ORIGINAL ARTICLE

3D-Printed Endoport vs. Open Surgery for Evacuation of Deep Intracerebral Hemorrhage

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ABSTRACT: ***Background:*** Large-sized clinical trials have failed to show an overall benefit of surgery over medical treatment in managing spontaneous intracerebral hemorrhages (ICH); less invasive techniques have shown to decrease brain injury caused by surgical manipulation in the standard open approach improving the clinical outcomes of patients. Thereby, we propose a low-cost 3D-printed endoport for a less invasive ICH evacuation. In this study, the authors compare the clinical outcomes of early surgical evacuation using a 3D-printed endoport vs. a standard open surgery (OS). ***Methods:*** A retrospective analysis was conducted comparing patients who underwent early evacuation of a deep hypertensive ICH through an endoport vs. OS at a single center from August 2017 to March 2019. Demographic, clinical, and radiologic data were reviewed. The primary outcomes were the 90-day post-stroke functional outcome and mortality. ***Results:*** A total of 36 patients were included. The two cohorts (18 endoport; 18 OS) showed no statistically significant differences in demographic, clinical, and radiologic characteristics, including median admission hemorrhage volume, Glasgow Coma Scale, and ICH scores. At 90-day post-stroke, 44% of patients in the endoport group and 17% in the OS group had a favorable functional outcome (mRS 0–3) ($p = 0.039$); moreover, the endoport group showed lower mortality (33% vs. 72%, $p = 0.019$). ***Conclusions:*** This study suggests that an endoport-assisted ICH evacuation may have better functional outcomes and lower mortality than OS. The proposed device could provide a safe, low-cost alternative for ICH's surgical treatment. More rigorous research is hence needed to assess the potential benefits of this technique.

RÉSUMÉ : Utilisation d'un dispositif imprimé en trois dimensions ou chirurgie ouverte en vue d'évacuer une hémorragie intracérébrale profonde. ***Contexte*** **:** Des essais cliniques de grande envergure n'ont pas permis de démontrer les avantages généraux de la chirurgie par rapport à un traitement médical dans la prise en charge des hémorragies intracérébrales (HIC) spontanées. Des techniques moins invasives ont par ailleurs montré pouvoir réduire les lésions cérébrales causées par les manipulations chirurgicales de l'approche ouverte standard, améliorant ainsi l'évolution de l'état clinique des patients. C'est ainsi que nous proposons l'utilisation de dispositifs à coûts modiques et imprimés en trois dimensions (des *endoports*) afin de permettre une évacuation moins invasive des HIC. Dans cette étude, nous avons donc voulu comparer des patients ayant bénéficié d'une évacuation chirurgicale précoce au moyen d'*endoports* à d'autres patients ayant bénéficié d'une procédure standard de chirurgie ouverte (PSCO). ***Méthodes*** **:** Une analyse rétrospective a été menée d'août 2017 à mars 2019 en comparant entre eux ces patients, et ce, dans le cadre d'un seul établissement de santé. Pour ce faire, nous avons analysé des données démographiques, cliniques et radiologiques. Les principaux aspects mesurés ont été, d'une part, leur autonomie fonctionnelle 90 jours après un AVC ainsi que leur taux de mortalité. ***Résultats*** **:** Au total, 36 patients ont été inclus dans cette étude. Nos deux cohortes (18 patients ayant bénéficié d'un *endoport* ; 18 autres, d'une PSCO) n'ont montré aucune différence statistiquement significative en ce qui concerne leurs caractéristiques démographiques, cliniques et radiologiques, ce qui inclut notamment les volumes médians d'hémorragie au moment d'être admis, leurs scores à l'échelle de Glasgow et leurs scores relatifs aux HIC. Au bout de 90 jours après un AVC, 44 % des patients ayant bénéficié d'un *endoport* et 17 % de ceux ayant bénéficié d'une PSCO ont donné à voir des résultats favorables en termes d'autonomie fonctionnelle (échelle modifiée de Rankin 0–3; $p = 0{,}039$). Qui plus est, le groupe de patients ayant bénéficié d'un *endoport* a montré un taux de mortalité plus faible (33 % contre 72 %; $p = 0{,}019$). ***Conclusions*** **:** Cette étude suggère en somme qu'il se pourrait qu'une procédure d'évacuation des HIC au moyen d'un *endoport* assure de meilleurs résultats en termes d'autonomie fonctionnelle et des taux de mortalité plus faibles. Un tel dispositif pourrait du coup constituer une possibilité sûre et peu coûteuse en vue du traitement chirurgical des HIC. Cela dit, des recherches plus rigoureuses sont nécessaires pour en évaluer les avantages potentiels.

Keywords: 3D printing, Craniotomy, Endoport, Hemorrhagic stroke, Intracerebral hemorrhage, Minimally invasive surgery

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Introduction

Hypertensive intracerebral hemorrhage (ICH) accounts for 50%–70% of all spontaneous ICH;[1] its morbidity and mortality rates are higher than any other stroke type.[2] Regardless of aggressive treatment or newer management strategies, the outcome of patients remains very poor; mortality at 1 month is over 40% and has not improved in the last decades,[3–6] and patients achieving a favorable functional outcome or an independent life after 1 year vary between 12% and 39%.[4–8] These numbers reveal that spontaneous ICH is not only a very lethal disease but that survivors constitute a significant burden on health care resources, even higher than that of ischemic stroke.[2]

In patients with a hypertensive ICH, primary injury occurs during the first hours due to hematoma expansion and brain parenchyma compression. Secondary injury results from perihematomal edema and hemotoxicity of blood degradation products.[9] Surgical hematoma evacuation and conservative therapy are the main treatments for ICH.[10,11] Surgery is conducted because an early volume reduction of the hemorrhagic lesion improves cerebral perfusion and avoids damage to neural tissue.[12] The most common hypertensive ICH sites are deep brain structures, such as the basal ganglia and the thalamus; a considerable layer of brain tissue must be crossed during surgery, which may cause iatrogenic damage to healthy cerebral tissue.

The International Surgical Trial in Intracerebral Hemorrhage (STICH) showed no overall benefit of open craniotomy over medical treatment alone.[13,14] Nevertheless, the high crossover rates and methodological issues left unclarified whether surgery may benefit specific groups of patients with supratentorial ICH, showing a slight but clinically relevant survival advantage for patients with spontaneous superficial ICH without intraventricular hemorrhage. Moreover, supratentorial hematoma evacuation might be considered a life-saving measure in deteriorating patients.[10] Surgery with less invasive approaches, such as endoscopic aspiration, or endoport-assisted evacuation, has shown potential benefits in the surgical management of spontaneous ICH by decreasing brain injury caused by surgical manipulation.[15–19] Therefore, we propose a low-cost 3D-printed endoport for a less invasive approach in the surgical management of hypertensive ICH patients. In this study, we compared the functional outcome and mortality rate of patients with deep supratentorial hypertensive ICH treated by early evacuation (less than 24 hours post-stroke) using two different techniques: endoport-assisted vs. standard open surgery (OS).

Material and Methods

Patient Selection

A retrospective analysis was conducted from medical records[20] of all adult patients who underwent early surgical evacuation of deep hypertensive ICH by open craniotomy or decompressive craniectomy at a single academic training center between August 2017 and March 2019. Cohorts were identified upon the surgical approach employed: endoport-assisted and OS. Secondary ICH was not included in the protocol. The excluded patients had incomplete radiologic or clinical data, more than a 24-hour evolution before surgery, lobar or infratentorial hemorrhages.

Fabrication of the 3D-Printed Endoport

The endoport was developed by some of the authors with material already in use for medical devices and produced at minimal cost using 3D printing technology. It was designed using an open-source 3D computer graphics software (Blender software, version 2.78, Blender Foundation) and made through additive manufacturing using a desktop-sized and affordable stereolithography 3D printer (Form 2, Formlabs Inc., Somerville, MA, USA) using a biocompatible resin (Dental SG Clear Resin, Formlabs Inc.). Finite element analysis was performed in Ansys Workbench (Ansys Inc., Canonsburg, PA, USA) to examine the behavior of the endoport under boundary loads and ensure the integrity of the device during surgery. The illumination circuit was designed in Proteus Design Suite (Labcenter Electronics Ltd, Grassington, North Yorkshire, England) and enclosed and insulated in the device. A sterilized cable is attached during surgery for connecting the device to the power source. A 14 mm working channel was chosen because, in lab tests, it was the smaller diameter at which the neurosurgeons were comfortable using suction and bipolar cautery. Although different diameters and lengths could be manufactured, this study utilized the 14 mm × 6 cm work channel endoport. The obturator tip geometry was designed using finite element analysis in Ansys Workbench to provide blunt dissection and minimal resistance to brain tissue.

The device consists of two cylindrical components (obturator and sheath) that, when assembled, could be inserted to provide access to the hematoma cavity through blunt dissection of subcortical areas (Figure 1). The obturator includes a central canal for the optional use of a neuronavigational pointer. An enclosed LED circuit board is mounted on the sheath to provide adequate surgical site illumination. Once the endoport is inserted and the obturator disassembled, the sheath includes corridor access and direct visualization of the subcortical surgical site. The fabrication cost was estimated to be about 40 USD, the same device, adequately sterilized, was employed for multiple patients. Each device was utilized only three times unless mechanical/electrical defects were found; before each use, the endoport was carefully inspected by a qualified bioengineer involved in its manufacturing process, and gas plasma sterilization was performed.

Surgical Approach

The endoport-assisted ICH evacuation consisted of the device placement through a 6 mm corticotomy in the middle temporal gyrus directed toward the clot's location (Figure 2). As the endoport entered the hematoma, the obturator (inner part) was pushed out with a variable amount of clot. Once the endoport was placed, the obturator was removed entirely, and the sheath (outer part) provided a 14 mm diameter and 6 cm length work channel with direct visualization of the cavity through which the hematoma was evacuated and hemostasis achieved. The surgery was performed without additional optic devices (i.e., microscope, surgical loupes).

In the OS group, a 2 cm corticotomy was performed in the middle temporal gyrus; then, by blunt dissection of the white matter with a bipolar cautery, the hematoma was located; to create a visibility corridor, malleable brain retractors were

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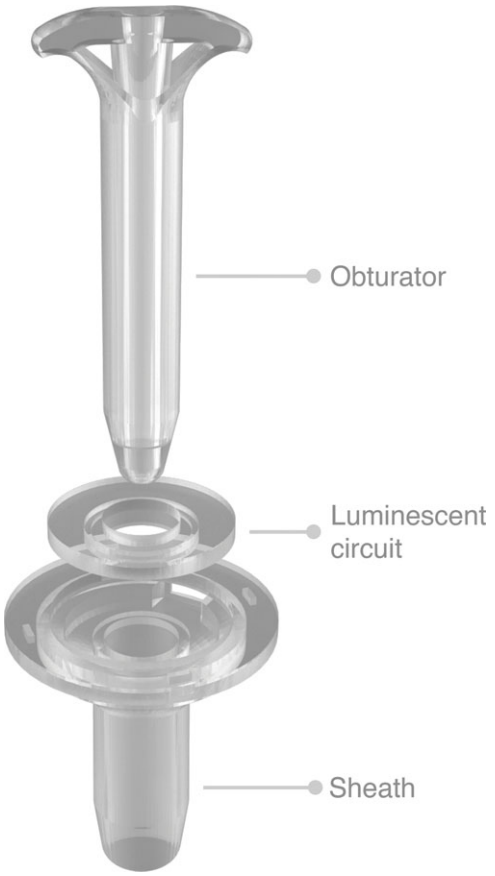

Figure 1: *Low-cost 3D-printed endoport for a less invasive approach in the surgical management of hypertensive ICH patients.*

employed. In both cases, hematoma evacuation was performed using suction and bipolar cautery. Hemostasis was achieved by continuous saline irrigation and pressure packing. The identified bleeding artery was electrically coagulated.

Clinical Outcomes

Our primary outcomes of interest were the functional outcome and the mortality measured at 90-day post-stroke. To assess the functional outcome, the authors used the Modified Rankin Scale for Neurologic Disability (mRS) measured at the moment of hospital discharge and 7-, 30-, and 90-day post-stroke. As a measure of long-term outcome in hypertensive ICH patients, the 90-day post-stroke functional outcome was further dichotomized in favorable and unfavorable outcomes, mRS 0–3 and 4–6, respectively.[21] These outcomes were identified from hospital records and death certificates.

Our secondary outcomes of interest were the postoperative midline shift and residual hematoma volume, clot evacuation rate, reoperations, hospital length of stay (LOS), and in-hospital mortality. The postoperative midline shift and residual hematoma volume were determined in a brain computed tomography (CT) performed 12–24 hours after surgery.

Covariate Data Collection

Baseline demographic, clinical, and radiologic variables were collected retrospectively from the hospital archives.

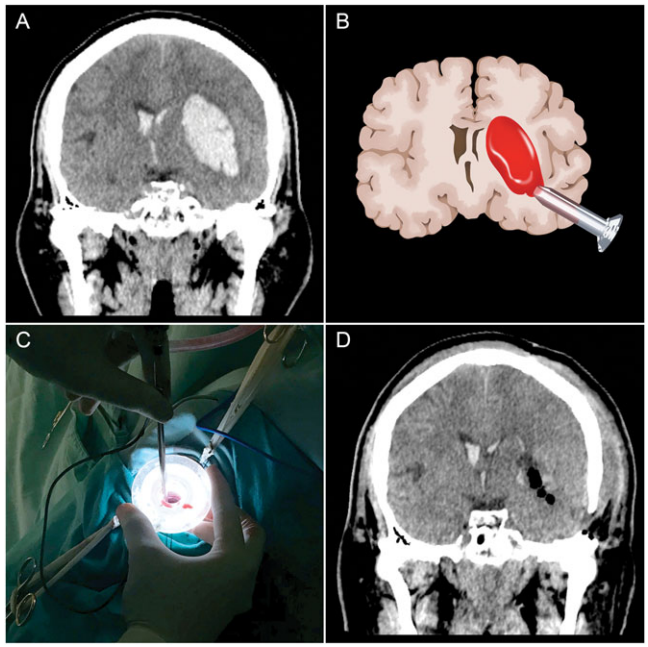

Figure 2: *An illustrative case of a large putaminal ICH in a hypertense 47-year-old man. (A) preoperative coronal CT scan without contrast. (B) An illustration of the endoport-assisted ICH evacuation. (C) Intraoperative images of hematoma evacuation, the 3D-printed endoport allows visualization without additional optics. (D) Postoperative CT scan showing complete hematoma evacuation.*

According to the institutional protocol, surgical intervention was considered for patients with supratentorial hypertensive ICH volume ≥ 30 ml, midline shift ≥ 5 mm, or cerebral herniation signs. Depending on the brain edema observed, the operating surgeon decided, in a nonrandomized fashion, whether to perform a craniotomy or decompressive craniectomy.

Hemorrhage volumes were estimated in brain CT by the ABC/2 method; intraventricular blood was not included. An independent, board-certified neuroradiologist performed the radiological image interpretation without knowledge of the study rationale or hypotheses. All other variables were identified from hospital records and death certificates.

Statistical Analysis

Data are reported using standard statistical methods. Continuous variables with normal distributions are presented as means with standard deviation (SD), whereas those with non-normal distributions (based on the Shapiro–Wilk test) are presented as medians with interquartile range. Categorical variables are presented as percentages. Comparisons of numerical data were performed using an unpaired *t*-test (parametric data) or Mann–Whitney *U*-test (nonparametric data). Comparisons of categorical data were made by chi-square (χ^2) and Fisher's exact tests, when appropriate. Survival analysis was performed by the Kaplan–Meier method censored 90 days after the hypertensive ICH; comparisons between groups were achieved through the log-rank test. Binomial logistic regression analyses were performed to adjust for the effect of potential confounders on the 90-day post-stroke favorable functional outcome and survival; well-known predictors of hypertensive ICH were used as covariates (i.e., age, hemorrhage volume, admission Glasgow Coma Scale (GCS),

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surgical procedure, ICH score, and the time from ICH to surgery). A p-value <0.05 was considered statistically significant; all p values were two-sided. Analyses were generated with Jamovi software, version 1.2 (The jamovi project, 2020). The local ethics committee approved this study, and the requirement for informed consent was waived due to the retrospective nature of the study.

Results

Patient Numbers

A total of 54 consecutive adult patients who underwent surgical evacuation of primary ICH by open craniotomy or decompressive craniectomy at our hospital between August 2017 and March 2019 were reviewed retrospectively. Twelve patients did not meet our selection criteria, including five patients with more than a 24-hour evolution before surgery, five lobar hemorrhages, and two hemorrhages originating from the mesencephalon and cerebellum; another six patients were excluded because they were transferred to other hospitals, and clinical data could not be obtained. Therefore, analyses were conducted on a final dataset of 36 adult patients who underwent early surgical evacuation of supratentorial hypertensive ICH classified into two groups: endoport and OS; both groups progressed simultaneously. Depending on the on-call schedule, eight neurosurgeons with 3–5 years of clinical experience performed the surgeries: 3 of them had previous experience utilizing endoport systems and used the proposed device in all their cases; the remaining five employed an OS.

Patient Characteristics

As detailed in Table 1, the two cohorts (18 endoport; 18 OS) showed no statistically significant differences in demographic, clinical, and radiologic characteristics, including median admission hemorrhage volume, GCS, and ICH scores. The average time interval between onset of symptoms related to the hypertensive ICH and surgery was similar in both cohorts (14 vs. 12 hours).

Functional Outcome

The endoport group was associated with a better functional outcome at hospital discharge and 7-, 30-, and 90-day post-stroke (Figure 3). At the 90-day follow-up, 44% of patients in the endoport group had a favorable functional outcome, compared to 17% in the OS group ($p = 0.039$).

Binomial logistic regression was performed to determine the effects of admission ICH score, the time interval from symptom onset to surgery, surgical procedure, and surgical approach on the likelihood that participants had a favorable functional outcome at the 90-day follow-up. The logistic regression model was statistically significant, $\chi^2(4) = 21.3$, $p < 0.001$. The model explained 63% (Nagelkerke R^2) of the variance in favorable functional outcome at the 90-day follow-up and correctly classified 86% of cases. Patients in the endoport group were 26 times more likely ($p = 0.049$) to have a favorable functional outcome at the 90-day follow-up than the OS group. An increase in the ICH score was associated with a reduction in the likelihood ($p = 0.026$) of a 90-day favorable functional outcome. The average time from the onset of symptoms to the time of surgery ($p = 0.053$) and the surgical procedure employed (i.e., craniotomy or decompressive craniectomy) ($p = 0.134$) did not add significantly to the model.

Table 1: Demographic and baseline characteristics of patients

Variables	3D-Printed endoport ($n = 18$)	Open surgery ($n = 18$)	p value
Age (years)*	46 ± 10	50 ± 11	0.258
Male	15 (83%)	16 (89%)	0.999
Hypertension	12 (67%)	14 (78%)	0.457
Diabetes	8 (44%)	6 (33%)	0.494
Other comorbidities	2 (11%)	1 (6%)	0.999
Symptom onset to admission time (hour)	6 (3–8)	3 (2–6)	0.189
Glucose level (mg/dl)	158 (135–238)	156 (124–227)	0.486
Blood pressure at admission			
Systolic BP (mmHg)	165 (160–180)	160 (143–200)	0.810
Diastolic BP (mmHg)	100 (90–108)	95 (80–108)	0.469
GCS at admission (points)	10 (7–12)	11 (8–12)	0.898
ICH side			
Right hemisphere	12 (67%)	10 (56%)	0.494
Left hemisphere	6 (33%)	8 (44%)	0.494
Clot location			
Thalamus	2 (11%)	5 (28%)	0.402
Basal ganglia	16 (89%)	13 (72%)	0.402
Admission CT			
ICH volume (ml)**	45 (35–61)	53 (39–68)	0.389
Midline shift (mm)	9 (8–11)	10 (7–12)	0.502
Intraventricular hemorrhage	13 (72%)	16 (89%)	0.402
ICH score (points)	3 (2–3)	3 (3–3)	0.754

BP = blood pressure; GCS = Glasgow Coma Scale; ICH = intracerebral hemorrhage; CT = computed tomography.
Data are median (IQR) or n (%).
*Data are mean ± SD.
**ICH volumes were estimated in brain CT by the ABC/2 method.

Mortality and Survival

The endoport group was associated with lower 90-day mortality (33% vs. 72%, $p = 0.019$). Kaplan–Meier analysis revealed a higher probability of survival at 90 days after stroke in the endoport group (67% vs. 28%; HR 0.32, $p = 0.015$) (Figure 4).

Binomial logistic regression was performed to determine the effects of admission GCS score, hemorrhage volume, surgical procedure, and approach on the likelihood that participants were alive at the 90-day follow-up. The logistic regression model was

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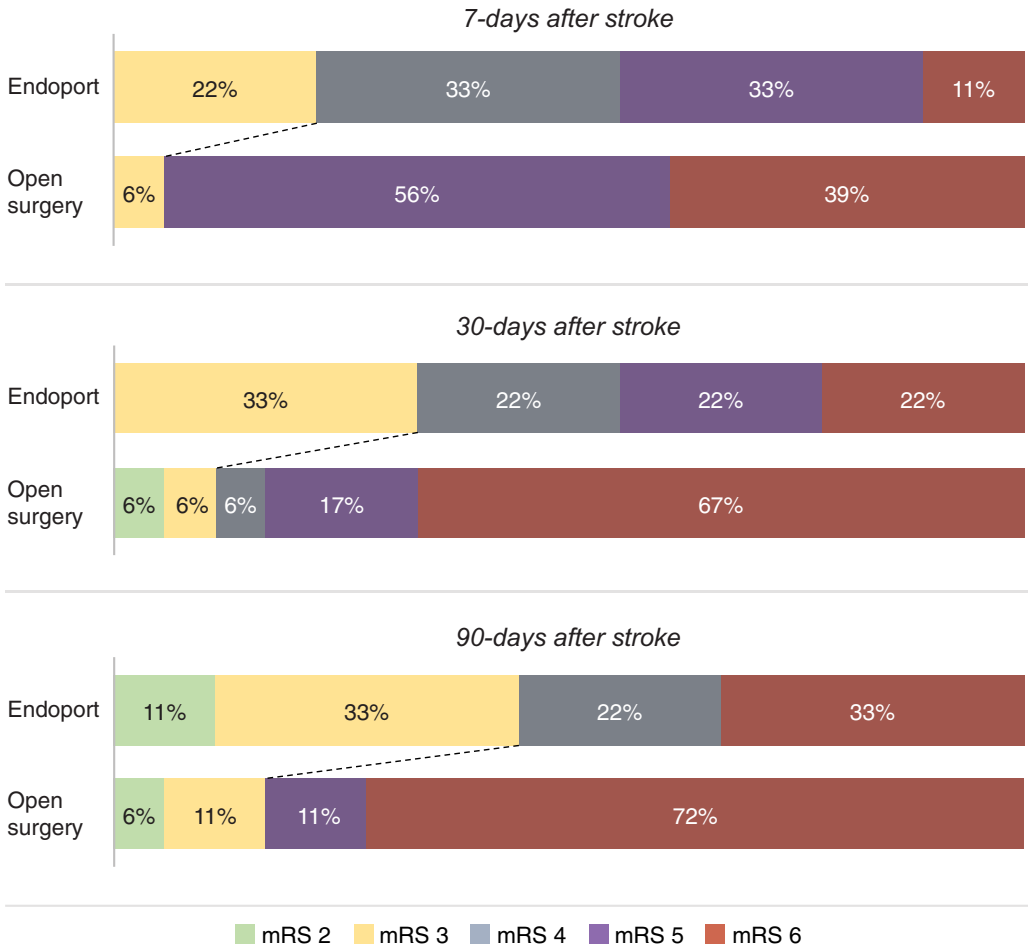

Figure 3: *Functional outcome. At the 90-day post-stroke follow-up, 44% of patients in the endoport group had a favorable functional outcome, compared to 17% in the STOS group ($p = 0.039$). mRS scores range from 0 (no disability) to 6 (death). mRS = modified Rankin Scale.*

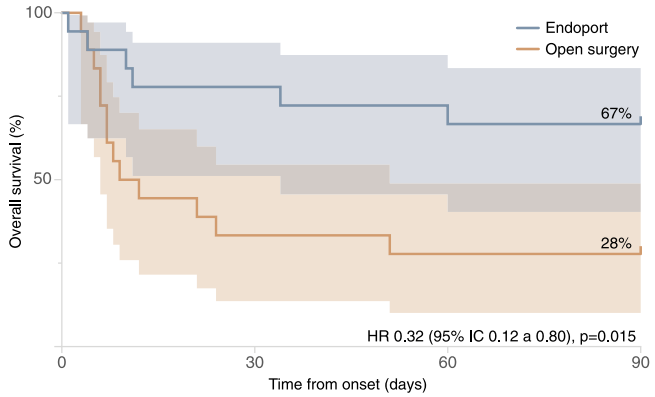

Figure 4: *Overall survival. Kaplan–Meier analysis revealed a higher probability of survival at 90 days after stroke in the endoport group (67% vs. 28%; HR 0.32 (95% CI 0.12, 0.80), $p = 0.015$). Data were censored at day 90. Shaded areas show 95% CIs.*

statistically significant, $\chi^2(4) = 25.8$, $p < 0.001$. The model explained 68% (Nagelkerke R^2) of the variance in 90-day survival and correctly classified 83% of cases. Patients in the endoport group were 17 times more likely ($p = 0.019$) to be alive at the 90-day follow-up than the OS group. An increase of one point of the GCS was associated with 2.7 times increased likelihood ($p = 0.012$) of 90-day survival. Hemorrhage volume ($p = 0.474$) and surgical procedure ($p = 0.578$) did not add significantly to the model.

Secondary Outcomes Analyses

Detailed information on the treatment variables and outcomes is shown in Table 2. Postoperative residual hematoma volume, clot evacuation rate, and postoperative midline shift showed no statistically significant differences between both groups. Seven patients were reoperated; the leading was a rebleed, followed by a surgical site abscess; there were no notable differences between groups.

Median LOS was similar in both groups; however, patients treated with an endoport were associated with lower in-hospital mortality. Fifty-three percent of patients died during the 90-day follow-up. Pneumonia was the leading cause of death (25% of patients), followed by renal failure (11%), pulmonary embolism (8%), heart failure (6%), and central nervous system infection (3%).

Discussion

This study compared the functional outcome and mortality of two different ICH evacuation techniques: endoport-assisted vs. OS. To the best of our knowledge, a low-cost 3D-printed endoport has not been proposed for a less invasive ICH evacuation.

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Table 2: Treatment variables and outcomes

Variables	3D-Printed endoport ($n = 18$)	Open surgery ($n = 18$)	p value
Symptom onset to surgery time (h)	14 (9–21)	12 (10–17)	0.558
Surgical procedure			
Craniotomy	8 (44%)	6 (33%)	0.494
Decompressive craniectomy	10 (56%)	12 (67%)	0.494
End of treatment CT			
Postoperative volume (ml)	4 (3–7)	1 (1–5)	0.210
Clot evacuation rate (%)	92 (88–94)	97 (99–99)	0.196
Postoperative midline shift (mm)	4 (2–6)	4 (3–6)	0.849
Reoperation	3 (17%)	4 (22%)	0.674
Rebleeding	3 (17%)	2 (11%)	0.999
Surgical site abscess	0 (0%)	2 (11%)	0.486
Hospital length of stay (days)	15 (8–31)	10 (6–20)	0.419
In-hospital mortality	5 (28%)	13 (72%)	0.008
mRS score			
7 days after stroke (points)	4 (4–5)	5 (5–6)	0.003
30 days after stroke (points)	4 (3–5)	6 (5–6)	0.011
90 days after stroke (points)	4 (3–6)	6 (5–6)	0.020
Good functional outcome	8 (44%)	3 (17%)	0.039
90-day all-cause mortality	6 (33%)	13 (72%)	0.019

CT = computed tomography; mRS = modified Rankin Scale.
Data are median (IQR) or n (%).

Large-sized clinical trials have failed to show an overall benefit of open or minimally invasive surgery over medical treatment in ICH management.[13,14,22–24] Nevertheless, several small-to-moderate-sized trials of minimally invasive surgery have yielded encouraging results. A meta-analysis of 14 surgical trials, including 2186 patients, concluded that there is evidence that surgery is of benefit if undertaken early before the patient deteriorates.[25] This study was highly influenced by a randomized, controlled minimally invasive surgery trial conducted by Wang et al., where they compared CT-guided aspiration craniopuncture plus lytic infusion to medical management, showing a substantial reduction in 90-day dependence rates.[26] Moreover, Zhou et al., in a meta-analysis of randomized controlled trials, concluded that patients with supratentorial ICH might benefit more from minimally invasive surgery than other treatment options.[16]

The Minimally Invasive Surgery Plus Recombinant Tissue Plasminogen Activator for Intracerebral Hemorrhage Evacuation Phase III Clinical Trial (MISTIE III), which involves the placement of a catheter in the hematoma cavity and the administration of a thrombolytic agent, failed to improve functional outcome compared to the standard medical care.[24] It is important to note that the MISTIE technique involves passive drainage through a catheter for several days, allowing secondary injury progression. Nevertheless, research suggests other less invasive approaches, such as endoscopic aspiration (Apollo or Artemis, Penumbra, Alameda CA, USA),[27–31] exoscope-assisted endoport system (BrainPath, Nico Corporation, Indianapolis, Indiana, USA),[32,33] and the herein proposed method, may improve clinical outcomes. This improvement is probably obtained by reducing brain injury compared to open surgical manipulation.[34] Additionally, in contrast to the MISTIE technique, these methods may achieve an immediate clot evacuation, potentially reducing injury progression.[9]

The Penumbra Apollo and Artemis endoscopic aspiration system (first and second generation, respectively) consists of an aspiration and irrigation cannula with a vibrational element to eliminate clot buildup. This system fits through the channels of commercially available endoscopes, allowing drainage under continuous endoscopic visualization.[27–29,35] As an alternative, endoports or tubular retractors, such as the BrainPath system and the herein 3D-printed device, provide radial retraction that symmetrically distributes the forces to the surrounding brain parenchyma and provide a protected corridor for access, visibility, and evacuation of the hematoma.[36,37] The technique using the BrainPath endoport system for ICH evacuation is described utilizing neuronavigation and high-definition extracorporeal optics.[32,33,38,39] Otherwise, the proposed endoport may provide adequate access and visibility without additional devices and its associated cost. Furthermore, the BrainPath system price is around 4,000 USD[40] compared to the 40 USD of the device described in this study. Thus, this may be of particular benefit for health care systems with limited resources.

The endoport group demonstrated a 27% absolute increase in favorable functional outcomes and a 39% absolute reduction in all-cause mortality contrasted to the OS at the 90-day follow-up. Although no statistically significant differences were noted between both groups, the endoport group showed an 8 ml lower median ICH volume, which may have affected the outcomes. Nevertheless, the statistical analysis showed that the endoport-assisted approach had an independent association with a better functional outcome and lower mortality.

Favorable functional outcomes obtained by the endoport group (44%) are comparable to those obtained by other retrospective studies of endoscopic aspiration (46%)[29] and endoport-assisted evacuation (44%–63%).[32,38,39] Likewise, the observed 30-day mortality in the endoport group (22%) was similar to endoscopic (9%–28%)[28,29] and other endoport systems (0%–36%).[32,33,39] It is important to note that a wide variation in mortality rates could be associated with data heterogeneity. Given that both endoport and OS cohorts had a median ICH score of 3, the OS group showed comparable 30-day mortality than its associated risk (67% vs. 72%),[41] supporting previous evidence discouraging the OS over medical treatment.[13,14]

In the present study, the endoport group tended to have a non-significant lower clot evacuation rate than the OS group (92% vs.

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97%). It is possibly associated with errors in the trajectory that may have led to inadequate ICH removal or because of the device's narrow corridor, limiting the surgical field's visibility. Despite this, the herein proposed endoport showed promising efficacy, comparable to evacuation rates described with the exoscope-assisted endoport system (95%),[33] and higher than the one reported by the endoscopic aspiration (54%–88%)[27,35] and MISTIE procedure (69%);[24] it is essential to note that the endoport-assisted ICH evacuation was performed without the need for navigation and extracorporeal optics, which may increase surgical costs. The endoport-assisted evacuation technique was safe concerning bleeding, infection, and reoperation rates; moreover, there were no notable differences between both groups in the LOS. These results were similar to those reported with minimally invasive techniques.[15,24,27,32,35,39]

This study has some limitations. First, it was a nonrandomized, retrospective study. Therefore, the authors could not deny the possibility of selection bias; the surgical technique's choice depended upon the surgeons' preference. Second, the number of patients is small to generalize our results and might not give sufficient power to detect slight differences between groups. Third, our cohorts' mortality rates are high, explained by the inclusion of patients with high ICH scores and large hematoma volumes. Our study population's mortality is comparable to prior published literature on patients with severe ICH score.[42] Fourth, there may have been differences in individual patient management that may have influenced our results. Fifth, these results may not apply to lobar ICH, more frequently associated with cerebral amyloid angiopathy; adults with lobar ICH are more likely to survive than adults with non-lobar ICH.[43] Sixth, because of the lack of a medical management group, the advantages of endoport surgical evacuation over medical treatment must not be inferred until adequate research is conducted. Finally, because patients were only followed for 3 months, the possibility of continuous improvement after this point was not evaluated.

Conclusions

Overall, this study suggests that endoport-assisted ICH evacuation may have better functional outcomes and lower mortality than standard OS. The proposed device could provide a safe, low-cost alternative for ICH's surgical treatment and help develop more cost-effective techniques that can be employed in a limited-resource setting. More rigorous research is hence needed and ongoing to assess the potential benefits of this technique.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/cjn.2021.185.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Statement of Authorship

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

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