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Case report

3D Slicer combined with neuroendoscopic surgery for the treatment of basal ganglia hemorrhage after cranioplasty: A case report and literature review

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A B S T R A C T

The minimally invasive surgery through transcranial endoscopic keyhole approach has become the main surgical method for treating cerebral hemorrhage. This method has the advantages of small trauma, short surgical time, low bleeding volume, and fast postoperative recovery. However, this method is not suitable for cases where cerebral hemorrhage occurs again after skull repair surgery. Our team used 3D Slicer reconstruction combined with virtual reality technology to find a suitable keyhole surgical approach and successfully completed a neuroendoscopic removal of basal ganglia hemorrhage through the eyebrow arch keyhole approach in a case of recurrent cerebral hemorrhage after cranioplasty.

1. Introduction

Cerebral hemorrhage is the most common cause of death and disability in stroke, accounting for only 13–20 % of all cases [1]. However, it is closely related to poor prognosis and poses a serious threat to patients' lives, health, and quality of life. Basal ganglia hemorrhage is the most common location of cerebral parenchymal hemorrhage, and hypertension leading to rupture of the lenticular artery is the most common cause of basal ganglia hemorrhage. Although the efficacy of surgical intervention in the treatment of cerebral hemorrhage is still controversial, surgical treatment is still the mainstream treatment measure internationally [2,3]. The traditional surgical methods include large bone flap craniotomy under a microscope or hematoma drilling and drainage surgery with/without navigation guidance, combined with urokinase treatment. In recent years, the development of neuroendoscopy has

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gradually replaced traditional craniotomy surgery, and the selection of surgical approaches has also undergone rapid changes [3–5]. Neuroendoscopic keyhole approach surgery is a new minimally invasive surgical method with advantages such as minimal trauma, fewer complications, and good prognosis. It offers a wide range of potential applications in the surgical treatment of cerebral hemorrhage.

In this case, we reported a case in which a titanium plate blocked all possible keyhole minimally invasive surgical approaches within the forehead and temporal hair bun, making it impossible to perform conventional neuroendoscopic keyhole minimally invasive surgery. Conventional surgical methods allow only the titanium plate to be removed along the large original surgical incision prior to hematoma removal surgery, which carries the risk of significant trauma, long surgical time, and multiple complications. Our team actively evaluated and simulated the surgical plan through preoperative 3D Slicer reconstruction of virtual reality images of the patient's hematoma and skull. We successfully removed the basal ganglia hematoma using a neuroendoscopic approach through the supraorbital eyebrow arch keyhole.

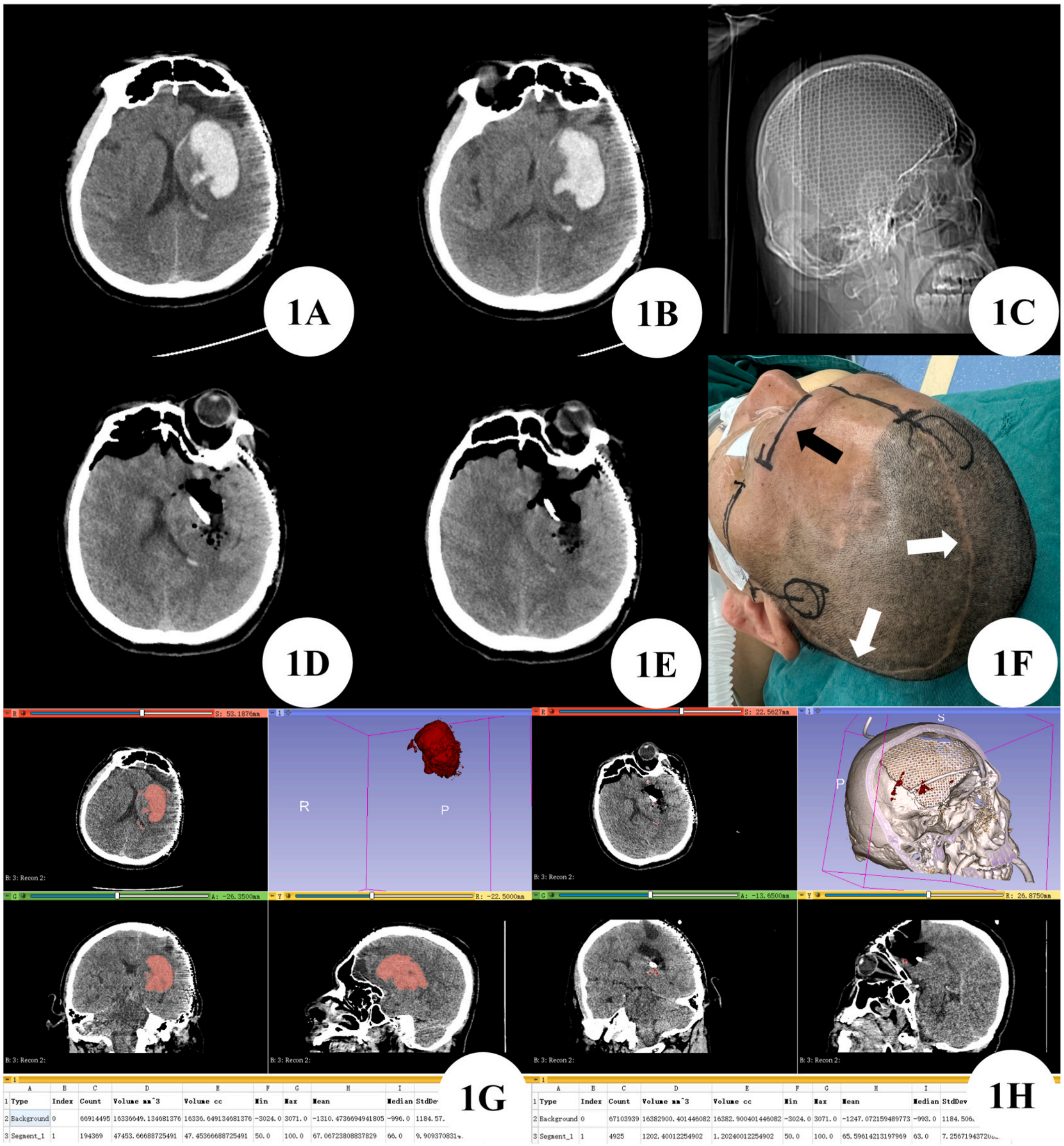

Fig. 1. A–B: Preoperative cranial CT shows cerebral hemorrhage in the left basal ganglia area. C: Preoperative cranial CT shows the left basal ganglia area. Preoperative cranial CT shows a large area of metal repair material in the left frontal and temporal skull. D–E: Postoperative cranial CT shows that the hematoma in the left basal ganglia area has been completely cleared. F: Giant original surgical scar (white arrow) and small eyebrow arch keyhole surgical incision marking line (black arrow). G–H: The 3D Slicer accurately calculated the amount of hematoma before and after surgery, and the calculated hematoma clearance rate was 97.47 %.

2. Cases presentation

A 33 years old male patient, admitted to the hospital for more than 6 hours due to a sudden consciousness disorder. Previous history of brain injury surgery, left frontotemporal parietal decompressive craniectomy and titanium plate skull repair, and history of hypertension. After admission, a cranial CT scan showed cerebral hemorrhage in the left basal ganglia area. The patient has consciousness disorders, a large amount of hematoma, and clear surgical indications. The conventional surgical plan can choose to undergo intracranial neuroendoscopic hematoma removal through the temporal or frontal hairpin keyhole approach. But the patient has a history of extensive titanium plate cranioplasty on the left frontal and temporal top, and currently, all suitable surgical approaches are blocked by titanium plates. In order to avoid using the original incision approach to remove the titanium plate for large bone flap craniotomy surgery, our team collected raw CT data of the patient's cranial thin layer before surgery, in the format of DICOM, and imported the above data of the patient into the 3D-Slicer system (https://www.slicer.org). Reconstructing the virtual reality model of hematoma, titanium plate, and skull revealed a small skull position at the supraorbital eyebrow arch that was suitable for keyhole surgery. After simulating the surgery with virtual reality technology, the feasibility was evaluated and the above plan was ultimately decided for surgical treatment. The intraoperative use of transcranial neuroendoscopy and Endoport technology for minimally invasive removal of hematoma resulted in good results. According to precise 3D Slicer calculations, the preoperative hematoma volume was 47.5ml, and

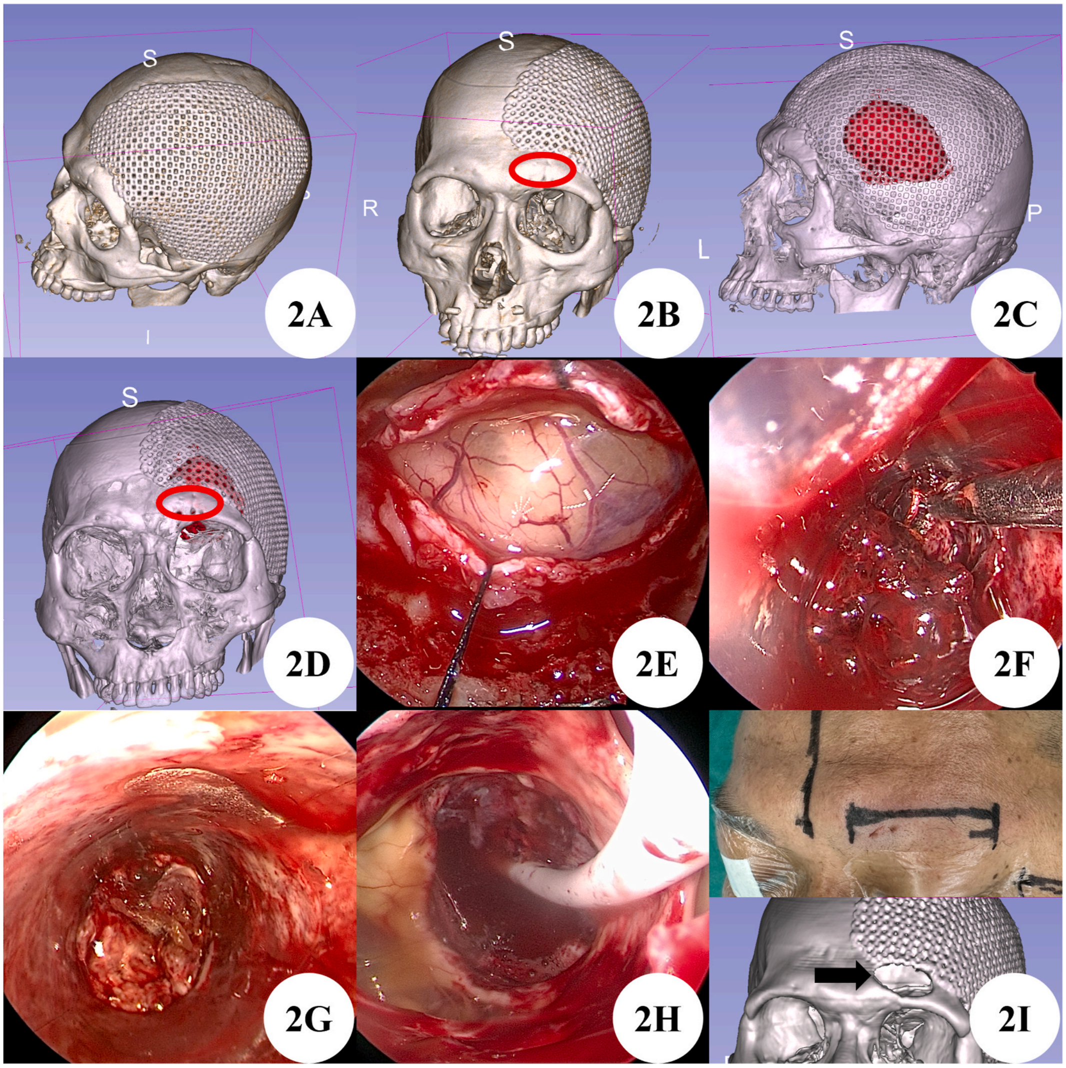

Fig. 2. A–D: Before surgery, 3D Slicer was used to reconstruct virtual reality images of the skull and hematoma, and a small area without titanium plate coverage (red ellipse) was found at the left eyebrow arch. After active comparison and virtual surgical simulation, neuroendoscopy can be used to minimally invasive remove the hematoma in the basal ganglia area through surgery at this location. E: Under neuroendoscopy, the dura mater was cut open and high intracranial pressure was observed. F–H: Neuroendoscopic removal of hematoma, rigorous hemostasis, and placement of hematoma cavity drainage tube under endoscopic visualization. I: Marking of incision for eyebrow arch keyhole surgery and 3D Slicer reconstruction of keyhole bone window after surgery (black arrow).

the postoperative hematoma volume was 1.2ml. The hematoma clearance rate was as high as 97.47 %. At the time of discharge 2 weeks after surgery, the patient had clear consciousness, normal muscle strength in the left limb, and muscle strength in the right limb was level 2. After 3 months of postoperative telephone follow-up, the patient was able to walk with crutches except for slightly weaker muscle strength in the right limb, and there were no other neurologically positive findings (Figs. 1 and 2).

3. Discuss

Cerebral parenchymal hemorrhage accounts for about 10–20 % of all strokes and has a poor prognosis [2]. The surgical benefits are largely dependent on the surgical approach and protection of the normal brain tissue structure around the hematoma. Traditional surgical methods often use a frontal or temporal cortical fistula approach, which has shortcomings such as high invasiveness, inability to protect still functional brain tissue, and even the need to remove the skull simultaneously when necessary to achieve complete decompression. This type of surgery has significant trauma and requires cranioplasty in the later stage, which brings enormous psychological, physiological, and economic pressure to patients and their families. For patients with small hematomas or discomfort from physical reasons undergoing craniotomy surgery, drilling drainage combined with urokinase to dissolve blood clots for drainage has previously been used extensively. This method is not thorough in reducing pressure and has a high rate of re bleeding. In recent years, minimally invasive brain hematoma removal surgery under neuroendoscopy has gradually replaced traditional craniotomy surgery to minimize unnecessary brain tissue damage. Compared with craniotomy, neuroendoscopic keyhole approach for intracerebral hematoma removal has the advantages of minimally invasive, high-definition, fast speed, fewer complications, and good prognosis [4,6,7]. Because neuroendoscopic keyhole surgery is a minimally invasive surgery, precise positioning and selection of surgical approach positions are particularly important. Lin et al. pioneered a surgical approach for treating hypertensive basal ganglia hemorrhage using a previously scaly suture centered keyhole approach [5]. This approach can form an accurate and reliable keyhole position, and enter the hematoma cavity of the basal ganglia area through the natural gap of the lateral fissure without damaging the cortex and important subcortical structures. A large number of clinical studies [1,6–8] have shown that Endoport technology assisted neuroendoscopic approach via the frontal or temporal cortex is currently the most common choice. Neuroendoscopic removal of intracerebral hematoma is a intracavitary surgery for hematoma, which helps to minimize the impact on normal brain tissue in the surgical pathway. Gao et al. [9] had shown that microsurgical treatment of basal ganglia hemorrhage through the distal lateral fissure approach has advantages such as minimal brain tissue damage, high hematoma clearance rate, and good neurological function recovery. On the basis of the aforementioned approach surgery, Liu et al. [3] attempted to remove basal ganglia hematoma through the lateral fissure approach assisted by Endoport technology. They found that the lateral fissure approach can enter the hematoma cavity through direct, short distance, and precise channels, causing minimal damage to the functional cortex and deep subcortical functional structures. Meanwhile, Endoport can also protect the blood vessels and neural structures along the surgical pathway. Kim et al. [10] and Chen et al. [11] reported early on that the transinsular approach for clearing basal ganglia hematoma can cross most important brain functional areas such as the midbrain, internal capsule, and thalamus, and has the highest hematoma clearance rate. Ding et al. [2] reported a case of minimally invasive anterior skull base keyhole craniotomy under neuroendoscopy for the treatment of basal ganglia cerebral hemorrhage. They pointed out that the minimally invasive anterior skull base approach has the potential for intracavitary assisted surgical approach. Yuan et al. [12] introduced laser guided puncture and drainage surgery for basal ganglia hematoma, emphasizing that this surgical method is a low-cost, accurate, and safe approach.

However, regardless of the above methods, if all possible approaches within the forehead and temporal hair bun are completely blocked by titanium plates, then all minimally invasive keyhole surgeries will not be successful. The only solution is to perform another craniotomy along the huge original surgical incision, remove the previously repaired titanium plate, and then proceed with cerebral hemorrhage surgery. If done in this manner, not only will the surgical time be extended, the trauma will be severe, and the amount of blood loss will be significant, but the incidence of postoperative complications will also be high [13]. Our team once faced a special patient who had a history of titanium plate cranioplasty after brain injury surgery. In the long term after surgery, there was ipsilateral basal ganglia cerebral hemorrhage, and the amount of bleeding needed to be treated again. All possible minimally invasive surgical approaches in the frontal and temporal hair buns were blocked by titanium plates, and conventional surgery had significant trauma, making it impossible to perform modified minimally invasive surgery. Our team used 3D Slicer to reconstruct the location of hematoma and titanium plate, and we performed a thorough preoperative evaluation and 3D simulation surgery. We found a skull above the eyebrow arch that had not been blocked by the titanium plate. We can try minimally invasive surgery through the supraorbital eyebrow arch keyhole approach. After active preoperative evaluation and 3D virtual reality technology simulation surgery, the final surgery was successfully completed with the assistance of transcranial neuroendoscopy and Endoport technology. Through precise 3D Slicer calculations, the hematoma clearance rate was as high as 97.47 %, with good results.

Our previous research [14–16] has shown that 3D Slicer reconstruction and combined with Sina/MosoCam/3D printing positioning technology can effectively guide preoperative planning and precise intraoperative positioning. This case is another excellent clinical application of 3D Slicer, combined with neuroendoscopy and Endoport technology, which can provide good preoperative planning and guidance for patients with cerebral hemorrhage requiring minimally invasive surgical treatment after artificial material cranioplasty. It also provides a new and good choice for such cases in the future.

4. Conclusion

Although recurrence of ipsilateral intracerebral hemorrhage after cranioplasty is extremely rare and the surgical difficulty is not high, conventional surgery is traumatic, time-consuming, and has many complications; However, the minimally invasive keyhole approach under neuroendoscopy needs to avoid repairing materials such as titanium plates perfectly, which poses certain difficulties. We innovatively used 3D Slicer to reconstruct virtual reality images for detailed preoperative evaluation and surgical simulation, and thoroughly cleared cerebral hemorrhage in the basal ganglia area through the supraorbital eyebrow keyhole approach under neuroendoscopy. Although this was the first attempt for this special case, we achieved good results, providing a new and good choice for future such surgeries.

Ethical approval

All patients or family members have signed informed consent forms for surgery. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the ethics committee of Clinical Research, Our Hospital (Renmin Hospital of Wuhan University, WDRY2023-K139, 2023-9-12).

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CRediT authorship contribution statement

Long Zhou: Writing – original draft, Methodology, Data curation. **Gang Xu:** Writing – original draft, Methodology, Data curation. **Kang Liu:** Writing – original draft, Methodology, Data curation. **Huikai Zhang:** Data curation. **Pan Lei:** Data curation. **Minghui Lu:** Data curation. **Ping Song:** Data curation. **Zhiyang Li:** Data curation. **Lun Gao:** Data curation. **Qiuwei Hua:** Data curation. **Qianxue Chen:** Data curation. **Qiang Cai:** Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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