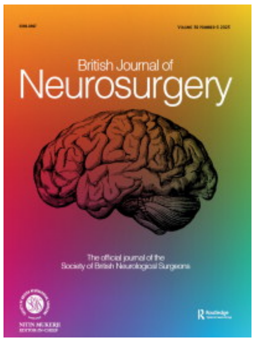

British Journal of Neurosurgery

ISSN: 0268-8697 (Print) 1360-046X (Online) Journal homepage: www.tandfonline.com/journals/ibjn20

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To cite this article: Klas Holmgren, Alba Corell, Merete Sunila, Per Enblad, Andreas Fahlström, Peter Lindvall, Caroline Leijonmarck, Riyad Donardi, Bjartur Sæmundsson, Richard Ågren, Robert Nilsson, Alexander Fletcher-Sandersjöö & Teodor Svedung Wettervik (04 Jan 2026): Decompressive craniectomy for intracerebral haemorrhage in contemporary practice: a Swedish, multi-centre study of utilization, indications, and outcomes, British Journal of Neurosurgery, DOI: 10.1080/02688697.2025.2611161

To link to this article: https://doi.org/10.1080/02688697.2025.2611161

BRITISH JOURNAL OF NEUROSURGERY
https://doi.org/10.1080/02688697.2025.2611161

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RESEARCH ARTICLE

Decompressive craniectomy for intracerebral haemorrhage in contemporary practice: a Swedish, multi-centre study of utilization, indications, and outcomes

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ABSTRACT

Background: This multi-centre study aimed to describe indications and outcomes in spontaneous supratentorial intracerebral haemorrhage (ICH) patients treated with decompressive craniectomy (DC).

Methods: All patients undergoing DC for spontaneous ICH at five Swedish neurosurgical centres between 2008 and 2022 were included ($n = 45$). Clinical, radiological, and outcome data were extracted. Outcome at six months was assessed using the modified Rankin Scale (mRS), dichotomized as favourable vs. unfavourable (mRS 0–3 vs. 4–6), and survival vs. mortality (mRS 0–5 vs. 6).

Results: Based on estimated ICH incidence, DC was performed in approximately 1.5 per 1000 cases. Median age was 47 years and the median ICH volume was 51 mL. Eighty-nine percent underwent ICH evacuation. DC performed as a primary procedure without ICP monitoring in 33%, whereas 67% underwent secondary DC due to refractory ICP elevation. Preoperative midline shift (median 11 mm) and basal cistern compression (present in 96%) significantly improved postoperatively ($p < 0.001$). Reoperation occurred in <10%. At follow-up, 28% were deceased and 40% had recovered favourably.

Conclusions: DC performed in a highly selected ICH population resulted in significant mass effect reduction and a relatively high rate of favourable outcome. Patient selection remains crucial but challenging, and larger prospective studies are warranted.

ARTICLE HISTORY
Received 26 June 2025
Revised 15 October 2025
Accepted 11 November 2025

KEYWORDS
Decompressive craniectomy; intracerebral haemorrhage; intracranial pressure; neurointensive care; outcome

Introduction

Spontaneous intracerebral haemorrhage (ICH) has an incidence of 25–30 per 100,000 person-years and carries a fatality rate of approximately 30%.[1,2] Management of supratentorial ICH is primarily medical and focuses on optimizing haemostasis, blood pressure, and identifying underlying aetiologies to limit hematoma expansion while preventing secondary ischemic brain injury.[3,4] The role of surgical intervention remains debated, particularly regarding indications (prophylactic vs. after neurological deterioration), timing (early vs. delayed), and surgical approach (craniotomy vs. minimally invasive techniques).[3–8] Current guidelines provide somewhat ambiguous recommendations within these aspects,[3,4,9] and ultimately, only a small subset (approximately 5%) of ICHs are surgically evacuated – typically

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/02688697.2025.2611161.

those in younger individuals with moderate-to-large hematomas.[10]

For the most severe cases, especially those presenting with impaired consciousness, transfer to a dedicated neurointensive care (NIC) unit is typically performed for neurological surveillance, and to monitor and manage intracranial pressure (ICP) and cerebral perfusion pressure (CPP), including proceeding with surgical treatment.[3,4,9,11] However, the optimal ICP and CPP thresholds, as well as the timing and escalation strategies for ICP-lowering interventions, remain controversial.[3,4] Standard NIC treatments include surgical evacuation of localized ICHs of significant size, head-of-bed elevation, maintaining normothermia, prevention of hyponatremia, and cerebrospinal fluid drainage (CSF) via an external ventricular drain (EVD), to avoid secondary brain injury.[3,11,12] In addition, decompressive craniectomy (DC) may be considered as a last-tier intervention for refractory intracranial hypertension. In this context, primary DC without ICP monitoring has been utilized in conjunction with ICH evacuation due to perioperative brain swelling, but also as a secondary intervention for refractory intracranial hypertension following prior ICH evacuation. While the role of DC has been extensively investigated in other acute brain injuries, such as traumatic brain injury (TBI)[13,14] and malignant middle cerebral artery (MCA) infarction,[15,16] its use in spontaneous ICH remains largely based on small, heterogeneous, single-centre studies.[17–23] Although ICH evacuation often alleviates mass effect, refractory cytotoxic and vasogenic brain oedema may still elicit ICP elevation and necessitate further interventions. However, there are concerns about whether the underlying brain injury is too severe to allow for meaningful recovery in patients with ICH who develop intracranial hypertension refractory to all treatments except DC, not least considering that long-term outcomes and prognostic factors remain poorly understood.[17–23] Another particularly debated approach is primary DC without hematoma evacuation as a treatment for haemorrhages that are deep-seated or in an eloquent area, which aims to alleviate mass effect while avoiding surgical trauma to surrounding brain tissue.[24–26] In the SWITCH trial, it was recently shown that such treatment led to superior functional outcomes compared with best medical management.[24] Although current guidelines acknowledge primary DC as a reasonable intervention in certain situations,[3,4,9] primary ICH evacuation nonetheless remains the first-line approach at most centres.[10,27] The role of DC on other indications, as mentioned above, than those in the SWITCH trial, remains unclear.

This study aimed to analyse real-world data on spontaneous supratentorial ICH patients who underwent DC in a Swedish multi-centre setting. Given the scarcity of large, high-quality studies on DC for spontaneous ICH, the aim of the current study was to provide further insights into clinical application, patient selection, and outcomes. By analysing nationwide data over 15 years, incidence, indications, and variations in DC for ICH across five Swedish neurosurgical centres were evaluated. Secondly, DC's short-term impact on mass effect, complication rates, and long-term outcomes were assessed. It was hypothesized that DC was reserved for highly selected cases, with considerable variation across centres. Furthermore, DC was stipulated to effectively reduce mass effect at an acceptable complication rate, while resulting in relatively favourable outcomes in a highly selected cohort.

Materials and methods

Patients and study design

This retrospective multicentre cohort study included all patients who underwent DC for spontaneous supratentorial ICH between 2008 and 2022 at the neurosurgical departments in Gothenburg, Linköping, Stockholm, Uppsala, and Umeå. Due to differences in local data availability, Gothenburg contributed cases from 2008–2018, whereas the other centres provided data for the entire study period. These centres collectively serve a catchment area of 8.6 million people, representing 82% of the Swedish population. Out of 518 stroke patients treated with DC, 337 with ischemic infarction, 123 with aneurysmal subarachnoid haemorrhage (aSAH), and 13 with cerebral venous thrombosis were excluded. Thus, the final study population comprised 45 patients with spontaneous ICH treated with DC.

Management

Each of the five centres included in the current study provides neurosurgical care to a large catchment area in Sweden, with populations ranging from roughly 1 million in Umeå to 2.5 million in Stockholm (Table 1). Patients were initially admitted via local hospitals and managed at stroke departments according to general stroke guidelines.[3,4,9] Those considered surgical candidates, typically presenting with moderate-to-large ICH volumes and impaired consciousness,

Table 1. DC rate in the entire cohort and for each centre.

Variables	All	Umeå	Uppsala	Stockholm	Gothenburg	Linköping
DC cases in total, *n*	45	12	20	4	3	6
Study period (years), *n*	13.8[a]	15	15	15	10	15
DC cases per year, *n*	3.3	0.8	1.3	0.3	0.3	0.4
Catchment population (million), *n*	8.6	0.9	2.2	2.4	2.0	1.1
Estimated ICH incidence per year[b], *n*	2236	234	572	624	520	286
Estimated DC rate per 1,000 ICH cases, *n* (95% CI)	1.5 (1.1–2.0)	3.4 (1.8–6.0)	2.3 (1.4–3.6)	0.4 (0.1–1.1)	0.6 (0.1–1.7)	1.4 (0.5–3.0)

DC: Decompressive craniectomy; ICH: Intracerebral haemorrhage.
[a]The population-weighted average study duration was 13.8 years, accounting for the slightly shorter study period in Gothenburg (10 years compared to 15 years at other centres).
[b]The estimated ICH incidence was 26 per 100,000 per year, based on a recent systematic review by Li et al.[1]

were transferred to neurosurgical departments for close monitoring and/or surgical evacuation.[10] Surgery, via craniotomy, was performed in ICH patients with the abovementioned characteristics if chances of survival with a clinically meaningful recovery was considered possible. In surgically treated patients with impaired consciousness who required further sedation and intubation, ICP monitoring was considered. ICP was maintained below 20 mmHg, with first-line ICP-lowering strategies, in addition to ICH evacuation, including head-of-bed elevation, CSF drainage via an EVD, mild hyperventilation, and the avoidance of hyperthermia.[11] DC indications could be summarized into four different categories: Primary DC without prior ICP monitoring (i), performed early in cases with severe mass effect or perioperative brain swelling, alongside ICH evacuation, and in some events limited to the size of the craniotomy customized for ICH evacuation. Secondary DC after ICP monitoring (ii), as a last-tier intervention for refractory intracranial hypertension. Primary DC as a standalone treatment (iii), considered in select cases where brain oedema was predominant despite a small-to-moderate ICH volume, including deep-seated hematomas and/or ICHs in eloquent locations. Lastly, standalone DC in patients with moderate-to-large ICH when an underlying arteriovenous anomaly (iv) could not be completely obliterated, and ICH evacuation was deemed unsafe. Moreover, a frontotemporoparietal hemicraniectomy was the preferred surgical approach, with the primary objective of all procedures being maximal decompression through the removal of a large bone flap and duraplasty.

Data acquisition

Clinical, radiological, and outcome data were collected from medical records and radiological imaging. Demographic variables included age and sex. Primary brain injury severity was assessed using clinical (Glasgow Coma Scale Motor [GCS M] Score) and key radiological findings (ICH volume/location/lateralization and presence of intraventricular haemorrhage [IVH]). ICH volume was calculated according to the ABC/2 formula.[28] The radiological assessments were performed by 1–3 neurosurgical trainees per centre. Pupillary reactivity was classified as normal vs. one or two unreactive pupils. Data on ICH evacuation, ICP monitoring, and barbiturate treatment were also recorded.

Mass effect was assessed using head computed tomography (CT) scans obtained before and after DC. This included quantification of midline shift (mm) and evaluation of the basal cisterns, categorized as open, compressed, or obliterated. The decompression area (cm^2) was also analysed by measuring the anteroposterior width (from the tabula externa) and the craniocaudal height of the decompression on CT imaging in accordance with a method outlined previously.[12] Postoperative complications were systematically reviewed and included reoperations; for hematoma evacuation, extension of the cranial decompression, surgical site infections, and subdural hygromas, respectively.

Lastly, the functional status was assessed by retrospective chart review and determined according to the modified Rankin Scale (mRS)[29] at a time point as close to six months post-DC as possible. The mRS was determined using information from clinic visits or telephone contacts whenever these were available. Assessments focused on the patient's functional independence, including living situation, mobility, and ability to work. If the available documentation did not allow a reliable grading, the mRS score was left unspecified. Chart reviews were performed by neurosurgical trainees (between one and three at each centre). To minimize variability in interpretation, all reviewers used a shared protocol with clearly defined variables, ensuring a harmonized approach to data extraction. Outcome was dichotomized into survival (mRS 0–5) vs. mortality (mRS 6) and favourable (mRS 0–3) vs. unfavourable (mRS 4–6).

Statistical analysis

Continuous and ordinal variables were summarized as medians with interquartile ranges (IQR), while categorical variables were reported as counts and proportions. To allow comparison across centres and time, DC rates per year and estimated ICH incidence were calculated. The latter was derived using an assumed ICH occurrence of 26 per 100,000 inhabitants per year, as reported by Li et al.[1] DC rates per 1000 ICH cases were described with 95% confidence intervals (CI) based on the Poisson distribution. Changes in radiological mass effect, including midline shift and status of the basal cistern, before and after DC were evaluated using the Wilcoxon or Bowker test, depending on the data type. With mortality and favourable outcome as dependent variables, demographic factors, injury severity, and surgical aspects of DC were analysed using univariate logistic regression, described with odds ratios (OR) and 95% confidence intervals (CIs). Unadjusted p-values of less than 0.05 were considered statistically significant. Statistical analyses were performed using RStudio software (version 2022.12.0).

Results

DC surgery per centre

A total of 45 ICH patients underwent DC (Table 1). The annual DC rate per centre and per estimated number of ICH cases (assuming an incidence of 26 per 100,000 persons/year)[1] varied substantially across centres. Uppsala had the highest annual DC rate (1.3), whereas Umeå demonstrated the highest estimated DC rate per 1000 ICH cases (3.4 [95% CI 1.8–6.0]). In contrast, Stockholm had the lowest annual DC rate (0.3) and DC rate per 1,000 ICH cases (0.4 [95% CI 0.1–1.1]).

Patient characteristics

In brief, the cohort included 45 patients (Table 2). The median age was 47 (IQR 34–62) years, and 56% were male. At admission, the median GCS M was 5 (IQR 3–6), and 43% had one or two unreactive pupils. Most (71%) ICHs were lobar, with a median volume of 51 (IQR 38–79) mL, and nearly half had IVH. Secondary causes were identified in 24% of cases.

Table 2. Demographics, admission variables, management, and functional outcome.

Variables	
Demography	
Age (years), median (IQR)	47 (34–62)
Sex (male/female), *n* (%)	25/20 (56/44%)
Admission variables	
GCS M at admission, median (IQR)	5 (3–6)
Pupillary status at admission (normal/1 unreactive/2 unreactive), *n* (%)	26/12/7 (58/27/16%)
Hemiparesis (yes), *n* (%)	36 (84%)
Dysphasia (yes), *n* (%)	18 (43%)
ICH location (central/lobar), *n* (%)	13/32 (29/71%)
ICH side (right/left), *n* (%)	27/18 (60/40%)
ICH volume (mL), median (IQR)	51 (38–79)
ICH aetiology (primary/secondary[a]), *n* (%)	34/11 (76/24%)
IVH (yes), *n* (%)	21 (47%)
Before DC	
GCS M before DC, median (IQR)	5 (2–5)
Pupillary status before DC (normal/1 unreactive/2 unreactive), *n* (%)	26/13/1 (65/33/3%)
Management	
Hematoma evacuation, *n* (%)	40 (89%)
ICP-monitoring	
No ICP-monitoring, *n* (%)	2 (4%)
EVD, *n* (%)	17 (38%)
Intraparenchymal, *n* (%)	17 (38%)
Both, *n* (%)	9 (20%)
Barbiturates (yes), *n* (%)	13 (33%)
Outcome	
mRS, median (IQR)	4 (3–6)
Favourable outcome, *n* (%)	17 (40%)
Mortality, *n* (%)	12 (28%)

Missing data: GCS M at admission ($n = 1$), hemiparesis ($n = 2$), dysphasia ($n = 3$), ICH volume ($n = 2$), GCS M before DC ($n = 10$, due to continuous sedation and the infeasibility of clinical examination), pupillary status before DC ($n = 5$), barbiturates ($n = 5$), mRS ($n = 2$).

AV: Arteriovenous; AVM: arteriovenous malformation; DC: Decompressive craniectomy; EVD: External ventricular drainage; GCS M: Glasgow Comas Scale Motor Score; ICH: Intracerebral hemorrhage; ICP: Intracranial pressure; IQR: Interquartile range; IVH: Intraventricular haemorrhage; mRS: Modified Rankin Scale.

[a]Secondary aetiologies included AVM ($n = 10$) and dural AV fistula ($n = 1$).

Almost all patients received ICP monitoring, and 89% underwent hematoma evacuation. Barbiturate therapy was used in 33% of patients.

DC – Indication, type, size, and impact on mass effect

Among the 45 patients, 33% underwent primary DC, while 67% had secondary DC (Table 3). All DCs (100%) were unilateral/hemi, with a median decompression area of 94 cm^2 (IQR 80–113). DC had a significant impact on intracranial dynamics, reducing the median midline shift from 11 mm (IQR 7–13) preoperatively to 4 mm (IQR 2–7) postoperatively ($p < 0.001$; Table 4). Additionally, basal cistern compression or obliteration decreased from 96% preoperatively to 40% postoperatively ($p < 0.001$).

DC – Complication rate

A subset of the DC cases required reoperation, including evacuation of postoperative hematomas (9%), enlargement of the cranial decompression (4%), or revision due to a surgical site infection (7%). Nine percent required a ventriculoperitoneal shunt at some point postoperatively due to a persistent CSF circulation disorder.

Table 3. DC: Indication, surgical aspects, and complications.

Variables	
Indication for DC (primary/secondary), *n* (%)	15/30 (33/67%)
Type of DC (hemi/bifrontal), *n* (%)	45/0 (100/0%)
DC size (cm^2), median (IQR)	94 (80–113)
Post-DC hematoma, *n* (%)	4 (9%)
Post-DC extension of bony decompression, *n* (%)	2 (4%)
Post-DC external brain herniation, *n* (%)	31 (69%)
Post-DC surgical site-infection, *n* (%)	3 (7%)
Post-DC subdural hygroma, *n* (%)	0 (0%)
Post-DC ventriculoperitoneal shunt, *n* (%)	4 (9%)

No missing data. All 4 post-DC hematomas were ipsilateral (3 epidural and 1 intracerebral).
DC: Decompressive craniectomy; IQR: Interquartile range.

DC – Functional outcome and prognostic factors

The median time point for outcome assessment was 6 (IQR 6–8) months post-ictus, with data missing for 2 patients (4%). At follow-up, the median mRS was 4 (IQR 3–6), with 40% of patients demonstrating a favourable outcome, and 28% being deceased (Table 2 and Figure 1).

No significant associations were found between mortality and demographic factors, initial injury severity, ICH characteristics, or DC indication (Table 5, Figure 2 and 3). However, presence of an IVH was significantly associated with a lower likelihood of favourable outcome (OR (95% CI) = 0.19 (0.04–0.71), $p = 0.018$).

Discussion

This retrospective, multi-centre study demonstrated the rare and highly selective use of DC in patients with spontaneous ICH, with only 45 cases recorded over 15 years in a near nationwide Swedish cohort. In this specific context, DC was predominantly a last-tier intervention employed with substantial variations across centres. Most DCs were performed either in conjunction with immediate ICH evacuation or at a later stage for refractory intracranial hypertension,

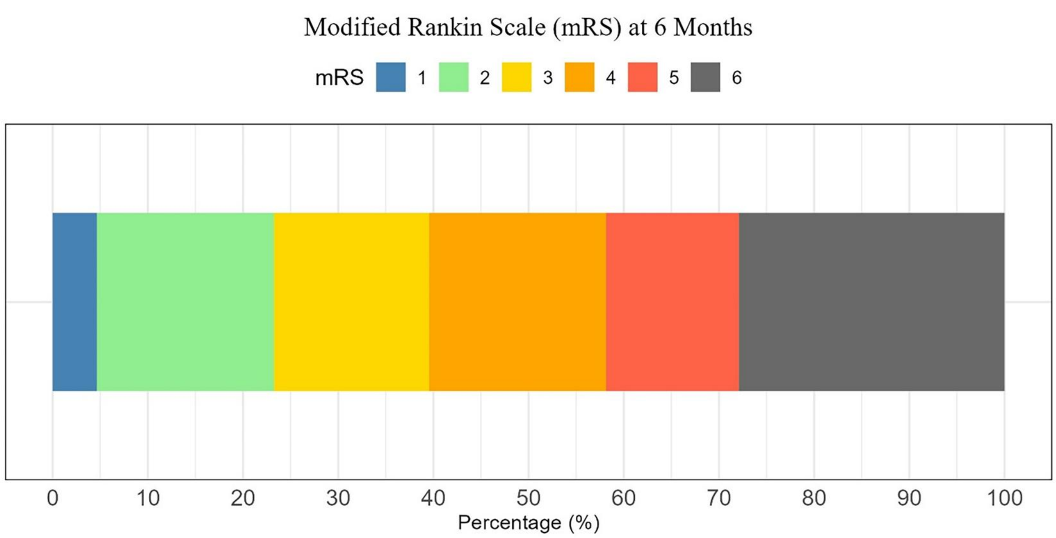

Figure 1. Long-term outcome following DC in spontaneous ICH. The figure demonstrates the distribution of mRS outcomes after DC in patients with spontaneous ICH ($n = 45$ in the entire cohort, but 2 with missing mRS data). DC: Decompressive craniectomy; ICH: Intracerebral haemorrhage; mRS: Modified Rankin Scale.

Table 4. Mass effect before and after DC.

Radiological variables	*Before*	*After*	*p*
Midline shift (mm), median (IQR)	11 (7–13)	4 (2–7)	***<0.001***
Basal cisterns (open/compressed/obliterated), n (%)	2/27/16 (4/60/36%)	27/13/5 (60/29/11%)	***<0.001***

No missing data. Bold and italics indicate statistical significance.
DC: Decompressive craniectomy; IQR: Interquartile range.

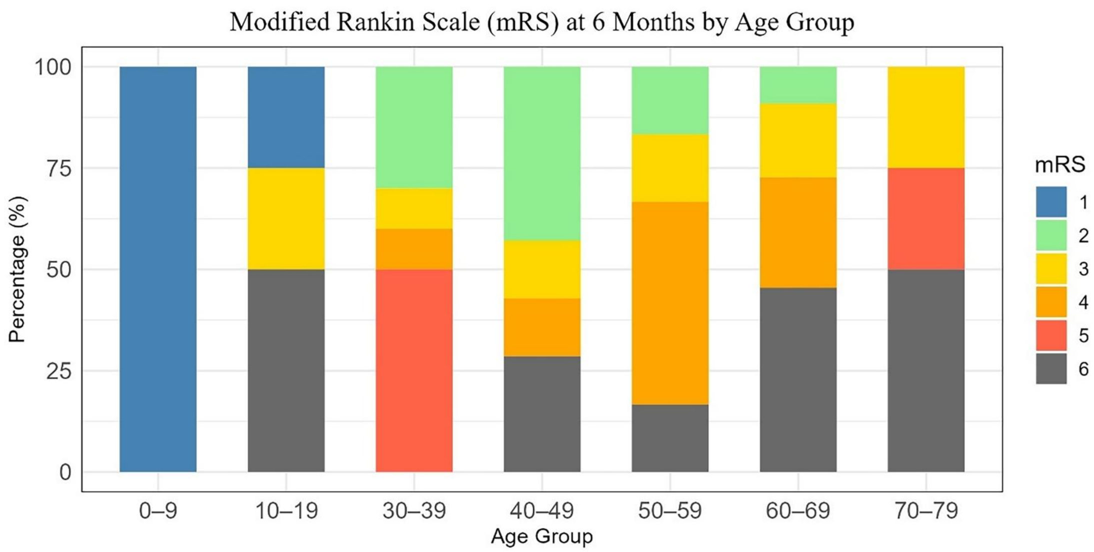

Figure 2. Long-term outcome following DC in spontaneous ICH for different age groups. There was no patient in the 20–29 group. The figure demonstrates the distribution of mRS outcomes after DC in spontaneous ICH ($n = 45$ in the entire cohort, but 2 with missing mRS data). Age group: 0 to 9 ($n = 1$), 10–19 ($n = 4$, 1 missing mRS), 20–29 ($n = 0$, 1 missing mRS), 30–39 ($n = 10$), 40–49 ($n = 7$), 50–59 ($n = 6$), 60–69 ($n = 11$), and 70–79 ($n = 4$). DC: Decompressive craniectomy; ICH: Intracerebral haemorrhage; mRS: Modified Rankin Scale.

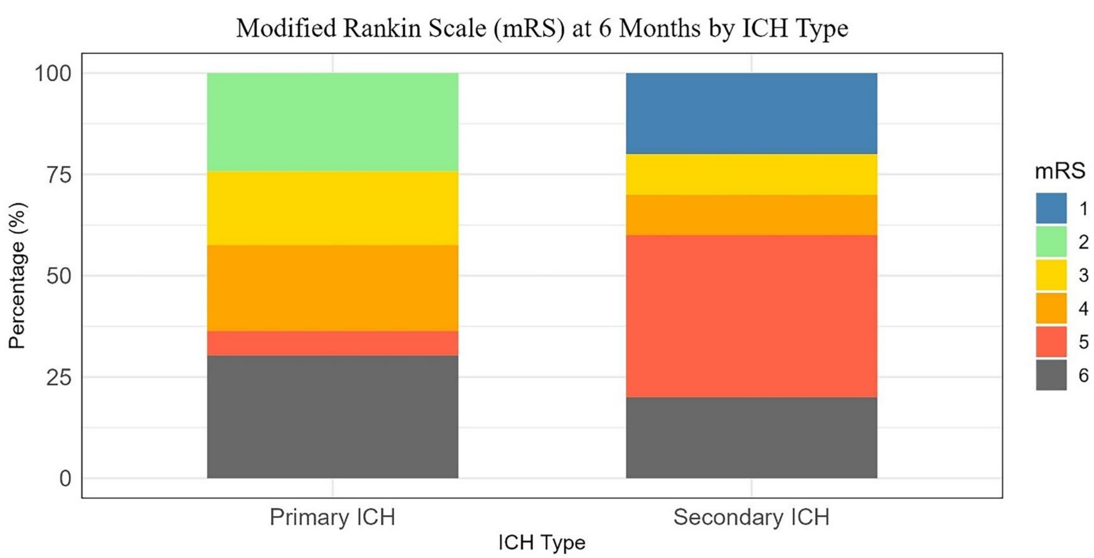

Figure 3. Long-term outcome following DC in spontaneous ICH for types of ICH. The figure demonstrates the distribution of mRS outcomes after DC in spontaneous ICH (n = 45 in the entire cohort, but 2 with missing mRS data). Primary ICH ($n = 33$) and secondary ICH ($n = 10$). Among the secondary ICH cases, 10 of 11 were AVM-related, while the remaining case was due to an AV fistula (mRS 5). AV: Arteriovenous; AVM: Arteriovenous malformation; DC: Decompressive craniectomy; ICH: Intracerebral haemorrhage; mRS: Modified Rankin Scale.

while in a few cases, DC was performed as a standalone procedure in patients for whom hematoma evacuation was deemed inadvisable. Despite the severity of the underlying brain injury, the unexpectedly high 40% rate of favourable outcome found herein is notable. However, this finding likely reflects the highly selective nature of the cohort, comprising patients deemed to have a potential for functional recovery despite severe ICP problems. Still, few predictors of outcome were identified, with the presence of IVH emerging as the most consistent, aligning with other studies on ICH prognostics.[30]

This study indicates that DC for spontaneous ICH remains exceptionally rare, performed in only 1.5 per 1000 ICH cases, with most Swedish centres averaging approximately one DC for ICH per year. In comparison, ICH evacuation, though also relatively uncommon, has been reported at a substantially higher rate of approximately 50 per 1000 cases, both in Sweden[10] and internationally.[27] These findings align with previous studies reporting on the exceptional infrequency of DC for spontaneous ICH, further supported by the fact that available studies primarily consist of small, single-centre case series.[17–23,25,26] By comparison, DC is by far more common in other acute brain injuries, such as aSAH and moderate-to-severe TBI, with incidence rates ranging between 1% and 10%.[31–34]

The DC cohort primarily consisted of middle-aged patients around 50 years old, and were hence 10 years younger than the average patient in ICH populations treated with surgical evacuation in Sweden.[10] The injury severity reflected the typical spectrum for ICH cases requiring intervention, with most patients showing neurological deterioration and impaired consciousness, yet relatively few presenting with critically poor motor responses (GCS M 1–3), suggesting that the majority were seriously ill but not beyond potential recovery. DC was performed in conjunction with or after primary ICH evacuation in the vast majority of cases (89%), with a slight preponderance of secondary DCs. A minority underwent DC without hematoma evacuation, mainly in cases of deep-seated ICH with a predominance of oedema, or in secondary ICH where an underlying AVM precluded evacuation. In Sweden, primary surgical treatment of ICH is uncommon, approximately 5% of all cases undergo primary evacuation,[10] and our real-world data underscore that primary DC has been used only in exceptional circumstances. This highlights the distinct treatment landscape in which DC is predominantly reserved as a last-tier intervention for refractory intracranial hypertension. The recent SWITCH trial[24] provides valuable RCT evidence regarding primary DC without hematoma evacuation in large, deep-seated ICH, demonstrating superiority over best medical management. While SWITCH offers important insights into this indication, its findings pertain to a different clinical scenario than what is chiefly captured in our cohort. Our observational data primarily reflect outcomes and decision-making in patients undergoing secondary DC for refractory intracranial hypertension, a subgroup for which evidence remains limited. Thus, although our study cannot be directly compared with the RCT design of SWITCH,[24] real-world epidemiological data and outcomes reported herein may be viewed as a complement and an important addition for another clinically relevant ICH population.

In the current cohort, GCS M slightly declined from admission to pre-DC assessment, and preoperative imaging consistently demonstrated significant mass effect, as evidenced by midline shift and compression of the basal cisterns. Postoperatively, the mass effect had decreased considerably, with reduced midline shift and reopening of the basal cisterns. The rate of DC complications was low-to-moderate, with reoperations due to postoperative hematoma found in 9% and surgical-site infection in 7% of cases. These numbers are relatively comparable with those after DC in other acute brain injuries such as TBI and aSAH.[31,35] The shunt dependency rate at 9% was slightly higher than those reported in TBI,[35] but lower than those in aSAH.[31,36] The somewhat high prevalence of IVH in our cohort (47%) likely contributed to the development of both acute and chronic CSF circulation disturbances, ultimately resulting in shunt dependency.

Furthermore, the 28% mortality rate found herein was considered relatively low, while 40% of patients achieved a favourable recovery. Given that there were no octogenarians (or older), most presented with a GCS M of 5 and ICH volume typically exceeding 30 mL, including 47% presence of IVH, the expected mortality rate would, based on the ICH score (2–3 points),[30] range from 26% to 72%, of which the majority herein would lie in the upper end of this spectrum. Thus, our observed mortality in this DC-exclusive cohort appears relatively low, while not least considering the severe underlying brain injury required for ICH to result in the need for DC. Nevertheless, the proportion of patients with a favourable outcome (40%, mRS 0–3) aligns fairly well with previous studies reporting within the range of 22%–46% for ICH patients treated with DC;[18,19,23] although, worse figures of favourable outcomes between 13% and 14% have also been demonstrated

Table 5. Clinical outcome in relation to demography, injury severity, clinical course, and surgical aspects – univariate logistic regression analysis.

	Mortality		Favourable outcome	
Variables	*Or (95% CI)*	*p*	*Or (95% CI)*	*p*
Demography				
Age (years)	1.02 (0.99–1.07)	0.244	0.98 (0.94–1.01)	0.177
Admission variables				
GCS M at admission	1.31 (0.88–2.13)	0.224	0.84 (0.58–1.20)	0.333
Pupillary status at admission (unreactive)*	2.22 (0.58–9.08)	0.250	0.82 (0.23–2.80)	0.748
ICH location (central)	NA	NA	0.69 (0.16–2.71)	0.606
ICH side (left)	3.42 (0.87–14.51)	0.082	0.57 (0.15–2.03)	0.395
ICH volume (mL)	1.00 (0.98–1.01)	0.728	1.00 (0.99–1.02)	0.603
ICH aetiology (secondary)	0.58 (0.08–2.83)	0.528	0.58 (0.11–2.51)	0.484
IVH (yes)	0.76 (0.19–2.91)	0.692	0.19 (0.04–0.71)	***0.018***
Before DC				
GCS M before DC	1.33 (0.83–2.33)	0.261	0.79 (0.51–1.21)	0.283
Pupillary status before DC (unreactive)	0.82 (0.15–3.81)	0.802	2.22 (0.59–8.88)	0.244
Midline shift (mm) before DC	1.08 (0.98–1.27)	0.192	0.98 (0.87–1.09)	0.767
Basal cisterns before DC (open)	1.00	NA	NA	NA
Compressed	0.29 (0.01–7.94)	0.400	NA	NA
Obliterated	0.56 (0.02–16.14)	0.699	NA	NA
Indication (secondary)	0.67 (0.17–2.74)	0.563	0.63 (0.17–2.30)	0.485
Surgical variables				
DC size (cm^2)	1.01 (0.98–1.03)	0.616	0.99 (0.97–1.02)	0.629

Bold and italics indicate statistical significance. The odds ratios for categorical variables reflect the effect of the level indicated in parentheses, representing the category compared to the reference group.

DC: Decompressive craniectomy; GCS M: Glasgow Comas Scale Motor Score; ICH: Intracerebral haemorrhage; ICP: Intracranial pressure; IVH: Intraventricular haemorrhage.

by a retrospective review[17] and the SWITCH trial.[24] In more unselected spontaneous ICH cohorts (including both surgical and conservative treatment), the favourable outcome rate at 6 months ranges between 40% and 50%.[37] However, direct comparisons across cohorts are challenging and most likely not valid due to underlying variations in patient selection. Still, our findings suggest that DC, as a last-tier intervention, may offer a reasonable chance of a favourable outcome – especially considering that the alternative would likely have been mortality. Nevertheless, it is again important to stress that results from the current study derive from a highly selected population where clinical anticipation of a reasonable likelihood of recovery served as a key determinant to proceed with treatment and introduces selection bias.

Interestingly, while DC is an established last-tier intervention in malignant MCA infarction,[15,16] TBI,[13,14] and, to some extent, aSAH,[31] its role in spontaneous ICH remains less established. This may partly reflect the fact that few ICH patients exhibit escalating ICP that remain refractory to other treatments after the hematoma has been evacuated. However, a subset of patients with persistent refractory oedema still develop intracranial hypertension[11] for whom DC may be a last-tier but life-saving intervention. Nevertheless, the controversy surrounding its role in ICH management stems from uncertainty about whether the underlying brain injury is too severe to allow for meaningful recovery. In comparison, aSAH typically involves immediate global brain injury from onset, compounded by focal damage from treatment complications after aneurysm occlusion and delayed cerebral ischemia, while malignant MCA infarctions result in a large and somewhat delimitable and predictable injury leading to irreversible cytotoxic oedema. For ICH, the brain injury is mostly focal rather than global, whereas the expected neurological deficits may vary substantially depending on hematoma size and location. Furthermore, the associated oedema, often vasogenic in nature, may involve potentially salvageable brain tissue, more akin to TBI than ischemic stroke. Taken together, these characteristics highlight the heterogeneity of spontaneous ICH, suggesting that the utility of DC likely depends on a complex interplay of prognostic factors. Accordingly, an exploratory analysis of predictors of mortality and favourable outcome was included in the present report. Consistent with previous reports on ICH,[30] the presence of IVH emerged as a significant predictor of worse outcome. However other factors such as age or hematoma volume did not reach statistical significance, likely due to the limited sample size and heterogeneity of the cohort. Thus, larger, prospective, multi-center studies are needed to explore these aspects in greater detail.

Methodological considerations

The primary strength of this study lies in its multicentre design, capturing the relatively rare application of DC in spontaneous ICH across most neurosurgical units in Sweden over a 15-year period. While DC has previously been investigated as a primary intervention in selected cases of deep-seated ICH,[24] its use as a last-tier procedure following hematoma evacuation remains uncommon and poorly defined. The lack of consensus regarding optimal patient selection and treatment thresholds, combined with ethical challenges in withholding potentially life-saving surgery, makes large randomized controlled trials exceptionally challenging to conduct. In this context, our study offers important real-world insights into current clinical practice and the treatment results thereof. Despite the limited cohort size, the data reflect decision-making and outcomes in ICH-patients treated with DC in Sweden. Furthermore, the dataset included detailed information on patient demographics, ICH characteristics, interventions, clinical trajectories, and outcomes, providing a robust foundation for observational analysis.

There are also some limitations. The retrospective design inherently introduces selection bias and residual confounding which are difficult to fully take into account. An additional consideration is the inclusion of patients from multiple centres. While a key aim of the study was to examine inter-centre variation in decision-making regarding DC for ICH, patient recruitment from several different centres inevitably introduces heterogeneity in treatment protocols and the potential for referral-related selection bias. While our findings reflect a cross section of DC for ICH in Sweden, we cannot fully determine the extent to which the observed differences reflect institutional policies versus individual clinical judgment, and it is likely that both factors contributed. One principal finding of this study – the proportion of patients achieving a favourable outcome – was based on retrospective chart review, which may be subject to inter-rater variability. Although outcome assessments were based on medical records that were sometimes summary, data collection was performed by experienced academic neurosurgeons adhering to strict evaluation criteria. In addition, when outcome status could not be determined due to insufficient information, data were preferably reported as missing. Furthermore, while the mRS assessments were based on medical chart review and subject to potential imprecision, all analyses were conducted using a dichotomized mRS classification (favourable outcome: mRS 0–3 vs. unfavourable outcome: mRS 4–6), effectively distinguishing between ambulatory and non-ambulatory patients. Furthermore, as the study dataset comprised of anonymized and aggregated data from several centres, details about bone flap storage and subsequent cranioplasty were not available. Considering the association between cranioplasty and increased chances of neurological recovery, the proportion of favourable outcomes may therefore be slightly underestimated in this study. Another important limitation is the absence of a reference group of ICH patients managed conservatively. This is important to note when the results are interpreted, as patients in a particularly poor condition may not have been deemed eligible for DC, potentially inflating the proportion of favourable outcomes observed. In addition, while this study utilized detailed clinical and radiological data commonly employed in clinical practice, only the presence of IVH emerged as a significant predictor of unfavourable outcome, whereas other conventional prognostic factors, such as age and injury severity, did not reach statistical significance. This likely reflects limited statistical power and a risk of type II errors due to the relatively small cohort size. Thus, larger prospective multi-centre studies will be necessary to strengthen multivariate regression models and refine our understanding of the role of DC in the management of ICH.

Conclusions

DC was performed in spontaneous ICH in a highly selected cohort (1–2 per 1000 cases), mainly as a last-tier treatment for intracranial hypertension. Patients presented with severe mass effect preoperatively that improved significantly on postoperative imaging. Notably, 40% achieved favourable outcomes, suggesting that DC may offer a relatively positive prognosis and may be reasonable to consider in highly selected patients. While IVH emerged as a negative predictor of outcome, no other prognostic factors to help guide management were identified, likely due to the small sample size and heterogeneity of the cohort. Overall, DC may be a viable option for severe ICH resulting in refractory ICP elevation, but large prospective randomized controlled studies are needed to confirm its efficacy and better define patient selection.

Acknowledgement

This work was conducted at the Uppsala University Hospital, Karolinska University Hospital, Linköping University Hospital, Sahlgrenska University Hospital, and Umeå University Hospital.

Ethics statement

The study was approved by the Swedish Ethical Review Authority (Dnr: 2023-02347-01, decision date: 2023-05-17). Informed consent was waived for this retrospective study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The study was supported by the Uppsala University Hospital and the Foundation for Stroke Research in Northern Sweden. All authors fulfil the ICMJE requirements for authorship. ChatGPT (GPT-4) was used for language editing of the manuscript.

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Data availability statement

The datasets used and analyzed are available upon request.

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