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# Mini Craniotomy in the Management of Supratentorial Spontaneous Intracranial Hemorrhage: A Single-Center Outcome of the Minimally Invasive Treatment

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**Abstract**

Hemorrhagic stroke accounts for a significant proportion of mortality and confers a poor quality of life with high dependency among survivors. Surgical evacuation of hematoma has the advantage of rapidly controlling the increased intracranial pressure, halting the ongoing herniation syndrome, and mitigating the secondary cascades of events mediated by the inflammatory and blood degradation products. The advantage is hindered by the concurrent insult to the healthy brain tissue while passing through the normal brain tissue. Therefore, minimally invasive approaches to evacuate the hematoma are employed, but the need for an expensive surgical armamentarium and the expert multidisciplinary team is the bottleneck for their application, particularly in low-income nations. We herein performed a study upon the role of mini craniotomy open surgical method of evacuating hematoma in selected patients with supratentorial intracerebral hemorrhage. We found a significant reduction in the surgery length, minimized risk of post-surgery complications, shortened intensive care unit stay, and reduced mortality compared to the full-fledged craniotomy and endoscopy-guided surgery. There is a need for a large-scale randomized multicenter prospective study to verify the advantages of minimally invasive approaches in the management of symptomatic supratentorial intracerebral hemorrhages.

**Keywords**

Brain · Craniotomy · Hematoma · Intracerebral hemorrhage · Minimally invasive surgery · Mortality

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## 1 Introduction

Spontaneous intracerebral hemorrhage is responsible for 9–27% of all strokes (Feigin et al. 2009). The mortality rate within 30 days has been reported to be as high as about 30% (Smajlović et al. 2008). Long-term survivors are often saddled with permanent deficits, with up to 75% suffering a significant disability. Surgical intervention is recommended for patients with a clot volume from 20 mL to 80 mL, worsening neurological status in relatively young patients, and hemorrhage causing midline brain shift or raised intracranial pressure (Siddique and Mendelow 2000). Various surgical strategies have been described ranging from craniotomies, decompressive surgery, to minimally invasive modalities like a stereotactic or endoscopic-aided aspiration. Craniotomy or decompressive large craniectomy facilitates good evacuation of hematoma and ensures effective hemostasis. However, the morbidity associated with general anesthesia, prolonged surgery duration, and blood loss is the inherent limitations. In minimally invasive procedures, the morbidity of extensive craniotomy can be obviated. Conventional craniotomy has a high mortality rate of 22–36%. Minimally invasive procedures have a high evacuation rate, low incidence of complication, better protection of normal neural tissue, and fewer surgery-related injuries. Direct visualization of bleeding points and coagulation of the responsible vessels also is feasible. The incidence of infectious complications is low, skin incisions are smaller, and surgery and intensive care unit stay are shorter (Zhang et al. 2014). Minimal invasiveness also encompasses collateral economic benefits, which plays an essential role in the health sector of low-to-middle income nations. The endoscopy-assisted evacuation of intracerebral hematoma is associated with a minimal rebleeding, reaching a meager 0–3.3% when compared to the 5–10% of the classical craniotomy approach (Gaab 2011). Minimally invasive procedures, however, require sophisticated and expensive armamentariums and the expert staff team for conducting specialized procedures such as endoscopy with neuro-navigation and catheter drainage. This study presents clinical outcomes in patients with spontaneous intracerebral hemorrhage treated with mini craniotomy in a tertiary hospital in Nepal. Minimally invasive surgery was performed with rather limited resources based on standard neurosurgical instruments, optimized direct visualization, and was aided with controlled brain retraction.

## 2 Methods

### 2.1 Patients

Eighty-five stroke patients, aged 52 ± 9 (M/F – 69/16), with lobar cortical and basal ganglia hemorrhages, treated with the minimally invasive approach of mini craniotomy in a tertiary hospital in Nepal were included in the study. A volume of hematoma was calculated from computer tomography (CT) images according to Kothari et al.'s (1996) formula. The specific anatomical site of the basal ganglionic hemorrhage was set according to Chung et al.'s (2000) localization scheme.

Inclusion criteria were as follows:

- Patient's age above 15
- CT scan showing spontaneous lobar or basal ganglia hemorrhage.
- Hematoma volume $\geq$ 30 mL
- Glasgow Coma Scale (GCS) motor score on admission $\geq$4 points

Exclusion criteria were as follows:

- Hemorrhage caused by secondary factors like vascular malformations, tumors, or head injury
- Features of advanced herniation with infarction seen in the neuroradiologic examination
- GCS motor score on admission <4 points
- Multiple intracranial hemorrhages
- Clotting disorders
- Preexisting neurological deficits like previous intracerebral hematoma or infarct
- Gross ventricular enlargement
- Consent refusal

## 2.2 Sample Size Calculation

The minimum statistically meaningful sample size of patients for this study was calculated using the formula:

$$N = z^2 \, x \, p \, x \, q/d^2$$

where $Z = 1.96$ at 95% confidence interval

$p$ = prevalence of hemorrhagic stroke taken as 30%
$q$ = 1-p
$d$ = margin of error taken as 10%

The result of the calculation was 80.8, and we included 85 patients in the study.

Overall, we recorded and evaluated the following elements: clinical and radiological outcomes, demographic data, hematoma volume, GCS on admission, duration of the surgical procedure, intraoperative and postoperative complications, and duration of stay in the intensive care unit (ICU) after surgery.

## 2.3 Surgical Approach

Surgery was performed under endotracheal general anesthesia. A linear skin incision was made. Mini craniotomy of 2.0–2.5 cm in diameter over a frontal or skull parietal area was depending on the shortest way to the epicenter of a hematoma. A cruciate dural opening followed by a small corticotomy was made over the relatively non-eloquent area. The hematoma was then evacuated using controlled suction aided with biopsy forceps to mince the hematoma. Hemostasis was achieved by continuous saline irrigation, pressure packing, using a bipolar cautery, and standard micro-neurosurgical techniques. The hematoma cavity was lined with fibrin sealant and the dura was left open and covered with gel foam. The bone was repositioned. The scalp was then closed in layers.

# 3 Results

Clinical features of hemorrhagic stroke patients are shown in Table 1. Although a documented history of arterial hypertension was present in 71 (83.5%) patients, compliance with antihypertensive treatment, the therapy was seen in only about one-third of them. The proportion of basal ganglia and cortical lobar bleeds was 3 to 1. In basal ganglia, the anatomically lateral variant was the most common hemorrhage site in 38 (59.4%) out of the 64 patients, followed by the massive hemorrhage in 19 out of the 64 (29.7%) patients, and the anterior variant in 7 (10.9%) out of the 64 patients. The mean volume of hematoma was 46.5 ± 10.5(SD) mL, the mean duration of the surgical procedure was 36.5 min, and the mean post-surgery time spent in the ICU was 3.2 ± 0.8 days. A difficulty in achieving hemostasis deep inside the hematoma cavity was seen in 2 cases only and the rebleeding occurred in 3 (3.8%) out of the 85 patients with re-evacuation carried out in 2 of them. Three (3.8) patients died, with pulmonary embolism accounting for two deaths and ventriculitis for one.

The mini craniotomy bone flap and the postoperative CT-reconstructed 3D skull image are schematically illustrated in Fig. 1. Representative examples of preoperative and postoperative CT images of the cortical and basal ganglia hemorrhage sites are demonstrated in Fig. 2.

# 4 Discussion

Primary injury caused by spontaneous intracerebral hemorrhage is mainly due to the mechanical mass effect of a hematoma. Secondary injuries are triggered by the developing inflammation and degraded blood products. The prime benefit of surgical evacuation is the rapid control of increased intracranial pressure, which mitigates the harmful cascade of cerebral herniation,

**Table 1** Clinical features

| | |
|---|---|
| Age (years) | 52 ± 9 |
| Male/female ratio | 69/16; 4.3:1.0 |
| History of hypertension (n) | 71 (83.5%) |
| Compliance with antihypertensive medications (n) | 30 (35.3%) |
| Mean volume of hematoma (mL) | 46.5 ± 10.5 |
| Basal ganglia/cortical bleeds ratio | 64/21; 3:1 |
| Anatomic distribution of basal ganglia bleeds | Anterior –7/64 (10.9%)<br>Lateral – 38/64 (59.4%)<br>Massive – 19/64 (29.7%) |
| Duration of surgical procedure (min) | 36.5 ± 5.2 |
| Complications | Rebleeding -3/85 (3.8%)<br>Mortality - 3/85 (3.8%) |
| Duration of stay in the intensive care unit (days) | 3.2 ± 0.8 |

Mean data are ±SD

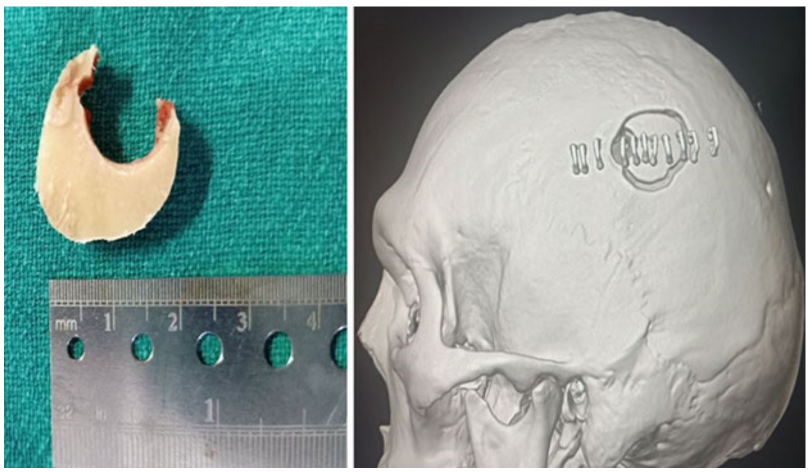

**Fig. 1** A mini craniotomy bone flap and the post-operative computer tomography reconstructed skull image

restores cerebral perfusion, and inhibits the development of inflammation (Gaab 2011). The recent progress in minimally invasive surgical techniques to treat intracerebral hematoma, like endoscopy-guided stereotactic aspiration, is advantageous in that the inescapable trauma to the normal brain tissue is minimized and the clot hematoma is rapidly evacuated. A small surgical wound and limited intraoperative blood loss make wound healing better. Further, shortened surgery duration in relatively stable patients promotes early extubation, decreases the odds of postoperative pulmonary complications, and reduces the duration of patient stay in the ICU, all of which is conducive to faster patient recuperation and post-surgery rehabilitation.

Nonetheless, the control of bleeding and proper manipulation of instruments in the restrained operational space are limiting factors in minimally invasive surgical procedures that require much training and expertise (Ratre et al. 2018). The cost factor associated with the use of such methods also plays a role in low-to-middle income nations. The financial burden accounts for a significant proportion of "leave against medical advice", i.e., abandoning useful medical procedures (Hasan et al. 2019). An incomplete clot evacuation is another major concern. Classical craniotomy has an obvious advantage of decreasing the raised intracranial pressure along with the evacuation of a hematoma. The minimal approaches lag on this account, and there is a risk

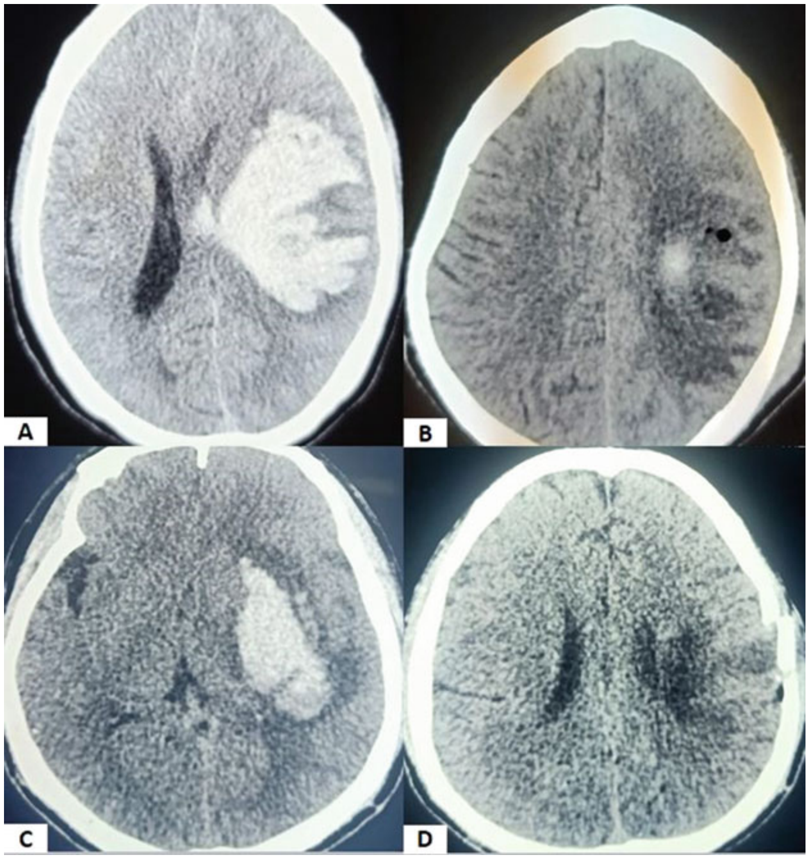


**Fig. 2** Representative examples of preoperative and postoperative computer tomography images of cortical (panel A and B) and basal ganglia (panel C and D) hemorrhage sites

of brain edema in a subset of patients despite hematoma evacuation, necessitating the need for conversion to a larger craniotomy. A minimally invasive technique would not be recommended in patients with a low Glasgow Coma Scale score, moribund neurological status, and clinico-radiological features of advanced brain herniation. The minimal approach sometimes has a limitation of ensuring hemostasis, especially at the depth of a cavity, or complete hematoma removal concurrent with the minimum brain retraction. The technical difficulty of appropriate surgical light focusing at the depth of a cavity also is a major concern. In the present study, we thoroughly assessed the practical feasibility of performing the minimally invasive procedure for intracranial hematoma evacuation in a selected group of stroke patients. We herein report that the procedure can be safely undertaken with the application of basic neurosurgical instruments, fulfilling the required criteria of surgical treatment of the ailment, with add-on advantages of less surgical insult to the brain, less anesthesia, and perioperative patient stress, and faster recuperation.

A higher proportion of male patients were found to suffer from spontaneous intracranial hemorrhage in the present study, which is in line with some of the previous reports (Khallaf and Abdelrahman 2019). However, the gender predominance of brain hematoma is a contentious issue as some other reports point to a similar incidence rate in both sexes (van Asch et al. 2010; Appelros et al. 2009). The most common location of a spontaneous brain bleed among both conservatively and surgically managed patients is the basal ganglia area (Rychen et al. 2020). We confirmed the predominance of basal ganglia in the present study with 75.3% of patients having a hemorrhagic stroke in this area. Likewise, the mean hematoma volume of 46 mL we found is in line with other reports (Luan et al. 2019; Rutkowski et al. 2019).

A previous comparative study showed a minimally invasive puncture and drainage as the least traumatic procedure with the least blood loss, followed by the endoscopy and craniotomy groups. However, the hematoma evacuation rate was lower in the minimally invasive puncture group (35.2%) compared with the other two groups where it amounted to 90.8% and 87.3%, respectively. Yet the minimally invasive puncture enjoyed the shortest treatment time of about 38 min, which is far less compared to the 98–120 min of the endoscopy-assisted removal of hematoma, with the latter being one-fourth the time taken for the classical craniotomy approach. On the downside, the minimally invasive puncture had the highest rebleeding rate. By contrast, a craniotomy was more effective in removing hematoma but resulted in marked trauma to the brain and also has the highest incidence of post-surgery pulmonary infection (Fu et al. 2019).

In the present study, the rebleeding occurred in just 3 (3.8%) out of the 85 patients. There also were three (3.8%) deaths. For comparison, there were 6 deaths out of the 40 (15%) patients and 4 out of the 25 (16%) patients undergoing minimally invasive craniotomy reported in the studies of Luan et al. (2019) and Rutkowski et al. (2019), respectively. Concerning other studies and other treatment modalities, data on the mortality rate are divergent. A study by Fu et al. (2019) has reported a mortality rate of 1.6% in the endoscopy-assisted management of intracranial hemorrhage, 3.6% in the minimally invasive puncture, and 5.0% in the craniotomy groups. By contrast, much higher mortality rates have been reported by Ratre et al. (2018) amounting to 11% in patients undergoing the endoscopy-assisted management of spontaneous bleed into the basal ganglia area and by Rychen et al. (2020) amounting to 21.3% in craniotomy with hematoma evacuation.

Pulmonary post-surgery embolism is a rare but mortal event. In this study, we noticed two such fatalities compared to one case in a study by Luan et al. (2019). We also noticed two (2.3%) cases of inflammation of the ependymal lining, with one of the ventriculitis being fatal. Surgical site infections are another leading cause of mortality among stroke survivors (Kuohn et al. 2020).

In conclusion, mini craniotomy evacuation of hematoma caused by spontaneous intracranial hemorrhage in patients suitable for this kind of surgery showed good clinical outcomes, minimizing the length of a surgical procedure, intraoperative and postoperative complications, length of stay in the ICU, and mortality rate when compared to reports on other treatment modalities such as classical craniotomy or endoscopy-assisted hematoma evacuation. The minimized surgical site infection and a shorter stay in the intensive care unit as seen in our patients promotes the "patient care bundle" approach by facilitating early rehabilitative programs. The relative ease of performing the procedure with basic neurosurgical instruments calls for the appraisal and validation of these findings in randomized multicenter prospective studies.

**Conflicts of Interest** The authors declare no conflicts of interest concerning this article.

**Ethical Approval** All procedures performed in studies involving human participants were in accord 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. The study was approved by the Institutional Review Committee of the College of Medical Sciences in Chitwan, Nepal; permit no. 2020-107.

**Informed Consent** Written informed consent was obtained from all individual participants included in the study or their guardians.

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