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Intraosseous needle for management of subacute and chronic subdural hematoma

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OBJECTIVE The primary objective of this study was to evaluate the safety and efficacy of using an intraosseous (IO) needle for decompressive management of subacute and chronic subdural hematomas (SDHs).

METHODS This is a single-center retrospective review of subacute and chronic SDHs treated with IO needle decompression from May 2022 to November 2023. Technical success, recurrence, procedure-related complications, major adverse events, patient demographics, and procedural details were analyzed using standard statistical analysis.

RESULTS Fifty-one patients (mean age 75.4 [SD 11.4] years) met the inclusion criteria. Technical success was achieved in all patients, with only 1 case of recurrence. Rates of procedure-related complications (3/51, 5.9%) and major adverse events (2/51, 4%) were low. There were no statistically significant differences between those with subacute SDHs compared with those with chronic SDHs.

CONCLUSIONS IO needle decompression is a feasible, safe, and effective option for management of subacute and chronic SDHs, with minimal recurrence.

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KEYWORDS subdural hematoma; intraosseous needle; burr hole; craniotomy; vascular disorders

A subdural hematoma (SDH) is a collection of blood that forms between the dura and arachnoid layers surrounding the brain.[1] An SDH can be acute (patient presenting within 3 days of hemorrhage formation), subacute (patient presenting 3–21 days after), or chronic (clot is more than 3 weeks old).[2] Chronic SDH is an increasingly frequent neurosurgical condition with a reported incidence of up to 20 per 100,000 annually, particularly among the older population.[3,4]

SDH can lead to increased intracranial pressure and brain herniation, necessitating emergency neurosurgical intervention. When indicated, conventional surgical treatment is drainage by burr hole craniotomy (BHC).[5] However, the creation of a burr hole, with a usual diameter of at least 14 mm, comes with its own risks and complications. In a study of 395 patients from a single center in Korea who underwent BHC and closed-system drainage for subdural lesions (hematoma or hygroma), 8% developed surgical complications that included acute intracranial hematoma, surgical or management error, newly developed seizure, meningitis, and wound dehiscence.[6] The authors concluded that the incidence of complications after BHC for subdural lesions is higher than previously believed.[6] Furthermore, the rate of SDH recurrence following BHC is reported to be at least 10%, and as high as 33% in some studies.[7,8]

The use of an intraosseous (IO) needle has emerged as a novel approach for decompressive management of extra-axial collections, including both epidural hematoma and SDH.[9,10] However, all documented cases thus far are either individual case reports or small case series, and primarily in the treatment of acute epidural hematoma.[11] As such, the objective of our study was to investigate the safety and efficacy of using an IO needle in the treatment of subacute and chronic SDHs.

Methods

Study Population

A retrospective analysis of all patients who underwent SDH management using an IO needle for decompression by a single operator (N.H.) at the Royal Columbian Hospi-

ABBREVIATIONS BHC = burr hole craniotomy; ICH = intracranial hemorrhage; IO = intraosseous; SDH = subdural hematoma.

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tal in New Westminster, British Columbia, between May 1, 2022, and November 30, 2023, was conducted. Based on the timing of presentation and imaging characteristics from CT of the head, patients with subacute or chronic SDH and predominantly liquid hematomas (homogeneous low attenuation) were included. Several patients had bilateral SDHs requiring bilateral IO procedures (often performed within 1–2 days after the first side was drained); in these cases, only 1 of the 2 procedures was included in the analysis for statistical reasons, as determined by a random number generator to select whether the first or second procedure was to be included. Patients with SDHs containing membranes or septations were included if the fluid components were dominant or it appeared that the fluid was contiguous through the membranes and septations. Conversely, patients presenting with acute SDH (based on the timing of presentation and imaging characteristics, including predominantly high-attenuation hematoma) or those with numerous membranes causing discrete loculations within the hematoma were not offered IO intervention. Cases with concomitant embolization of the middle meningeal artery, or those with acute-on-chronic presentation recognized to require staged/planned reintervention, were excluded from the study. Those with middle meningeal arterial embolization (a small cohort of 3 patients) were excluded because all were receiving systemic unreversible anticoagulation agents, which required immediate drainage; these patients were considered to represent a separate patient demographic better investigated in future research. Patients with liver failure, other coagulopathies, or current use of anticoagulation therapy without being held or reversed were also excluded from the study. Those on antiplatelet agents or those who had anticoagulation appropriately held or reversed before performing the procedure were not excluded. Antiplatelet agents were held for 5 days prior to drainage if the patient could wait or stopped the day of the procedure if neurological deterioration warranted immediate drainage. Direct oral anticoagulation therapy was held for 2 days prior to drainage for neurologically stable patients. Warfarin was reversed with Octaplex (Octapharma) and vitamin K for patients warranting immediate drainage, whereas warfarin was held and vitamin K was administered for stable patients, and the procedure was performed when the international normalized ratio was less than 1.5. The time frame to restart antiplatelet and/or anticoagulation administration varied based on the patient's $CHADS_2$ score, resolution of SDH on follow-up imaging, and clinical trend of improvement, and was often restarted after 2 weeks, 6 weeks, or occasionally longer.

Institutional approval was obtained by the University of British Columbia Clinical Research Ethics Board. The need for individual patient consent for participation in the study was waived. Incentive for this technique originated because the standard subdural evacuation port system (Medtronic) used for bedside SDH decompression was on back order and unavailable, thus requiring development of an improvised technique or necessitating an operative procedure in the operating room. This technique was found to be feasible and hence implemented, with the risks, benefits, and alternatives explained to patients. All patients provided consent at the time of the procedure, either directly or through their proxies.

Procedural Technique

No procedures were performed with the patient under general anesthesia. Corresponding to the area of maximal SDH thickness, the target needle location is prepped with 2% chlorhexidine gluconate and 70% alcohol solution and draped. To provide local anesthesia, 1% lidocaine is injected into the subcutaneous tissues. Using the Arrow EZ-IO System (Teleflex) (Fig. 1), a 25-mm needle (15 gauge) is inserted into the target location using the Arrow EZ-IO reusable needle driver. During needle insertion, there is resistance in the outer table, followed by give-way in the diploic space, then resistance at the inner table, and then give-way once through, at which point the needle is advanced an additional 5 mm (Fig. 2). The stylet is removed, allowing for connection of the extension tubing, which is attached to a suction evacuator bulb drain to provide ongoing negative pressure. The IO needle is left in place for as little as 1 hour and as long as overnight. A postprocedural CT head scan is acquired ideally either later that day or the following day, with subsequent removal of the IO system after there is no further drainage or after demonstrating a goal of 50% reduction or more in hematoma size (as measured on the coronal plane at the point of maximum thickness). However, if no further drainage is encountered or blood products are replaced with CSF density, then the endpoint is deemed to be achieved. Drainage through the IO needle is quite abrupt, with drainage often completed within the first 1–2 hours. There is often minimal to no access-site drainage noted following removal of the IO system. If necessary, a small gauze dressing is applied temporarily. If patients present ambulatory the day before or the day of the procedure, they are often discharged home after 6 hours of observation or the following day. The hospital length of stay can otherwise be affected by comorbidities and hospital transfer logistics. Subsequent imaging is performed typically at 2 weeks or as needed on an ad hoc basis, based on clinical status. Patients are followed up in the clinic within 2–4 weeks after discharge.

Outcomes

The primary outcomes of interest were technical success, recurrence rate, procedure-related complications, and major adverse events within 30 days. Technical success was defined as successful insertion of the IO needle and catheter into the subdural space with egression of hematoma at bedside, and subsequent decrease in SDH size on postprocedural imaging (as measured as the point of largest diameter in the coronal plane). Recurrence was defined as reaccumulation of the hematoma requiring repeat surgical decompression. Procedure-related complications included new intracranial hemorrhage (ICH), failed access, access-site–related infection or bleeding, new-onset seizure, or other complications. Major adverse events included stroke or transient ischemic attack, myocardial infarction, pulmonary embolism, and death.

Secondary outcomes of interest included patient demographics (i.e., age, sex), use of anticoagulation or anti-

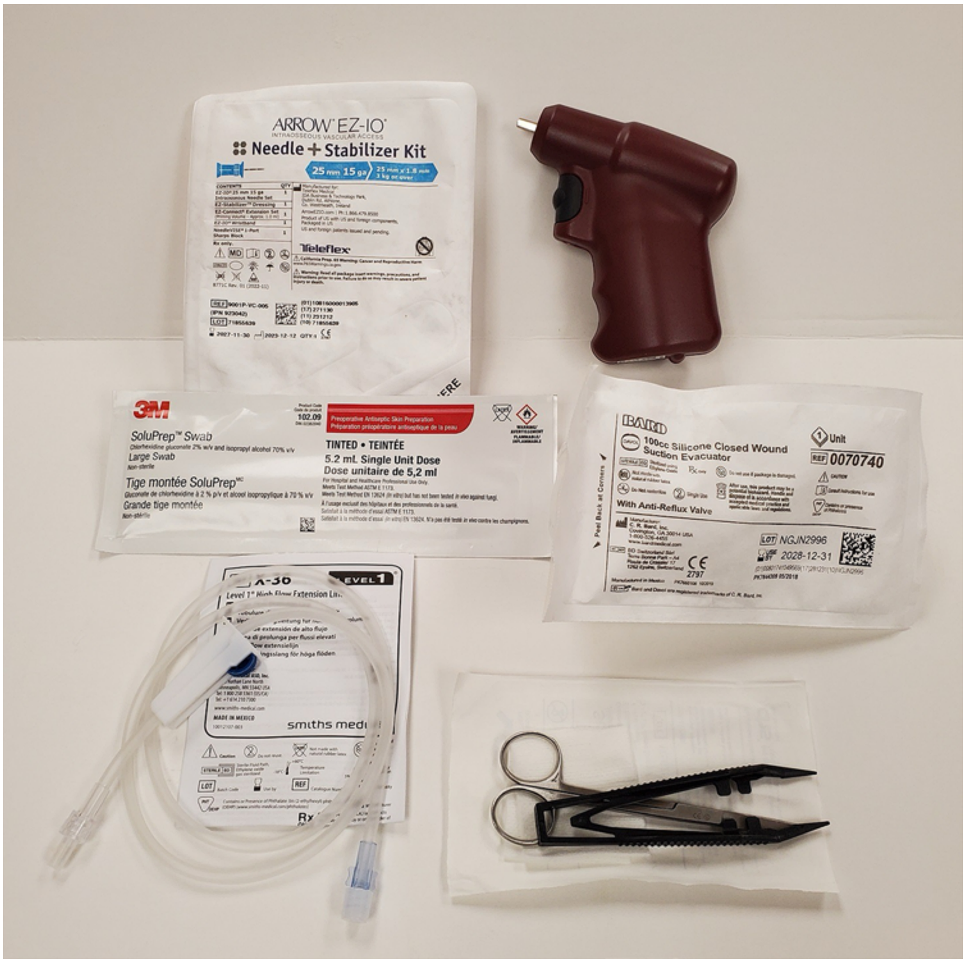

FIG. 1. Equipment used during the procedure (top to bottom), including the IO needle system, reusable drill, chlorhexidine and alcohol cleaning swabs, suction bulb evacuator, extension tubing, plastic forceps, and scissors. Figure is available in color online only.

platelet agents, SDH location, timing of presentation, presenting symptoms, CT imaging characteristics, location of procedure, procedural duration, hospital length of stay, and follow-up duration.

Statistical Analysis

Primary and secondary endpoints with continuous data were analyzed using the Student t-test for independent-samples data and the paired t-test for paired data, with the mean (SD) reported. Dichotomous data were analyzed using the chi-square or Fisher exact tests and are presented as frequencies with percentages. All analyses were conducted using R version 4.2.1 (The R Foundation for Statistical Computing). Two-sided $p < 0.05$ was considered statistically significant.

Results

During the study period, 51 IO drainage procedures were performed in 51 patients (mean age 75.4 [SD 11.4] years) who met the inclusion criteria. Most patients were male (70.6%). Eleven patients (21.6%) were receiving anticoagulation therapy prior to the procedure, which was either held or reversed, and 9 (17.6%) were receiving antiplatelet therapy (all 9 on aspirin only), which were similarly held. Confusion was the predominant presenting symptom (17 patients, 33.3%), followed by motor weakness in 13 patients (25.5%), headache in 12 patients (23.5%), and falls in 9 patients (17.6%). Most of the procedures (86.3%) were performed bedside on the neurosurgical ward, while 7 (13.7%) were performed bedside in the emergency department. The mean hospital length of stay was 8.7 (SD 14.1) days, with a median of 3.0 days. The mean clinical follow-up duration was 98.5 (SD 67.5) days, which does not include 11 patients who did not clinically follow up with the neurosurgeon (9 of whom continued to receive follow-up imaging at least 1 month after the procedure).

SDH characteristics of the included patients are presented in Table 1. Two-thirds were cases of chronic SDH (66.7%) (Fig. 3). There was a slightly increased prevalence of left-sided SDH (54.9%). Membranes were present on preprocedural CT in 12 patients (24%). All patients underwent postprocedural CT within 2 days (36% same day,

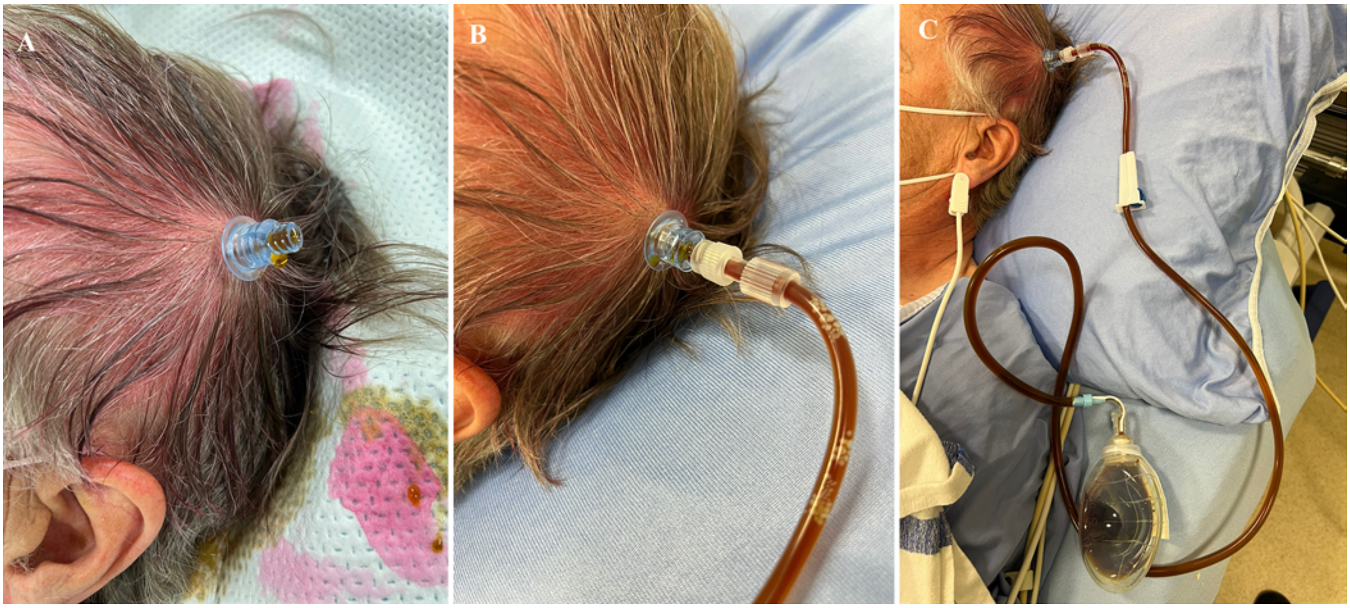

FIG. 2. Postprocedural photographs of a patient with the IO needle inserted within the left parietal calvaria (**A**), which is then connected via extension tubing (**B**) to a suction bulb evacuator drain (**C**). Figure is available in color online only.

38% next day, and 26% 2 days later). All patients except for one (lost to follow-up without further imaging) underwent further follow-up imaging, typically 2 weeks after the procedure or as needed based on clinical status.

TABLE 1. SDH characteristics and procedural outcomes in 51 patients who underwent IO needle decompression

	Value
SDH type	
Subacute	17 (33.3)
Chronic	34 (66.7)
SDH side	
Lt	28 (54.9)
Rt	23 (45.1)
Membranes present	12 (23.5)
Technical success	51 (100)
Recurrence	1 (2.0)
Procedural complications	
New ICH	1 (2.0)
Failed access	0 (0)
Access-site infection	0 (0)
Seizure	1 (2.0)
Persistent blurry vision	1 (2.0)
MAE w/in 30 days	
Stroke or TIA	0 (0)
Myocardial infarction	0 (0)
Pulmonary embolism	1 (2.0)
Death	1 (2.0)

MAE = major adverse event; TIA = transient ischemic attack.
Values are presented as the number of patients (%).

Technical success was achieved in all 51 patients (Table 1). There was one recurrence that required repeat left frontal IO drainage 8 days after the index procedure for persistent chronic SDH (the patient was not receiving anticoagulation or antiplatelet agents and the SDH did not have membranes). Correspondingly, freedom from recurrence was observed in 50 of 51 patients (98.0%, 95% CI 89.6%–100.0%) and was not significantly different ($p > 0.99$) between those with membranes (12 of 12 [100%], 95% CI 73.5%–100.0%) and those without membranes (38 of 39 [97.4%], 95% CI 86.5%–99.9%). Procedural complications included new ICH in 1 patient, new-onset seizure in 1 patient, and persistent unilateral blurry vision in 1 patient. Major adverse events were pulmonary embolism (n = 1) and death (n = 1). All patients had symptomatic improvement immediately following the procedure, and 38 of 39 patients had returned to baseline at the last clinical follow-up visit, excluding the 11 patients lost to clinical follow-up and 1 patient who died. The 1 patient who did not return to baseline had developed new and persistent unilateral blurry vision, which continued to be symptomatic at the last clinical follow-up 50 days after the procedure.

Subgroup analysis was performed comparing patients with subacute SDHs versus those with chronic SDHs (Table 2). There were no statistically significant differences in any variable, including age, sex, anticoagulation therapy, antiplatelet therapy, technical success, recurrence, procedural complications, or major adverse events.

Discussion

Our study describes the technical approach, efficacy, and safety of IO needle decompression in the management of subacute and chronic SDH. Despite the conventional view of BHC as the gold standard in chronic SDH surgical management, rates of surgical complications are reported

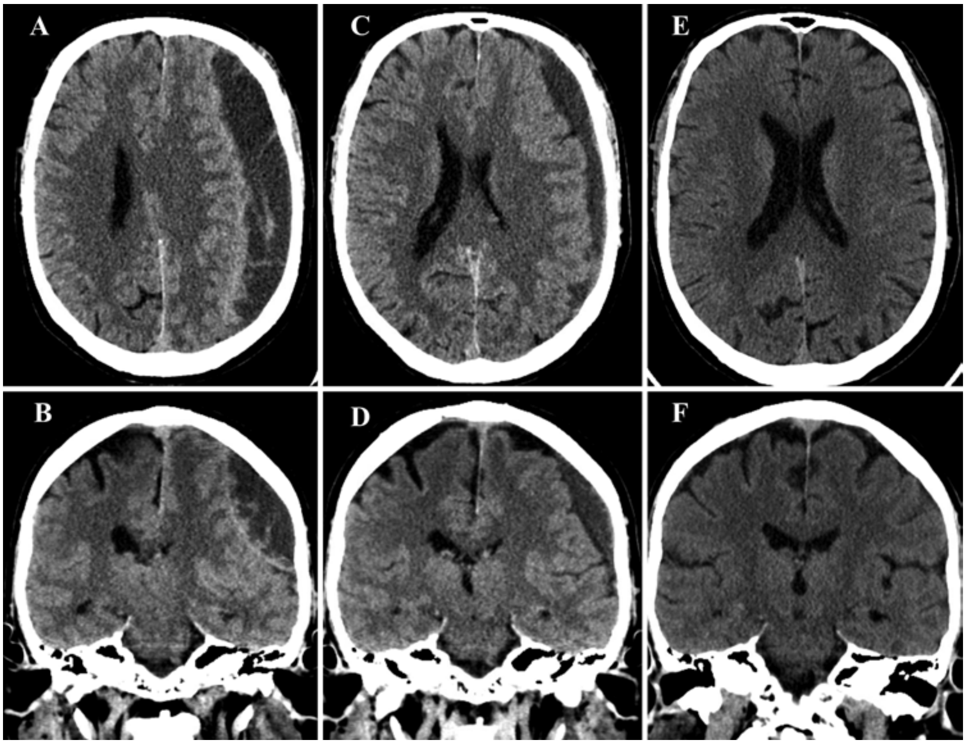

FIG. 3. Axial and coronal CT scans of the head obtained in a 71-year-old male who presented with headache, right-sided weakness, and confusion. **A and B:** CT images showing a large left SDH of mixed but predominantly low attenuation measuring up to 21 mm in maximal diameter and causing associated parafalcine and transtentorial herniation. Bedside IO needle decompression was performed in the emergency department. **C and D:** Postprocedural CT images showing the SDH decreased to 12 mm in size, with improvement in associated mass effect. **E and F:** Follow-up CT images acquired 5 months after the procedure showing complete resolution of the SDH.

as high as 20% and recurrence continues to be a major challenge.[8,12] In BHC, burr holes 12–14 mm in diameter are drilled into the skull, with resulting incision and tearing of the dura mater to allow for suction and irrigation.[13] Modified techniques, such as twist-drill craniostomy, involve the creation of a smaller (< 5 mm) burr hole, which still necessitates tearing of the dura mater with associated high recurrence rates ranging from 28% to 31%.[13,14]

The shortcomings of BHC and twist-drill craniostomy, namely the high rate of recurrence, have opened the door for novel decompression techniques. Particularly in the setting of acute epidural hematoma, there are a handful of case reports that describe off-label use of IO needles as an emergency temporizing treatment before definitive surgical intervention.[10,11,15–18] All but one were performed by nonneurosurgeons, with mixed outcomes of survival and neurological recovery. Interestingly, 3 of the case reports were in pediatric patients.[11,17,18] Only 1 case series of 2 patients by Barro et al. described the use of IO decompression in SDH, albeit in the acute presentation and performed by a nonneurosurgeon.[9] Table 3 outlines the reported cases of IO needle decompression for treatment of extra-axial hematoma.

To our knowledge, we present the first study demonstrating the use of IO needle decompression in a sample size greater than a case series of 2 patients with SDHs. In our sample of 51 patients, technical success was achieved in 100%, with only 1 case of recurrence. Partially owing to appropriate patient selection (i.e., subacute or chronic SDH of predominantly homogeneous liquid hematoma, with appropriate holding or reversal of anticoagulation or antiplatelet therapy), the low rate of recurrence in our study is a significant advantage compared with conventional BHC or twist-drill craniostomy. We hypothesize that this is largely attributable to the much smaller trephination (15-gauge needle corresponding to a 1.8-mm outer diameter) created by the IO needle, with reduced likelihood of dural tears. Also, as the IO needle is maintained in position across the dura mater for the duration of the procedure, the body of the needle could tamponade any access-related bleeding.

In our cohort, the procedural complications were limited but included 1 patient with new ICH remote from the needle site, 1 with new-onset seizure thought to be secondary to cortical irritation by the residual SDH, and 1 with persistent blurry vision. The case of new ICH was in a patient who was not receiving anticoagulation therapy and underwent left-sided IO drainage of a large (29 mm on the coronal plane) subacute left-sided SDH, with a concomitant smaller (8 mm) right-sided chronic SDH. On follow-up imaging 2 days after the procedure, the left-sided SDH had decreased in size and the patient was experiencing improvement in the associated right-sided weakness, although a new acute component to the right-sided parietal SDH was noted. The patient was initially managed conservatively as the new ICH remained asymptomatic

TABLE 2. Subgroup analysis of IO drainage in the subacute SDH group compared with the chronic SDH group

	Subacute SDH	Chronic SDH	p Value
No. of pts	17	34	
Mean age, yrs (SD)	71.6 (12.4)	77.3 (10.5)	0.09
Male sex	13 (76.5)	23 (67)	0.78
Therapeutic agent			
Anticoagulation	4 (23.5)	7 (20.6)	>0.99
Antiplatelet	4 (23.5)	5 (14.7)	0.70
Technical success	17 (100)	34 (100)	>0.99
Recurrence	0	1 (2.9)	>0.99
Procedural complications			
New ICH	1 (5.9)	0 (0)	0.33
Failed access	0 (0)	0 (0)	>0.99
Access-site infection	0 (0)	0 (0)	>0.99
Seizure	0 (0)	1 (2.9)	>0.99
Persistent blurry vision	0 (0)	1 (2.9)	>0.99
MAE w/in 30 days			
Stroke or TIA	0 (0)	0 (0)	>0.99
Myocardial infarction	0 (0)	0 (0)	>0.99
Pulmonary embolism	0 (0)	1 (2.9)	>0.99
Death	0 (0)	1 (2.9)	>0.99

Pt = patient.
Values are presented as the number of patients (%), except where indicated otherwise.

at that time. However, over the next few days, the patient demonstrated progressive deterioration of ambulation with new left-sided weakness, requiring craniotomy on postoperative day 8 for this contralateral acute-on-chronic SDH. Additionally, 1 patient had a seizure on postoperative day 9 but was then seizure free after starting antiepileptic medications. Lastly, the patient with persistent blurry left-sided vision initially presented with a chronic right-sided SDH, which fully resolved on interval imaging. No clear mechanism of persistent visual disturbance was determined. Major adverse events included 1 case of pulmonary embolism, as well as 1 death that occurred on postoperative day 22 due to pulseless electrical activity. However, the etiology of the cardiac arrest remains unknown.

The mean hospital length of stay for our cohort was 8.7 days, which might seem longer than expected for a minimally invasive procedure that excludes operating room or intensive care unit recovery time. However, the median length of stay was 3.0 days. While many patients left the hospital the same day of the procedure or the following day, several patients had prolonged stays due to comorbidities such as concomitant pathological fracture requiring kyphoplasty, alcohol use disorder with resulting Wernicke-Korsakoff syndrome, and background major neurocognitive disorder requiring convalescence. Furthermore, many patients had varying clinical statuses and were transferred from other hospitals to undergo the neurosurgical procedures; as such, the total time in hospital was likely inflated, accounting for the time waiting for transfer and time spent in convalescence after returning to the local hospital. For these reasons, as reflected by the SD of 14.1 days, there was considerable variation in patient demographics and characteristics, which could explain the length of stay findings.

A major advantage to this approach is the ability to perform all procedures with local anesthesia, either bedside on the ward or in the emergency department, without requiring an operating room or general anesthesia. When comparing BHC to twist-drill craniostomy, a study of 73 patients who were treated for chronic SDHs demonstrated

TABLE 3. Literature review of case reports and case series involving IO needle decompression in the treatment of extra-axial hematomas

Authors & Year	Sample Size	EDH or SDH	Pt Age (yrs)	Acute or Subacute/Chronic	Operator	Outcome
Current study	51 pts, 58 ops	SDH	75	Subacute/chronic	Neurosurgeon	100% technical success, 1 recurrence
Bulstrode et al., 2017[15]	1	EDH	43	Acute	Neurosurgeon	Craniotomy in OR w/in 8 mins, pt survived w/ excellent recovery
Durnford et al., 2018[10]	1	EDH	69	Acute	Nonneurosurgeon, w/ telephone guidance by a neurosurgeon	Pt died 2 days later
McClung et al., 2020[16]	1	EDH	38	Acute	Nonneurosurgeon	Craniotomy 45 mins later, pt died 2 days later
Barro et al., 2020[9]	2	SDH	65, 30	Acute	Nonneurosurgeon	Pt 1 died during resuscitation; pt 2 had craniotomy 1 hr later, no neurological improvement & transitioned to nursing facility
Grossman et al., 2022[17]	1	EDH	17	Acute	Nonneurosurgeon	Transferred to neurosurgery center for definitive management, discharged home on day 4, full recovery
Weber et al., 2023[11]	1	EDH	7	Acute	Nonneurosurgeon	Transferred for subsequent craniotomy, discharged day 8, full recovery
Sen et al., 2022[18]	1	EDH	18	Acute	Nonneurosurgeon	Transferred for craniotomy, discharged day 8, full recovery

EDH = epidural hematoma; OR = operating room.

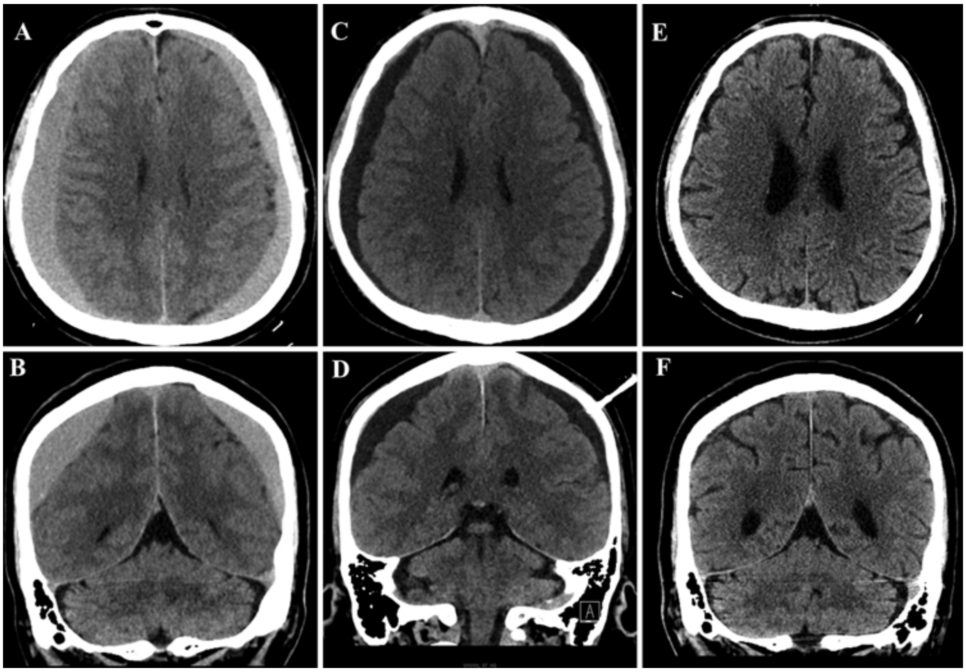

FIG. 4. Axial and coronal CT scans of the head obtained in a 70-year-old male who presented with headache and gait imbalance, with history of fall a few weeks prior. **A and B:** Noncontrast CT images showing bilateral right-greater-than-left subacute SDHs. Bilateral IO needle decompression was performed. **C and D:** CT images acquired the following day showing decreased size and attenuation of the SDHs, with coronal reconstruction showing the IO system inserted into the left parietal calvarium. **E and F:** Follow-up CT images acquired 2 months later showing resolution of both subdural collections.

that twist-drill craniostomy was associated with a lower total cost of treatment, which can be partially attributable to the similar advantage of obviating the need for an operating room or extended intensive care unit stay.[19] In the same study, the total hospital length of stay for the twist-drill craniostomy cohort was comparable to that in our study (mean 9.3 vs 8.7 days, respectively).[19] Although nominal relative to total hospitalization costs, the cost per procedure for the IO technique is almost one-third of the cost per twist-drill craniostomy procedure ($178.00 for all IO equipment vs $524.00 for the Medtronic subdural evacuation port system) at our center. The lower recurrence rate for the IO technique could potentially compound the overall healthcare cost savings.

Our study had limitations, including its retrospective nonrandomized single-center design. Outcomes were limited to short-term follow-up, which might not capture potential long-term neurological complications. While larger than any other study of a similar approach, statistical and subgroup analyses are limited by the sample size of 51 patients. Given the retrospective design, the lack of a matched control group further limits direct comparison to conventional BHC. As the purpose of this study was to describe and discuss our experience with this novel technique, we chose to include patients who underwent bilateral procedures to demonstrate the technique's versatility and ability to be performed in patients presenting with bilateral SDHs (Fig. 4); however, for statistical reasons, only 1 of the 2 patients was included in the analysis. Given these initial promising results, further evaluation with a prospective randomized controlled trial is to be considered. Additionally, as IO needles are a widely available tool in emergency settings for fluid resuscitation, another potential area of research might be whether this treatment method would be an option outside of centers with dedicated neurosurgical support.

Conclusions

The use of an IO needle is an effective decompressive treatment of subacute and chronic SDHs, with a low rate of complications. Procedures can be performed bedside using local anesthesia, negating delays in care and costly resources associated with operating room surgeries, while maintaining high rates of technical success. The smaller trephination size and focal perforation of the dura mater might explain the minimized risk of recurrence, which is a known pitfall of BHC and twist-drill craniostomy.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: N Heran, Behboudi. Acquisition of data: N Heran, Yan, Kadyschuk. Analysis and interpretation of data: Yan, MKS Heran. Drafting the article: N Heran, Yan. Critically revising the article: N Heran, Yan, MKS Heran, Kadyschuk. Reviewed submitted version of manuscript: N Heran, Yan, MKS Heran, Kadyschuk. Approved the final version of the manuscript on behalf of all authors: N Heran. Statistical analysis: Yan. Administrative/technical/material support: N Heran, Kadyschuk. Study supervision: N Heran.

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