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Intraoperative ultrasonographic-guided surgery of intracerebral hemorrhage

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Abstract

Background The location of the cortical incision and maximum evacuations of parenchymal intracerebral hematoma are crucial points. Intraoperative ultrasonography is a real-time tool with great benefit at these points

Methods A retrospective study of patients with parenchymal intracerebral hemorrhage that underwent evacuation using intraoperative ultrasound guidance was included. Preoperative clinical and radiological assessments were studied. The postoperative imaging and clinical outcome were assessed. A late follow-up after 6 months was done.

Results The age of study patients ranged from 9 to 73 (mean 45.3 ± 20.4 years). There were 14 males (58.3%). The mean preoperative Glasgow Coma Scale (GCS) was 9.8 ± 2.9. The preoperative hematoma volume ranged from 32 to 135 cm^3 with a mean of 68.5 ± 30.5 cm^3. The rate of evacuation ranged from 90 to 100%. The mean postoperative GCS was 11.7 ± 2.5. None of the patients had a recurrent hemorrhage. There was a significant rate of evacuation of the hematomas (P value < 0.001*). Also, there was a marked improvement in postoperative GCS and the late modified Rankin Scale (P value < 0.001*).

Conclusion Ultrasonography is a useful, efficient, real-time tool for the localization and evacuation of parenchymal intracerebral hemorrhage. It maximizes evacuation and decreases parenchymal insult. It is an important aid to the neurosurgeon.

Keywords Intracerebral hemorrhage, Intraoperative ultrasound, CT scan, Real-time, Evacuation

Introduction

Spontaneous intracranial hemorrhage (SICH) carries great personal, familial, social, and economic burdens, with significant mortality and morbidity [1]. SICH incidences reach up to 9–27% of strokes all over the world [2–4]. The incidence of hemorrhagic strokes is increasing especially in low- and middle-income countries [4]

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Mortality rate of SICH at one month is 40% and reaching up to 54% at 1 year, thus carrying poor outcome that put a priority for standard and effective management [5, 6]. Early and effective evacuation may give the patient a better chance for improvement [7]. Minimally invasive tools are being tried to maximize the safety of hematoma evacuation and decrease the cost and hospital stay [8, 9]. Endoscopic-guided evacuation of SICH uses a single Burrhole with a narrow cortical corridor, decreasing the iatrogenic injury from dissection [10, 11]. The ultrasound-guided evacuation had the advantage of localizing the cortical incision that allow the shortest track to the hematoma minimizing brain injury and provides real-time navigation and maximizing the evacuation's effectiveness [10, 12–14].

Methods

Between January 2021 and December 2021, a prospective study including 24 consecutive patients admitted with spontaneous ICH to the main university and affiliated hospitals was conducted. Preoperative evaluation including patient demographics and present history; neurological examination was assessed at presentation by Glasgow Coma Scale and also by the modified Rankin Scale (mRS) [15]. All patients underwent CT brain to assess the size and site of the hematoma. Patients were admitted to the ICU. CTA, MRI, and DSA were done in some cases where underlying pathology was suspected so all young patients and those without a history of hypertension underwent angiography.

A small craniotomy located over the hematoma was done after general anesthesia. The US transducer (BK medical intraoperative ultrasound using a standard convex phased-array probe with 8–10 MHz transducer frequencies) was draped in a sterile case and covered by a sterile glove partially filled with a coupling gel. B-mode (grayscale) ultrasound was used for the localization of the site, direction, and depth of the hematoma. This was done before the dural incision with saline irrigation. The cortical incision was done at a point nearest to the hematoma followed by hematoma evacuation with US scanning of the brain during the procedure as many times as necessary to verify the extent of hematoma evacuation. The hematoma cavity was irrigated with saline, and a last US scanning was done to verify complete removal of the hematoma, and then hemostatic agents (Gelfoam and Surgicell®) were placed in the cavity to prevent rebleeding. The patients were managed in the neuro-ICU. The preoperative and postoperative data of the patients were collected including demographic, clinical, and imaging findings. Clinical and radiologic follow-up was done for about 6 months.

CT scan was done at the end of the procedure to confirm complete hematoma evacuation. Neurological status was assessed by the GCS immediately postoperative, on the third postoperative day, and at discharge, and by (mRS) on discharge, and during follow-up examinations conducted monthly for 6 months.

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (Armonk, NY: IBM Corp). Categorical data were represented as numbers and percentages. For continuous data, they were tested for normality by the Shapiro–Wilk test. Quantitative data were expressed as a range (minimum and maximum), mean, standard deviation, and median for normally distributed quantitative variables Paired t-test was used to compare two periods. On the other hand, for not normally distributed quantitative variables Wilcoxon signed ranks test was used to compare two periods. The significance of the obtained results was judged at the 5% level.

Results

The age of the study patients ranged from 9 to 73 (mean 45.3 ± 20.4 years). There were 14 males (58.3%). The mean preoperative Glasgow Coma Scale (GCS) was 9.8 ± 2.9. The preoperative hematoma volume ranged from 32 to 135 cm^3 with a mean of 68.5 ± 30.5 cm^3 (Table 1). Most of our hematomas were located in the fronto-parietal lobe and basal ganglia, 9 cases and 7 cases respectively. The rate of evacuation ranged from 90 to 100%. We had 3 (12.5%) mortalities; the mean postoperative GCS was 11.7 ± 2.5 (Tables 2, 3). None of the patients had a recurrent hemorrhage. There was a significant rate of evacuation of the hematomas (P value < 0.001*), (Figs. 1, 2). Also, there was marked improvement in postoperative GCS and late modified Rankin Scale (P value < 0.001*), (Table 3).

Table 1 Distribution of the studied cases according to different parameters ($n = 24$)

	No. (%)
Sex	
Male	14 (58.3%)
Female	10 (41.7%)
Age (/years)	
Mean ± SD	45.3 ± 20.4
Median (Min.–Max.)	54 (9–73)
HTN	14 (58.3%)
Location	
BG	7 (29.2%)
FP	9 (37.5%)
PR	1 (4.2%)
PO	2 (8.3%)
FR	1 (4.2%)
TEMP	1 (4.2%)
PO + IVH	1 (4.2%)
Thalamic + IVH	2 (8.3%)
Side	
Right	14 (58.3%)
Left	10 (41.7%)
Outcome	
Died	3 (12.5%)
Improved	21 (87.5%)

SD Standard deviation, *BG* basal ganglia, *Pr* parietal, *FP* frontoprietal, *PO* Parieto-occipital, *Fr* frontal, *IVH* intraventricular hemorrhage, *temp* temporal, *DSA* digital subtraction angiography, *HTN* hypertension

Table 2 Comparison between preoperative and postoperative according to volume and GCS ($n=24$)

	Preoperative	Postoperative	Test of Sig	p
Volume				
Mean ± SD	68.5 ± 30.5	1.2 ± 3.6	Z = 4.286*	< 0.001*
Median (Min.–Max.)	61.5 (32–135)	0 (0–18)		
GCS				
Mean ± SD	9.8 ± 2.9	11.7 ± 2.5	$t=0.8014$*	< 0.001*
Median (Min.–Max.)	10 (5–15)	12 (7–15)		

GCS Glasgow Coma Scale, *SD* Standard deviation, *t*: Paired t-test, *Z* Wilcoxon signed ranks test

p: *p* value for comparing preoperative and postoperative

*Statistically significant at $p \leq 0.05$

Table 3 Comparison between discharge and at 6 months according to MRS (n = 24)

	Discharge	At 6 months	Z	p
MRS				
Mean ± SD	3.3 ± 1.5	1.7 ± 1.9	4.030*	< 0.001*
Median (Min.–Max.)	3 (0–6)	1 (0–6)		

MRS modified Rankin Scale, *SD* Standard deviation, *Z* Wilcoxon signed ranks test

p: *p* value for comparing Discharge and at 6 months

*Statistically significant at $p \leq 0.05$

Discussion

The global incidence of hemorrhagic strokes is increasing with its devastating sequelae [4, 15]. The management of SICH includes either conservative or surgical evacuation [2, 7, 16, 17]. Evacuation can be done using standard craniotomy or minimally invasive tools [7]. The use of minimally invasive tools is increasingly adopted in those cases in a trial to decrease the economic burden by decreasing the hospital stay and accelerating patients' recovery [7–9, 18]. In their meta-analysis, Tang et al. [8] found that minimally invasive hypertensive hematoma evacuation was superior to conservative medical treatment or standard craniotomy as regards mortality and quality of life. The evacuation of parenchymal hematomas through narrow cortical windows decreases the iatrogenic injury to eloquent areas. Also, it shortens the operation time. The use of real-time imaging during the planning for brain surgery became an essential technology for maximum safe and effective surgery [9]]. Intraoperative MRI and CT scans are used in hybrid rooms but are expensive and time-consuming [10, 14]. Also, intraoperative MRI-based navigation is less accurate due to marked brain shift [10]. IOUS is being used for evacuation of ICH and excision of brain tumors. Fusion with the navigation systems can be done through specific software [10].

Lee et al. [14] used the IOUS in basal ganglia hematoma cases without brain herniation under local anesthesia. They evacuated the hematoma through a single temporal burr hole with the IOUS guidance followed by urokinase irrigation. Sadahiro et al. [10] used IOUS through a temporal burr hole combined with endoscopic evacuation through a second burr hole. Their mean preoperative hematoma volume was 65.2 ± 37.1 cm^3, and the mean percentage of hematoma that was evacuated was 96%. By using the real-time IOUS, they were able to identify the endoscope position in the center of the hematoma to prevent brain damage and to identify residual hematoma. In the present study, the mean preoperative hematoma volume was 68.5 ± 30.5 with a 98.2% evacuation rate. Chartrain et al. [12] used intracavitary IOUS to detect residual clots after endoscopic evacuation in their cases. Kumar et al. [13] used IOUS and reached complete BG hematoma evacuation in 41.2% of cases with a mean residual volume of 9.72%. Naritaka et al. [19] operated their patients with endoscopic emergency surgery under US monitoring with superb microvascular images SMI, a fusion technique and a contrast agent technique, with the probe on the brain surface during surgery. SMI provided information on the extent of intracranial hematoma and residual hematoma with no vessels and no flow inside it, in contrast to the normal brain that contains flow and vessels. They achieved total evacuation with no residual in their series except one case.

Conclusion

Ultrasonography is a useful, efficient, real-time tool for the localization and evacuation of parenchymal intracerebral hemorrhage, and it is much simpler, cheaper, and less time-consuming. It maximizes evacuation and decreases parenchymal insult. It is an important aid to the neurosurgeon.

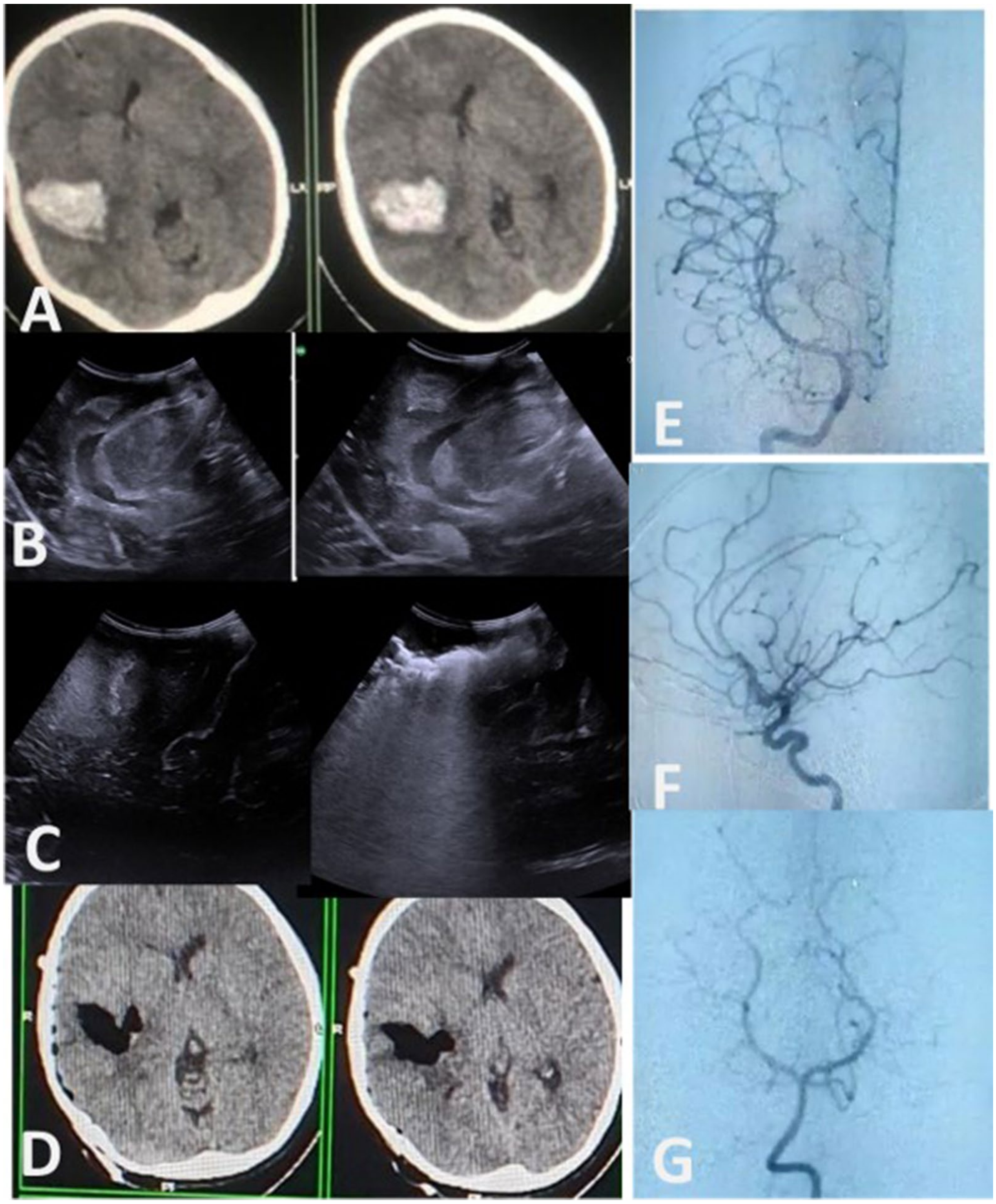

Fig. 1 A 7 years old child presented with deterioration of the conscious level (DLC) and left sided weakness. surgery was decided with the use of intraoperative angiography and IOUS. **A** the preoperative CT scan showing ICH. **B** IOUS image before evacuation showing the hyperechoic hematoma. **C** IOUS image after evacuation showing the disappearance of the hyperechoic hematoma. **D** postoperative CT scan showing complete hematoma evacuation. **E**–**G** intraoperative DSA of right internal carotid and left vertebral arteries without vascular pathology

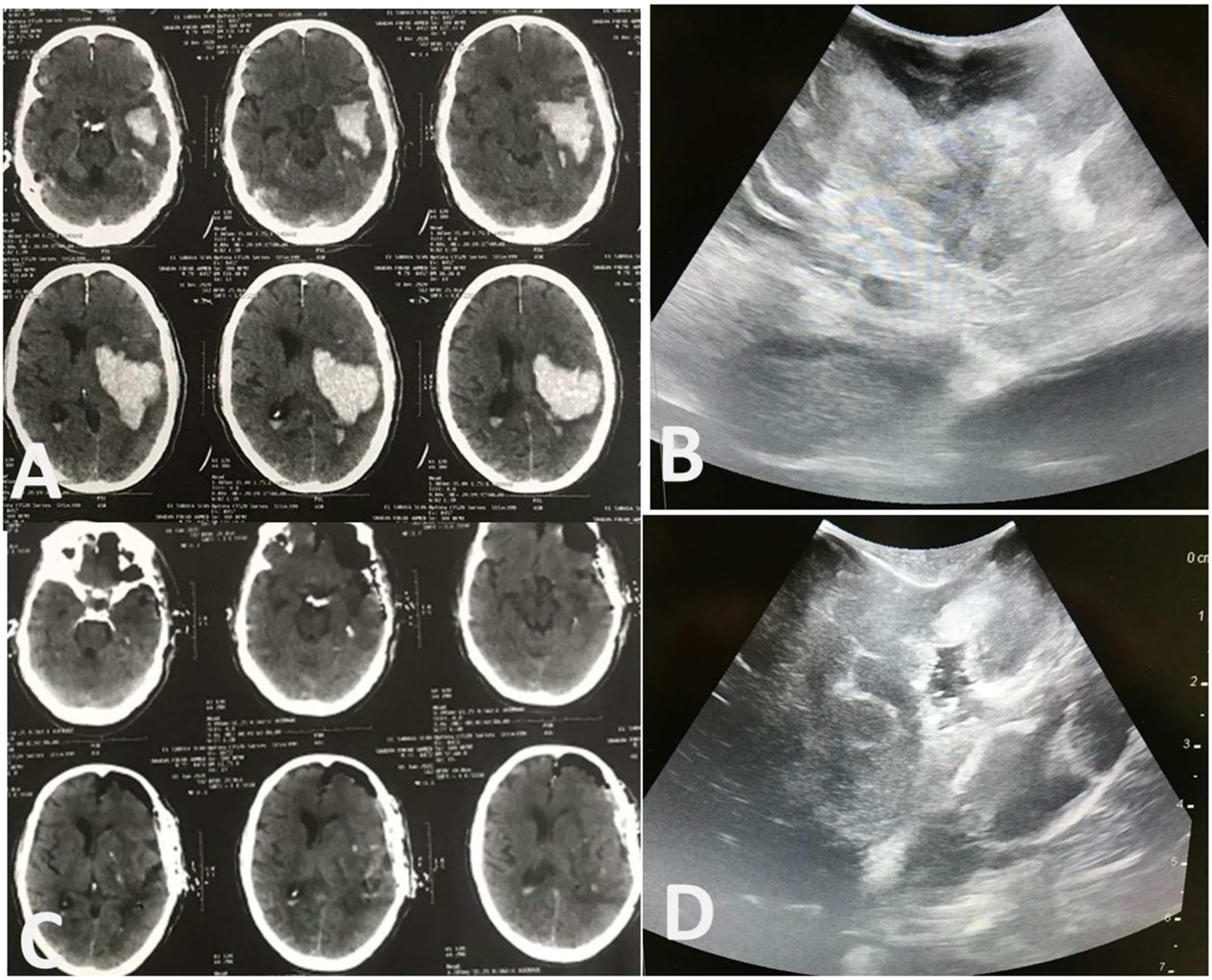

Fig. 2 A 62 year old patient presented with DLC and right sided weakness. surgery was decided with the use of IOUS. **A** the preoperative CT scan showing ICH. **B** IOUS image before evacuation showing the hyperechoic hematoma. **C** postoperative CT scan showing complete hematoma evacuation. **D** IOUS image after evacuation showing the disappearance of the hyperechoic hematoma

Abbreviations

GCS	Glasgow Coma Scale
SICH	Spontaneous intracranial hemorrhage
IOUS	Intraoperative ultrasound
mRS	Modified Rankin Scale
CTA	Computed tomography angiography
MRI	Magnetic resonance imaging
DSA	Digital subtraction angiography

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Author contributions
AS analyzed and interpreted the patients' data regarding the risk factors, operative details, and clinical outcomes. MA and AE performed statical analysis and English editing. All authors performed clinical evaluation of patients, and surgical interventions, and helped in reviewing and editing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The research protocol was approved by the ethical committee in the faculty of medicine—its monthly session. Informed written consent was obtained from each patient. The reference number is: Member of ICLAS, http://iclas.org/members/member-list, http://www.hhs.gov/ohrp/assurances/index.html. IRB NO: 00012098(Expires 6-10-2022) -F WA NO: 00018699 (Expires January 2026), serial no.:0305419.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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