Turk Neurosurg, 2024

Original Investigation

DOI: 10.5137/1019-5149.JTN.46194-23.2

Received: 28.12.2023
Accepted: 19.02.2024

Published Online: 23.10.2024

Nonacute Subdural Hematoma Evacuation Using a Rigid Endoscopy System: A Clinical Study

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ABSTRACT

AIM: To determine the clinical relevance of a rigid endoscopy surgical method for subdural hematomas, as previously described in a cadaver study.

MATERIAL and METHODS: Between May 2021 and September 2023, 21 patients underwent subdural hematoma drainage using a 0-degree rigid endoscope. Traumatic acute subdural hematomas were excluded. The demographic data of the patients, antiplatelet/ antiaggregant use, perioperative findings, and pre- and post-surgery modified Rankin Scale (mRS) scores were recorded and analyzed.

RESULTS: The mean age of our cohort was 65.63 (±20.52), and the male/ female ratio was 3.2: 1. The hematoma was unilateral in 90.5% of the patients, and the rate of trauma history was 42.9%. The most common radiological diagnosis was chronic subdural hematoma with septa (61.9%). The percentage of patients with a history of antiplatelet/ antiaggregant therapy was 23.8%. No mortality related to the surgery was observed in the early postoperative period; however, two patients underwent reoperation for further bleeding. The neurological grade was the only preoperative factor that had a statistically significant effect on the mRS score at discharge, with significantly better discharge mRS scores in grade 1 and 2 patients (p=0.014).

CONCLUSION: The procedure was found to be safe and feasible, with surgery-related morbidity and mortality within acceptable limits.

KEYWORDS: Subdural, Endoscopy, Hematoma, Minimally invasive

INTRODUCTION

Subdural hematoma (SDH) is the accumulation of blood products in the subdural space. It can result in neurological deficits ranging from mild headaches to coma (29). The incidence of chronic SDH (cSDH) in the general population is 1.72–20.6/ 100,000 people per years (3) but the figure increases to 58.1/ 100,000 in those aged over 65 (7). The incidence is rapidly increasing due to the aging population (18) and the use of antiaggregant/ anticoagulant therapy (22) and is predicted to have doubled by 2030 (14). Traditionally, a large craniotomy is recommended for acute SDHs (24). However, in subacute and chronic SDH, the range of appropriate procedures includes twist-drill craniostomy, burr hole craniostomy, and small and large craniotomy (9).

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Recent case series have presented effective endoscopy-assisted approaches for acute, subacute, and chronic SDHs (8,24). There is no consensus at present as to the best type of endoscope (rigid vs. flexible) to use with these approaches or the optimum anatomical location for craniotomy (the place where the hematoma is the thickest or elsewhere) (5,8,11). Our previous cadaver study identified the most suitable location for mini craniotomies (31). On the basis of that study, we believe that a rigid endoscope could show the anterior/ middle fossa and falx cerebri/ tentorium by applying the same craniotomy method to supratentorial SDHs. This study aims to investigate the clinical applicability of the method described in our cadaver study (31).

MATERIAL and METHODS

Study Design and Data Collection

The study retrospectively evaluated 21 patients who underwent endoscopic subdural collections drainage. In our previous cadaveric study, we determined that the procedure requires a subdural working area for the endoscope of at least 6 mm in width to prevent cortical damage. Therefore, patients with a hematoma thickness ≥6 mm were included in the study. Patients with traumatic acute SDHs (aSDHs) were excluded. The following data for each patient were obtained from the electronic medical records of our institution and telephone interviews: sex, trauma history, uni/ bilateral hematoma, antiplatelet/ antiaggregant therapy, radiological findings (subacute, chronic, hygroma, and presence of septa), clinical symptoms, neurological grade (19), comorbidities, pre-/post-operative modified Rankin Scale (mRS) scores (6), surgical time, postoperative drainage time, complications, rebleeding/ reoperation, and followup duration. Written informed consent to the use of their medical records and images in future research was obtained from all patients or their relatives at the time of hospitalization. The study was conducted in accordance with the tenets of the 2013 revision of the Declaration of Helsinki and was approved by the institutional ethics committee.

Surgical Method

The surgical method of craniotomy was as described in our previous study (31): a 3-cm craniotomy was performed between the mid-pupillary line and the superior temporal line at the most convex posterior point of the parietal bone. A 0-degree rigid endoscope was used for hematoma evacuation, septum fenestration, bridging vein coagulation, and subdural space irrigation (Figure 1). A drain was inserted into each patient following the procedure and removed 2–5 days later. The bone tissue was replaced using a plate-screw system.

Follow-up Assessment

Preoperative neurological grading (Markwalder grade) (19) was evaluated as follows: grade 0, neurologically intact; grade 1, mild symptoms; grade 2, drowsiness or disorientation with variable focal signs; grade 3, severe focal signs; and grade 4, comatose. All patients underwent preoperative magnetic resonance imaging (MRI) and computed tomography (CT). In the early postoperative period, a followup CT was performed. Major procedural complications were defined as those resulting in death or morbidity with mRS scores ≥2. A good clinical outcome was defined as an mRS score of 0–1. All patients underwent MRI at their 6-month followup.

Statistical Analysis

SPSS v. 11.5 was used in the analysis of the data. Mean (± standard deviation[SD]) and median (minimum-maximum) were used as descriptors of quantitative variables, and the number of patients (percentage) was used for qualitative variables. Differences between quantitative variables with non-normal distributions were examined using the Mann-Whitney U test. Fisher's exact test was used to examine the relationships between qualitative variables. The McNemar test was used to examine differences between dependent qualitative variables. The statistical significance level was set at $p<0.05$.

RESULTS

Patient Characteristics

Our study's male/female ratio was 3.2:1, and the mean patient age was 65.63 (±20.52). Hematoma was unilateral in 90.5% (18) of patients, and the rate of antiplatelet/ antiaggregant use was 23.8% (5/21). The proportion of patients with a history of trauma was 42.9%, and the most common radiological finding was cSDH with septa. The most common clinical finding was motor weakness. Most patients (61.9%) were neurological grade 1 and 57.1% had comorbidities. The mean duration of surgery was 43.52 (±12.92) minutes, and drainage was maintained for an average of 3.90 (±1.14) days. The proportion of patients undergoing surgery because of rebleeding was 9.5% (2/21). The preferred reoperation method was endoscopy. The mean followup duration was 16.9 (±6.4) months. All data are summarized in Table I.

Surgical Outcomes

Worsening of the preoperative mRS score was observed after surgery in two patients, but no significant difference was observed when the preoperative and discharge mRS scores were compared (p=0.125) (Table II). The discharge mRS scores of those patients with neurological grades of 1 and 2 were significantly better than those of grade 3 patients (p=0.014). Two of the patients who were grade 3 upon admission with worsened postoperative mRS scores were cancer patients (lung cancer and medulloblastoma). These two patients died in the subsequent 6 months of their comorbidities. There was no significant relationship between the other variables and the discharge mRS scores (Table III).

DISCUSSION

Endoscope-assisted drainage is used with increasing frequency in supratentorial SDHs, especially the subacute and chronic types (2,5,8,12,13,27,30,33). However, despite this increase, there has yet to be any standardization regarding the anatomical location and size of craniotomies for this patient population. In our previous cadaveric study (31), we found

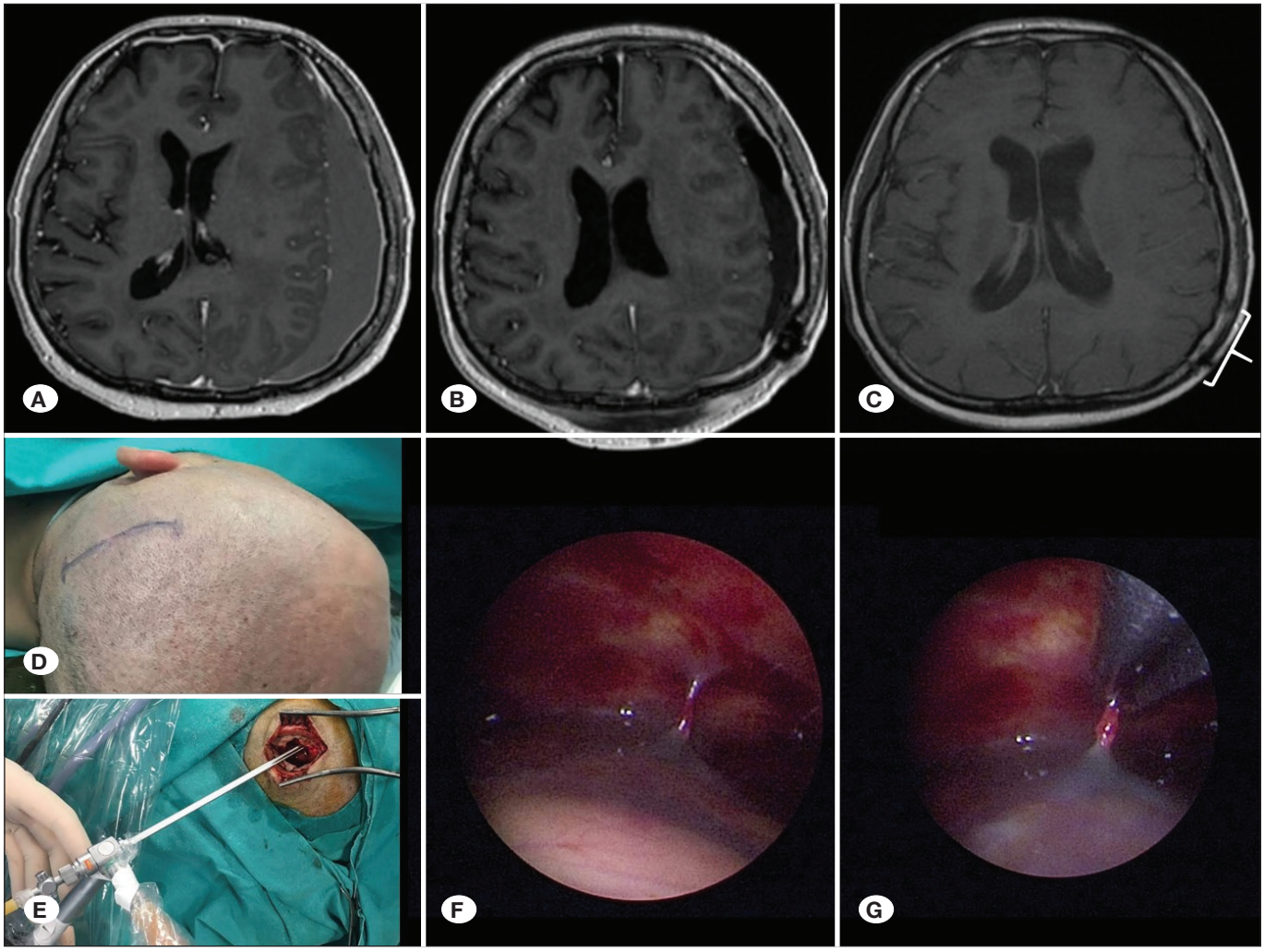

Figure 1: Illustrative case of left frontoparietal subacute subdural hematoma. **A)** Preoperative magnetic resonance imaging (MRI); **B)** Immediate postoperative MRI; **C)** 3-month followup MRI showing complete resolution of the hematoma and mini craniotomy (white bracket); **D)** Patient positioning and incision location; **E)** The use of endoscopy in mini craniotomy; **F)** Endoscopic visualization of the bridging vein; **G)** Cauterized by bipolar electrocautery (image from the same craniotomy).

that the anterior/ middle fossa and the falx cerebri/ tentorium could be visualized simultaneously during craniotomies for supratentorial SDHs using our proposed approach. The present clinical study demonstrated that our method is safe and effective.

Clots, membranous structures, and trabeculae can be safely removed by direct endoscopic visualization (21,28). Using this method, we preferred not to remove midline clots as, in our first cases, we found it difficult to stop the bleeding in these. Previous studies have reported cortical damage in the presence of a blind angle (5,21). However, despite the use of a rigid endoscope, no cortical damage was observed in any of the patients. This was because our method eliminates the blind angle problem, allowing command of the anterior/ middle fossa and the falx cerebri/ tentorium via the location of the craniotomy. Clot removal was achieved by irrigation of all regions reachable with the endoscope, and bipolar cautery could be used (Figure 1) when necessary, although this is not the case in craniostomy. Direct visualization with endoscope allows the placement of a drain in the most appropriate area.

We used a 0-degree endoscope similar to that used in our cadaveric study. While there are reports in the literature on the use of angled endoscopes, these have demonstrated the use of different angled endoscopes, when necessary, rather than comparing the benefits of different endoscope angles (11,16,17). We believe that the use of angled endoscopes could aid the success of this procedure but only after a surgeon has become proficient in the method using a 0-degree endoscope.

In nonacute SDH surgery, craniotomy or craniostomy are the preferred methods of modern neurosurgeons (33). However, there is an increasing amount of research promoting endoscopic approaches, although comparative studies are limited. In a single-center study of 106 cSDH patients who underwent standard craniotomy or an endoscopic procedure,

Table I: Demographic and Perioperative Data for all Patients Included in the Study

Variables		
Age (years)	Mean±SD	65.63 ± 20.52
	Median (Min-Max)	68.00 (17-88)
Gender, n (%)	Female	5 (23.8)
	Male	16 (76.2)
Side, n (%)	Unilateral	19 (90.5)
	Bilateral	2 (9.5)
Trauma History, n (%)	No	12 (57.1)
	Yes	9 (42.9)
Antiplatelet/antiaggregant Therapy, n (%)	Anticoagulant	1 (4.7)
	Antiaggregant	4 (19)
Radiological Findings, n (%)	Subacute hematoma+septa	7 (33.3)
	Chronic hematoma+septa	13 (61.9)
	Hygroma	1 (4.8)
Clinical Symptom, n (%)	Motor weakness	8 (38.1)
	Cognitive impairment	7 (33.3)
	Headache	4 (19.0)
	Headache+motor weakness	1 (4.8)
	Increased head circumference + uneasiness	1 (4.8)
Markwalder Neurological Grading, n (%) (2)	Grade 1	13 (61.9)
	Grade 2	5 (23.8)
	Grade 3	3 (14.3)
Comorbidity, n (%)	Absent	9 (42.9)
	Present	12 (57.1)
	Hypertension	4 (19.0)
	Chronic obstructive pulmonary disease	2 (9.5)
	Diabetes Mellitus	2 (9.5)
	Psychosis	1 (4.7)
	Pancytopenia	1 (4.7)
	Dementia	1 (4.7)
	Lung cancer	1 (4.7)
	Medulloblastoma	1 (4.7)
	Chronic renal failure	1 (4.7)
	Stroke	1 (4.7)
Preoperative mRS, n (%)	0-1	15 (71.4)
	2-5	6 (28.6)
Surgical Time (min)	Mean±SD	43.52 ± 12.92
	Median (Min-Max)	40.00 (30.00-90.00)
Postoperative Drainage (day)	Mean±SD	3.90 ± 1.14
	Median (Min-Max)	4.00 (2.00-5.00)

Table I: Cont.

Variables		
Rebleeding, n (%)	No	19 (90.5)
	Yes	2 (9.5)
Reoperation, n (%)	No	19 (90.5)
	Yes	2 (9.5)
mRS at Discharge, n (%)	0-1	19 (90.5)
	2-5	2 (9.5)
Follow-up Time (months)	Mean±SD	16.9 ± 6.4
	Median (Min-Max)	16 (8-29)

SD: *Standard Deviation,* ***Min:*** *Minimum,* ***Max:*** *Maximum.*

Table II: Comparison of Mrs Score Change in the Preoperative Period and at Discharge

		mRS at Discharge		p-value
		0-1	2-5	
		n (%)	n (%)	
Preoperative mRS	0-1	15 (100.0)	0 (0.0)	0.125[a]
	2-5	4 (66.7)	2 (33.3)	

a: *Mc-Nemar test.*

Table III: Comparison of mRS Score at Discharge with Perioperative Data

Variables		mRS at Discharge		p-value
		0-1 (n=19)	2-5 (n=2)	
Age	Mean±SD	64.17 ± 20.88	79.50±12.02	0.190[a]
	Median (Min-Max)	66.00 (0.17-88.00)	79.50 (71.00-88.00)	
Side, n (%)	Unilateral	17 (89.5)	2 (100.0)	1.000[b]
	Bilateral	2 (10.5)	0 (0.0)	
Trauma History, n (%)	No	11 (91.7)	1 (8.3)	1.000[b]
	Yes	8 (88.9)	1 (11.1)	
Antiplatelet/antiaggregant Therapy, n (%)	No	14 (87.5)	2 (12.5)	1.000[b]
	Yes	5 (100.0)	0 (0.0)	
Radiological Findings, n (%)	Subacute+septa	6 (85.7)	1 (14.3)	1.000[b]
	Chronic+septa	12 (92.3)	1 (7.7)	
	Hygroma	1 (100.0)	0 (0.0)	
Markwalder Neurological Grading, n (%)	Grade 1	13 (100.0)	0 (0.0)	**0.014[b]**
	Grade 2	5 (100.0)	0 (0.0)	
	Grade 3	1 (33.3)	2 (66.7)	
Comorbidity, n (%)	No	9 (100.0)	0 (0.0)	0.486[b]
	Yes	10 (83.3)	2 (16.7)	
Surgical Time (min)	Mean±SD	44.16 ± 13.43	37.50 ± 3.54	0.400[a]
	Median (Min-Max)	40.00 (30.00-90.00)	37.50 (35.00-40.00)	
Reoperation, n (%)	No	17 (89.5)	2 (10.5)	1.000[b]
	Yes	2 (100.0)	0 (0.0)	

SD: *Standard Deviation,* ***Min:*** *Minimum,* ***Max:*** *Maximum,* ***a:*** *Mann-Whitney U test,* ***b:*** *Fisher-exact test.*

the morbidity rate, average operation time, and blood loss were significantly lower in the endoscopy group, showing the endoscopic method to be safer and more effective (33). Another study comparing craniotomy and endoscopy reported a significantly lower rebleeding/ reoperation rate in the endoscopy group, with no increase in surgical complications (2). However, craniotomy remains the primary treatment for recurrent hematoma, hematoma with clot, allowing re-expansion of displaced brain tissue, and relieving mass effect of brain edema on the hemisfere (33). The endoscopic approach is believed to be more suitable for recurrent SDH (13). While we concut with other three indications; we also perform craniotomy for hematomas with clots, to allow re-expansion of brain tissue and to relieve mass effect.

Limitation of endoscopic approach in management of subdural hematomas is the septation in subacute and chronic hematomas which renders risk of recurrence in these cases (10,25). This issue was discussed in the literature that majority of the studies still demonstrated effectiveness of endoscopic approach in septated subdural hematomas (2,8,34) while some studies indicated that burr hole craniostomy is more effective (32). Yan et al. (32) found no significant difference in recurrence rates between the two methods. However, other studies have reported significantly less recurrence this s in their endoscopic patients (2,8,34). The main reason for this difference may be due to the smaller sample size in the study by Yan et al. (32). Craniostomy was considered superior by Yan et al. (32) due to the shorter surgical time and the lesser financial burden in the endoscopic method. Other studies have confirmed the higher surgical duration of the endoscopic method (8,34). These disagreements over the optimum approach may be resolved in the future by large prospective randomized studies.

Risk factors for recurrence include bilateral cSDH with a septum, clots, trabecular structures, male sex, age ≥60 years, a poor Markwalder grade, preoperative midline shifts of ≤10 mm, ambient cistern compression, membranectomy, postoperative midline shifts of >10 mm, and neo-vessels (1,4,28,32). A histopathological study found that the outer membrane can be classified as red, yellow, or white, with white membranes increasing the risk of recurrence (16). Among our cohort, those patients requiring reoperation for recurrence were male, aged ≥60 years, and had poor Markwalder grades. We did not record the outer membrane color.

Traditionally, a large craniotomy is recommended for aSDH, but the endoscope-assisted approach has been popularized by recent research (12,15,16,17,20,23). The mean age of the patient groups in these studies is generally above 65 years, which is unsurprising as an atrophic brain will not swell enough to require decompressive craniectomy in cases of SDH. The number of endoscopically treated aSDH data is limited and only 122 patients were found in a literature review published in 2021 (23). Although favorable outcomes reported range between 26.7–96.4% in cases since 1990, mortality in these cases was between 0–40%. Katsuki et al. argue that the endoscopic approach is preferable in patients with comorbidities likely to increase the morbidity risk of large craniotomy performed under general anesthesia, in patients whose CT scan and clinical findings indicate that decompressive craniectomy is not required, and those whose hematoma is not expanding. They suggest that, while an endoscopic approach does not improve functional outcomes in patients over the age of 70, it reduces intraoperative blood loss and surgical duration (16). All published reports have found the approach effective and efficient in selected patients. In addition, although the present study excluded patients with aSDH, the endoscopic procedure has been found effective in aSDH (26).

The retrospective nature of this study may have caused selection bias. Moreover, the small sample size was also a limitation. However, the patient number was limited because the surgical approach used was determined by treating clinicians on a case -by-case basis. The lack of a SDH group drained by craniotomy for a comparison of efficacy can also be considered a limitation.

CONCLUSION

This study showed that the rigid endoscope surgical method described in our previous cadaveric study to be effective and safe for use with nonacute SDHs. The use of this method in nonacute SDHs will likely increase with technological advances that improve the comprehensiveness of the endoscope's visualization and the increasing experience of the surgical team.

Declarations

Funding: There is no funding to report.

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

Disclosure: The authors declare that they have no competing interests, financial or otherwise, or personal relationships that could have influenced the work reported in this paper.

Ethics Statement: The Pamukkale University Ethics Committee approved this study on 09.05.2023 (approval no: 8).

AUTHORSHIP CONTRIBUTION

Study conception and design: EE, FY
Data collection: UAD, EC, AN, BA, RA
Analysis and interpretation of results: BB
Draft manuscript preparation: FY, YD, DS, MEC
Critical revision of the article: EE, FY
All authors (EE, UAD, EC, AN, YD, DS, RA, BB, BA, MEC, FY) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Amano T, Miyamatsu Y, Otsuji R, Nakamizo A: Efficacy of endoscopic treatment for chronic subdural hematoma surgery. J Clin Neurosci 92:78-84, 2021. https://doi.org/10.1016/j.jocn.2021.07.058
2. Balser D, Farooq S, Mehmood T, Reyes M, Samadani U: Actual and projected incidence rates for chronic subdural hematomas in United States Veterans Administration and civilian populations. J Neurosurg 123:1209-1215, 2015. https://doi.org/10.3171/2014.9.JNS141550

3. Berhouma M, Jacquesson T, Jouanneau E: The minimally invasive endoscopic management of septated chronic subdural hematomas: Surgical technique. Acta Neurochir (Wien) 156:2359-2362, 2014. https://doi.org/10.1007/s00701-014-2219-1
4. Boyaci S, Gumustas OG, Korkmaz S, Aksoy K: Endoscopic evacuation of subdural collections. Turk Neurosurg 26:871-877, 2016
5. Broderick JP, Adeoye O, Elm J: Evolution of the modified rankin scale and its use in future stroke trials. Stroke 48:2007-2012, 2017. https://doi.org/10.1161/STROKEAHA.117.017866
6. Chen JC, Levy ML: Causes, epidemiology, and risk factors of chronic subdural hematoma. Neurosurg Clin N Am 11:399-406, 2000. https://doi.org/10.1016/S1042-3680(18)30101-3
7. Du B, Xu J, Hu J, Zhong X, Liang J, Lei P, Wang H, Li W, Peng Y, Shan A, Zhang Y: A clinical study of the intra-neuroendoscopic technique for the treatment of subacute-chronic and chronic septal subdural hematoma. Front Neurol 10:1408, 2020. https://doi.org/10.3389/fneur.2019.01408
8. Gelabert-González M, Iglesias-Pais M, García-Allut A, Martínez-Rumbo R: Chronic subdural haematoma: Surgical treatment and outcome in 1000 cases. Clin Neurol Neurosurg 107:223-229, 2005. https://doi.org/10.1016/j.clineuro.2004.09.015
9. Hohenstein A, Erber R, Schilling L, Weigel R: Increased mRNA expression of VEGF within the hematoma and imbalance of angiopoietin-1 and -2 mRNA within the neomembranes of chronic subdural hematoma. J Neurotrauma 22:518-528, 2000. https://doi.org/10.1089/neu.2005.22.518
10. Hong KT, Hsu SW, Chen CH, Hueng DY, Chen YH, Ju DT, Bau DT, Tang CT: Endoscope-assisted manipulation of chronic subdural hematomas provides a novel solution for eliminating the septum and inner membrane leading to reduced recurrence. In Vivo 36:2774-2779, 2022. https://doi.org/10.21873/invivo.13014
11. Hwang SC, Shin DS: Endoscopic treatment of acute subdural hematoma with a normal small craniotomy. J Neurol Surg A Cent Eur Neurosurg 81:10-16, 2020. https://doi.org/10.1055/s-0039-1685509
12. Ichimura S, Takahara K, Nakaya M, Yoshida K, Fujii K: Neuroendoscopic technique for recurrent chronic subdural hematoma with small craniotomy. Turk Neurosurg 30:701-706, 2020
13. Iliescu IA: Current diagnosis and treatment of chronic subdural haematomas. J Med Life 8:278-284, 2015
14. Katsevman GA, Arteaga D, Razzaq B, Marsh RA: Burr-hole evacuation of an acute epidural hematoma using the artemis neuroevacuation device with flexible endoscopic visualization: 2-dimensional operative video. World Neurosurg 150:18, 2021. https://doi.org/10.1016/j.wneu.2021.03.021
15. Katsuki M, Kakizawa Y, Nishikawa A, Kunitoki K, Yamamoto Y, Wada N, Uchiyama T: Fifteen cases of endoscopic treatment of acute subdural hematoma with small craniotomy under local anesthesia: Endoscopic hematoma removal reduces the intraoperative bleeding amount and the operative time compared with craniotomy in patients aged 70 or older. Neurol Med Chir (Tokyo) 60:439-449, 2020. https://doi.org/10.2176/nmc.oa.2020-0071
16. Katsuki M, Kakizawa Y, Wada N, Yamamoto Y, Uchiyama T, Nakamura T, Watanabe M: Endoscopically observed outer membrane color of chronic subdural hematoma and histopathological staging: White as a risk factor for recurrence. Neurol Med Chir (Tokyo) 60:126-135, 2020. https://doi.org/10.2176/nmc.oa.2019-0203
17. Khattar NK, McCallum AP, Fortuny EM, White AC, Ball TJ, Adams SW, Meyer KS, Wei G, John KD, Bak E, Sieg EP, Ding D, James RF: Minimally invasive endoscopy for acute subdural hematomas: A report of 3 cases. Oper Neurosurg (Hagerstown) 20:310-316, 2021. https://doi.org/10.1093/ons/opaa390
18. Kolias AG, Chari A, Santarius T, Hutchinson PJ: Chronic subdural haematoma: Modern management and emerging therapies. Nat Rev Neurol 10:570-578, 2014. https://doi.org/10.1038/nrneurol.2014.163
19. Markwalder TM, Steinsiepe KF, Rohner M, Reichenbach W, Markwalder H: The course of chronic subdural hematomas after burr-hole craniostomy and closed-system drainage. J Neurosurg 55:390-393, 1981. https://doi.org/10.3171/jns.1981.55.3.0390
20. Miki K, Nonaka M, Kobayashi H, Horio Y, Abe H, Morishita T, Iwaasa M, Inoue T: Optimal surgical indications of endoscopic surgery for traumatic acute subdural hematoma in elderly patients based on a single-institution experience. Neurosurg Rev 44:1635-1643, 2021. https://doi.org/10.1007/s10143-020-01351-x
21. Mobbs R, Khong P: Endoscopic-assisted evacuation of subdural collections. J Clin Neurosci 16:701-704, 2009. https://doi.org/10.1016/j.jocn.2008.06.023
22. Shofty B, Grossman R: Treatment options for chronic subdural hematoma. World Neurosurg 87:529-530, 2016. https://doi.org/10.1016/j.wneu.2015.09.035
23. Spencer RJ, Manivannan S, Zaben M: Endoscope-assisted techniques for evacuation of acute subdural haematoma in the elderly: The lesser of two evils? A scoping review of the literature. Clin Neurol Neurosurg 207:106712, 2021. https://doi.org/10.1016/j.clineuro.2021.106712
24. Tanaka T, Goto H, Momozaki N, Honda E: Endoscopic hematoma evacuation for acute subdural hematoma with improvement of the visibility of the subdural space and postoperative management using an intracranial pressure sensor. Surg Neurol Int 14:1, 2023. https://doi.org/10.25259/SNI_1084_2022
25. Tanikawa M, Mase M, Yamada K, Yamashita N, Matsumoto T, Banno T, Miyati T: Surgical treatment of chronic subdural haematoma based on intrahematomal membrane structure on MRI. Acta Neurochir 143:613-619, 2001. https://doi.org/10.1007/s007010170067
26. Urquiaga JF, Patel MS, El Tecle N, Quadri N, Alexopoulos G, Bucholz RD, Mercier PJ, Kemp JM, Coppens J: Endoscope-Assisted Evacuation of Acute-on-Chronic Subdural Hematomas: A Single-Center Series. Cureus 14(8): e27575, 2022. https://doi.org/10.7759/cureus.27575
27. Wakuta N, Abe H, Fukuda K, Nonaka M, Morishita T, Arima H, Inoue T: Feasibility and safety of endoscopic procedure in burr-hole surgery for chronic subdural hematoma in patients of very advanced age. World Neurosurg 134:e1037-e1046, 2020. https://doi.org/10.1016/j.wneu.2019.11.080

28. Wakuta N, Abe H, Nonaka M, Morishita T, Higashi T, Arima H, Inoue T: Analysis of endoscopic findings in the chronic subdural hematoma cavity: Bleeding factors in chronic subdural hematoma natural history and as predictors of recurrence. World Neurosurg 124:e241-e251, 2019. https://doi.org/10.1016/j.wneu.2018.12.078
29. Wu L, Guo X, Ou Y, Yu X, Zhu B, Yang C, Liu W: Efficacy analysis of neuroendoscopy-assisted burr-hole evacuation for chronic subdural hematoma: A systematic review and meta-analysis. Neurosurg Rev 46:98, 2023. https://doi.org/10.1007/s10143-023-02007-2
30. Yadav YR, Ratre S, Parihar V, Bajaj J, Sinha M, Kumar A: Endoscopic management of chronic subdural hematoma. J Neurol Surg A Cent Eur Neurosurg 81:330-341, 2020. https://doi.org/10.1055/s-0039-1698388
31. Yakar F, Egemen E, Dere UA, Celtikci E, Dogruel Y, Sahinoglu D, Cuneyit I, Bakirarar B, Adiguzel E, Coskun E: Subdural hematoma evacuation via rigid endoscopy system: A cadaveric study. J Craniofac Surg 32:e402-e405, 2021. https://doi.org/10.1097/SCS.0000000000007031
32. Yan K, Gao H, Zhou X, Wu W, Xu W, Xu Y, Gong K, Xue X, Wang Q, Na H: A retrospective analysis of postoperative recurrence of septated chronic subdural haematoma: Endoscopic surgery versus burr hole craniotomy. Neurol Res 39:803-812, 2017. https://doi.org/10.1080/01616412.2017.1321709
33. Zhang J, Chen J: The therapeutic effects of craniotomy versus endoscopic-assisted trepanation drainage for isolated chronic subdural haematoma (ICSH): A single-centre long-term retrospective comparison study. Brain Res Bull 161:94-97, 2020. https://doi.org/10.1016/j.brainresbull.2020.04.014
34. Zhang J, Liu X, Fan X, Fu K, Xu C, Hu Q, Jiang P, Chen J, Wang W: The use of endoscopic-assisted burr-hole craniostomy for septated chronic subdural haematoma: A retrospective cohort comparison study. Brain Res 1678:245-253, 2018. https://doi.org/10.1016/j.brainres.2017.10.017