routinely used to relieve the increased ICP.

The first aspiration volume was 50 ml on the operation day. One day after MID, the level of consciousness had improved. Cerebral edema was slightly alleviated on

brain CT scan with decreased decompressed contralateral ventricle but still with significant midline shift (Figure 1 t). Then, we performed the second asipiration but suctioned only a small volume of 10 ml of necrotic brain tissue due to high resistance. During the following days (Figure 1 u), we attempted to suction more necrotic tissue by adjusting the position of the drainage tube but all failed. Six days after MID surgery (Figure 1 v), she was alert but hemiplegic, obeying commands, and decreased midline shift was visible on the head CT scan (Figure 1 w and x). Therefore, the aspiration tube was removed by that time. Surprisingly, she was able to communicate with single words 9 days after surgery, and discharged from the hospital 24 days after the surgery for further rehabilitation. Her mRS score was up to 3 for independent movement at 6 months' follow-up.

Discussion

In this study, we developed MID surgery as a potential therapeutic method for supratentorial MMI, including those with additional involvement of the anterior and/or posterior cerebral artery territory. Here, we showed three representative cases of MMI that successively received MID and got satisfactory outcomes (Table 1).

DHC had been recommended by international guidelines as the first-line treatment of MMI [14,15], especially for patients under 60 years old with hemispheric infarction within 48 hours of onset, to relieve intracranial hypertension which may otherwise cause transtentorial herniation [14]. While, a single-center cohort study recently showed that the prognosis of MMI patients who have undergone DHC after 48 h was not worse than those performed within 48 h [15]. Age, infarct volume, and NIHSS scores before hemicraniectomy were considered the independent predictors of unfavorable outcomes after surgery [7,16, 17]. Patients with an infarct volume of > 258 ml before DHC tend to present an unfavorable outcome after surgery [16]. In the subgroup analysis of hemispheric cerebral infarction involving additional anterior and/or posterior artery territories, intracranial pressure reduction after DHC was not always satisfactory. Enhanced postoperative management, such as the possible removal of necrotic tissue by secondary strokecectomy, can further reduce the mortality in patients with hemispheric infarction beyond the MCA region [18,19]. However, a secondary surgical procedure was required; and the risk of surgery and complications (infection, hemorrhage, hydrocephalus, epilepsy, etc.) and medical costs increased.

Different from hemicraniectomy, strokectomy which had been performed by surgical removal of enough infarct brain tissue was designed to alleviate the deleterious effects of progressive ICP with preservation of the integrity of the skull. Compared with DHC, patients with strokectomy had a smaller craniotomy diameter (85±4.1mm vs. 120±13.1mm) and less common complications (25% vs. 55%)[20]. In some studies, as a postoperative adjuvant treatment to control refractory ICP or severe herniation after DHC, strokectomy had been demonstrated to further reduce the mortality of 8% of patients with large supratentorial infarction [21,22]. Recently, published data from small series of clinical research in some stroke centers showed that strokectomy alone is beginning to be used as a major treatment for MMI [23]. Although they found that strokectomy may be comparable to DHC for the treatment of supratentorial infarction, and efficiently reduced mortality and improved prognosis with lower risk of complications, however [23], it has not been widely recognized and used by neurologists due to the lack of evidence from large-scale randomized controlled clinical trials. But it showed that it is possible and maybe a safe method to remove necrotic tissue by accurate aspiration to relieve ICP and reduce mortality in a subgroup of patients with MMI.

In this study, Dr Yang had developed MID surgery which was modified on the strokectomy for those who refused to take invasive DHC surgery. For the operation of MID, necrotic brain tissue was suctioned through a minimal cranial window (5mm diameter) without removal of a bone flap. The unique advantage of MID over DHC and strokectomy for treatment of MMI is that we did not consider aging as a restriction on therapy due to the minimally invasive procedure and the low risk of the operation. Meanwhile, it avoids the inherent risks of surgery including general anesthesia, blood loss, secondary grafting and postoperative complications. Aspiration volume and frequency varied according to symptoms and brain CT imaging. In this report, the three patients showed relatively good outcomes. Multiple decompressive aspiration for the third patient was difficult in light of suction resistance. The total drainage vol-

ume of the third patient was only 60 ml although she presented supratentorial herniation,but her prognosis is surprisingly satisfactory.

The most concern for MID is the hemorrhagic transformation during and after the operation. In a MMI, the infarct tissue undergoes liquefactive necrosis with no signs of blood perfusion within a few hours after ischemia onset, then grossly turns to swollen, soft, and inactivated albino mass [24]. Therefore, it is theoretically possible to relieve ICP by partial resection of infarct brain tissue without affecting the surviving region either through strokectomy under a smaller cranial window or mild aspiration without craniectomy instead of extensive DHC surgery. Due to the compressive effect of space-occupying edema and lack of blood perfusion, there is a low risk of hemorrhagic transformation during aspiration under proper management of the timing and suction volume [25]. The second patient underwent hemorrhagic transformation due to massive effusion and subsequently frequent aspiration with a big total suction volume of 183ml. None of the published clinical studies on strokectomy either as a primary or adjuvant treatment for MMI mentioned the incidence of cerebral hemorrhage, which suggested that cerebral hemorrhage transformation was not considered as a major complication, or at least as a dominant factor affecting the prognosis of MMI treated by aspiration [20-23,25,26].

Recently, a similar treatment for MMI in patients older than 60 years by stereotactic aspiration of necrotic brain tissue in a clinical center in China had been reported [27]. For patients accepted stereotactic aspiration, the 30--day mortality rate was 15.4% and the satisfactory outcome was observed in 54.5% patients. A later randomized controlled trial showed outstanding clinical efficacy in stereotactic aspiration treated patients in comparison to DHC [28]. Our case report concurred with the previous literature suggested that MID alone maybe a feasible, safe and effective method to treat MMI; and MID may be an alternative to DHC in the management of MMI in some patients. However, unpredictable challenges may be encountered during operation, such as complication of severe pneumonia for first patient, the large exudation for the second patient, and high suction resistance for the third patient. Developed as a new and exploratory therapeutic method for supratentorial MMI, the surgical procedure of MID needs to be optimized such as the operation timing, frequency, intervals, volume of the aspiration and the duration of catheter reservation.

Conclusion

Our study provided a brand-new perspective on treating supratentorial malignant hemispheric infarction. Based on this report, we believe that MID may have a satisfactory therapeutic effect on MMI in some patients. However, it's necessary to conduct more research with large populations to obtain more reliable results.

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Contributorship statement

Jinbo Yang: developed and performed MID surgery, responsible for interpretation of the surgery procedure; Yuqi Pei: collected and analysed data, firstly drafted manuscript, and followed-up for patients; Rujuan Li, Xiaohui Ma and Huanfeng Hou participated in the MID surgery, provided care for study patients; Xiangjian Zhang: designed study, responsible for quality control of the study; Lili Cui: designed study, drafted and revised manuscript, responsible for acquisition and interpretation of data. All authors revised and approved the final version of the manuscript.

Competing Interests

The authors declare that there are no conflicts of interest.

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Ethics Approval

Approval was obtained from the ethics committee of Xingtai Ninth Hospital.

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