Chinese Medical Journal®

Efficacy analysis of flexible neuroendoscopy combined with dry-field techniques in the treatment of chronic subdural hematoma

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Chronic subdural hematoma (CSDH) is a common and frequently occurring disease in neurosurgery, whose incidence accounts for around 10% of all intracranial hematomas.[1] There have been many theories about the mechanism of CSDH, including acute subdural hematoma, slow hemorrhage after bridge vein injury, and traumatic subdural effusion evolution.[2] With improvements in medical imaging technology and related basic research, the perception of CSDH as an inflammatory vascular proliferative disease has gradually reached consensus.[3] In addition to head trauma, brain atrophy leading to expanded subdural space is the premise and primary reason for the occurrence of CSDH in the older adult population.[4]

The development of CSDH is relatively slow, and most patients can be cured if they can be diagnosed and treated in time.[5] Surgical treatment is still the preferred therapy for CSDH, and burr-hole drainage remains the traditional surgical procedure for its treatment. It can quickly release hematoma, reduce intracranial pressure, and readily improve clinical symptoms and focal neurologic dysfunction. However, the application of burr-hole drainage always leads to increased post-operative complications and recurrence rates.[6] With the development of endoscopic neurosurgical techniques, the application of flexible neuroendoscopy in the treatment of CSDH has gradually demonstrated its unique advantages and satisfactory efficacy over recent years.

This study analyzed retrospectively the efficacy of flexible neuroendoscopy combined with dry-field techniques (DFTs) in the treatment of these patients with CSDH. From January 2006 to June 2018, patients with CSDH were treated with burr-hole drainage, flexible neuroendoscopy only, and flexible neuroendoscopy combined with DFTs in this study. Based on the application time of flexible neuroendoscopy, 201 patients were divided into the non-endoscopic group and endoscopic group, whereby 126 cases of CSDH were treated by burr-hole drainage in the non-endoscopic group from January 2006 to December 2010, and 75 cases were treated by flexible neuroendoscopy in the endoscopic group from January 2011 to June 2018. Based on the application of DFTs, 75 cases in the endoscopic group were divided into the endoscopic DFT group (44 cases) and endoscopic non-DFT group (31 cases). The status of all patients on admission, drug history, and pre-operative neurologic dysfunction are shown in Supplementary Table 1 (http://links.lww.com/CM9/A40). The computed tomography (CT) findings of all patients on admission are shown in Supplementary Table 1. Mortality, operative time, hematoma clearance rate, placement time of drainage tube, length of hospital stay, complications, and recurrence rate were compared between the non-endoscopic and endoscopic groups. The study was conducted by the *Declaration of Helsinki* and was approved by the Institutional Review Board of Capital Medical University. Inclusion criteria were as follows: (1) medical history of head trauma or no clear medical history; (2) symptoms such as headache, vomiting, blurred vision, seizures, memory and mental retardation, or mental disorders; (3) neurologic dysfunction, such as hemiplegia or aphasia; (4) CT showed crescent, half-moon, or fusiform low density appearing mainly below the inner plate cranial bone, possibly accompanied by brain deformation and midline shift; (5) no medication history for CSDH; (6) suspension of anticoagulant drugs such as aspirin for more than 10 days; and (7) non-recurrent CSDH. Exclusion criteria were as follows: (1) recurrence CSDH; (2) patients with severe systemic diseases; (3) nutritional status is insufficient to withstand surgery; (4) patients with severe cognitive dysfunction and mental disorders. In the study,

Access this article online

Quick Response Code:	Website: www.cmj.org
	DOI: 10.1097/CM9.0000000000000249

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Chinese Medical Journal 2019;132(11)

Received: 09-12-2018 **Edited by:** Qiang Shi

surgical instruments included the electronic flexible neuroendoscope (Fujinon, Tokyo, Japan) has the following features: 3.8-mm outer diameter, 1.2-mm working channel diameter, 120° view of a surgical field, and 365 mm working length. Individual surgical instruments for flexible neuroendoscopy included micro-biopsy forceps, scissors, and monopolar coagulation (Aesculap, Center Valley, PA, USA).

The same medical team performed all surgeries in this study. (1) Non-endoscopic group: Routine burr-hole drainage was performed under local or general anesthesia. (2) Endoscopy group: All surgeries were performed under general anesthesia. The craniotomy process was the same as that used for the non-endoscopic group. (a) DFT group: A flexible neuroendoscope was placed into the hematoma cavity, and the bloody liquid in the hematoma cavity was gradually evacuated. The endoscopic depth and view were adjusted in the dry field to inspect and evaluate the actual status of the hematoma cavity multi-directionally and multi-angularly [Figure 1A–1D]. The hematoma cavity boundary was defined [Figure 1E and 1F]. The residual blood clot or semi-solid blood component in the hematoma cavity was evacuated by flexible neuroendoscopy with DFT [Figure 1G and 1H]. For false-separated CSDH, the residual blood in the compartment could be removed by local rinse and suction [Figure 1I–1L]. For real-separated CSDH, the penetration, and communication of the compartments guaranteed free efflux of the hematoma fluid [Figure 1M–1P]. Local rinsing and suction

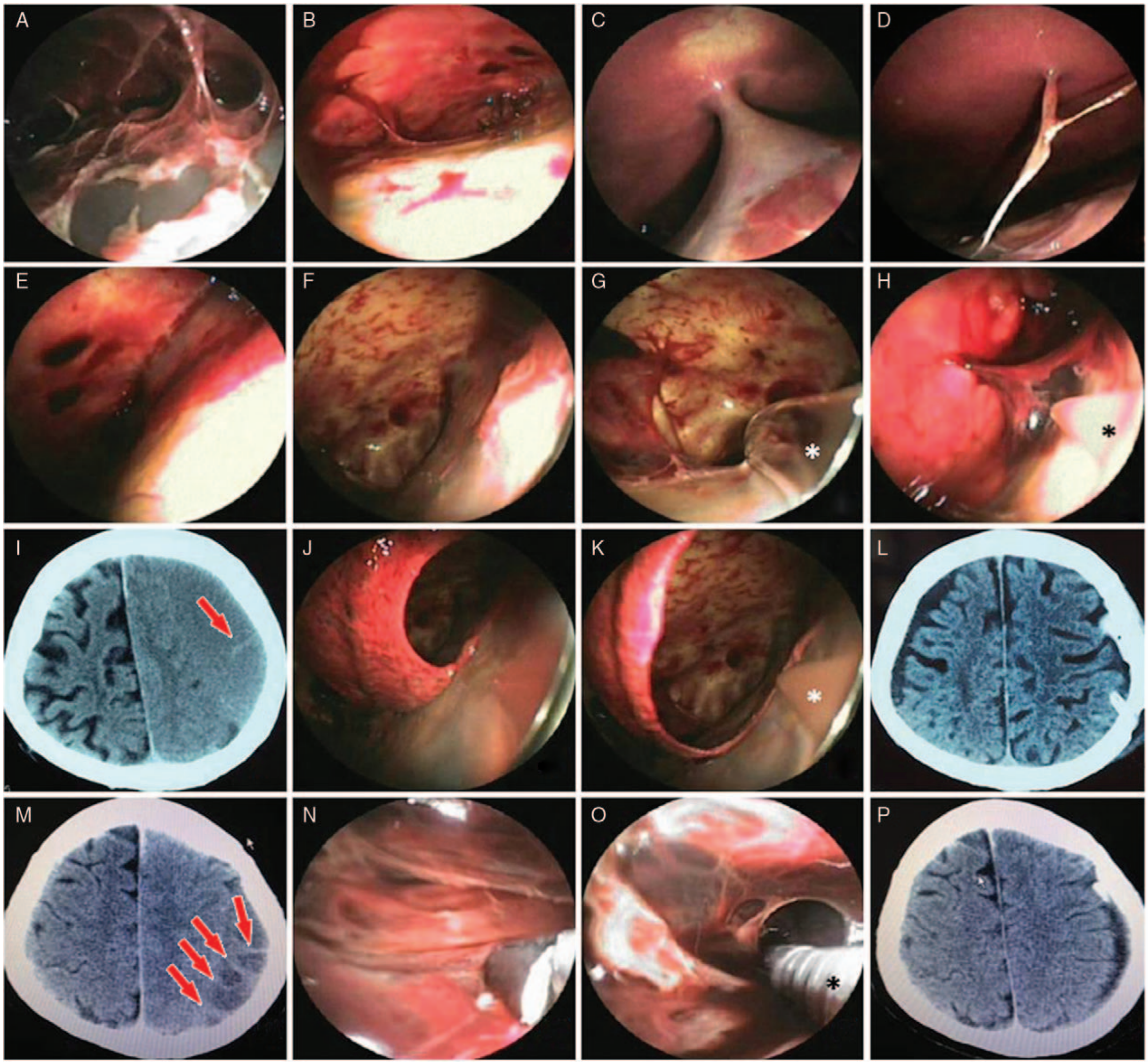

Figure 1: Intraoperative images of flexible neuroendoscopy combined with DFT and CT scans. (A, B) Multiple-septum in the hematoma cavity. (C, D) Different types of bridging veins in the hematoma cavity. (E, F) Endoscopic inspection to identify the boundary of the hematoma. (G) Endoscopic removal of residual blood clots by a local rinse (*) in the hematoma cavity. (H) After penetration of the septum, a local rinse (*) was applied to remove residual blood in the compartment. (I–L) False-separated CSDH: (I) CT scan showed a septum (red arrow) was visible in the hematoma cavity. (J, K) The endoscopic inspection identified false-septum and complete removal of hematoma with a local rinse (*) in the dry field. (L) CT scan showed that CSDH was evacuated entirely after the surgery. (M–P) Real-separated CSDH: (M) CT scan showed a left frontoparietal multiple-septum CSDH (red arrows). (N) The endoscopic inspection identified true-septum. (O) Penetration and communication of the septum with micro-biopsy forceps (*). (P) CT scan showed that hematoma was evacuated entirely after the surgery. DFT: Dry-field techniques; CT: Computed tomography; CSDH: Chronic subdural hematoma.

in the compartment then completely evacuated the CSDH. Under the guidance of the neuroendoscope, a 12F flexible silicone drainage tube was placed in the forefront of the hematoma cavity. Gas in the hematoma cavity was replaced entirely with warm saline under flexible neuroendoscopic guidance. (b) Non-DFT group: Routine or pressurized lavage was applied to replace the bloody fluid in the hematoma cavity to ensure that the surgical field was clear to facilitate endoscopic operation. The boundary of the hematoma cavity was inspected in a liquid medium. During the penetration and communication of the compartments, the bloody fluid in the compartment affects the clarity of the field, so pressurized lavage was required to ensure a clear surgical field. The drainage tube was placed in the hematoma cavity in the same way as that for the DFT group. The operative time was defined as the entire process from scalp incision to incision sutured. Follow-up was performed through outpatient visits to the clinic or by telephone. Statistical analysis was performed using a Chi-squared test and *t* test. Statistical data were analyzed using SPSS 17.0 statistical software (SPSS, Chicago, IL, USA).

The result of the study showed that there was no statistically significant difference in age, sex ratio, the proportion of the Glasgow coma scale scores, and hematoma volume on admission between the endoscopic and non-endoscopic groups. The mean age was 71.4 years (range 61.3–87.5 years) in the non-endoscopic group, 71.0 (63–82) years in the endoscopic DFT group, and 68.3 (60–81) years in the endoscopic non-DFT group. There was no significant difference in mean age among the groups ($P > 0.05$). There were 75 males (59.5%) in the non-endoscopic group, 22 males (50%) in the endoscopic DFT group, and 19 males (61.3%) in the endoscopic non-DFT group, showing no gender-related difference among the groups ($P > 0.05$). The mean hematoma volume was 114.6 mL (35.2–157.5 mL) in the non-endoscopic group, 117.3 mL (33.2–170.5 mL) in the endoscopic DFT group, and 109.3 mL (30.4–167.9 mL) in the endoscopic non-DFT group. There was no significant difference in hematoma volume among the groups ($P > 0.05$). There was no mortality. The mean operative time in the endoscopic DFT group (37.4 min) was significantly shorter than in the non-endoscopic group (43.1 min) and endoscopic non-DFT group (68.8 min) ($P < 0.001$). The mean hematoma clearance rate on the first post-operative day in the endoscopic DFT (98.2%) and non-DFT (97.4%) groups was significantly higher than that in the non-endoscopic group (87.1%) ($P < 0.001$). The mean placement time of drainage tube in the endoscopic DFT group (20.1 h) was shorter than those in the endoscopic non-DFT group (23.3 h) ($P < 0.05$) and non-endoscopic group (49.1 h) ($P < 0.001$). The proportion of patients with modified Rankin scale ≤3 on the first post-operative day and at discharge in the endoscopic DFT and non-DFT groups was significantly higher than that in the non-endoscopic group ($P < 0.05$). The mean hospital stay in the endoscopy group was not significantly different from that in the non-endoscopic group ($P > 0.05$). In the non-endoscopic group, there were 23 cases (18.3%) of pneumocephalus, 17 cases (13.5%) of fever, two cases (1.6%) of subarachnoid hemorrhage, two cases (1.6%) of brain contusion, eight cases (6.4%) of epilepsy, and 11 cases (8.7%) of subdural effusion. In the endoscopic non-DFT group, there were two cases (6.5%) of pneumocephalus, three cases (9.7%) of fever, two cases (6.5%) of epilepsy, and three cases (9.7%) of subdural effusion. In the endoscopic DFT group, there were two cases (4.6%) of pneumocephalus, two cases (4.6%) of fever, and one case (2.3%) of epilepsy. The post-operative complication rate in the endoscopic DFT group (4.6%) was significantly lower than that in the endoscopic non-DFT group (12.9%) and the non-endoscopic group (22.2%) ($P < 0.001$) [Table 1]. All patients were successfully followed up in this study. During a follow-up of 0.5 to 10 years, the recurrence rates in the endoscopic DFT (6.8%) and non-DFT (9.7%) groups were significantly lower than that in the non-endoscopic group (15.1%) ($P < 0.001$).

In 2002, Schroeder and Gaab[7] first reported the application of DFT in neuroendoscopic resection of intraventricular colloid cysts. Subsequently, several scholars also reported the application of DFT to hemostasis of

Table 1: Clinical outcome and recurrence of 201 patients with CSDH.

	Endoscopy ($n = 75$)		
Items	**DFT ($n = 44$)**	**Non-DFT ($n = 31$)**	**Non-endoscopy ($n = 126$)**
Mean operative time (min)	$37.4 \pm 4.4^{*,\dagger}$	68.8 ± 7.9	43.1 ± 7.3
Mean hematoma clearance rate (post-operation 1st day) (%)	$98.2 \pm 0.9^{\dagger}$	97.4 ± 1.4	87.1 ± 5.7
Mean placement time of drainage tube (h)	$20.1 \pm 2.4^{\dagger,\ddagger}$	23.3 ± 2.2	49.1 ± 6.0
Mean length of hospital stay (days)	7.9 ± 1.6	8.0 ± 1.4	8.2 ± 2.0
mRS score 0-3			
On post-operation 1st day	32 (72.7)§	22 (71.0)	63 (50.8)
At discharge	42(95.5)§	30(96.8)	112 (88.9)
Complications	2(4.6)*,†	4(12.9)	28 (22.2)
Mortality	0	0	0
Recurrence	3(6.8)†	3(9.7)	19 (15.1)
Recurrence time (months)	8.2 ± 1.6	8.6 ± 2.0	6.6 ± 2.1

Values are *n* (%) or mean ± standard deviation. $^{*}P < 0.001$, $^{\ddagger}P < 0.05$, compared with the endoscopic non-DFT group. $^{\dagger}P < 0.001$, $^{\S}P < 0.05$, compared with the non-endoscopic group. CSDH: Chronic subdural hematoma; DFT: Dry field techniques; mRS: Modified Rankin scale.

ventricular lesions, whereby there were no serious complications such as cortical collapse and intracranial infection.[8-10]

In this study, the advantages of flexible neuroendoscopy combined with DFT in the treatment of CSDH are reflected in the following aspects: (1) Visualized maneuverability is the most significant advantage. The surgical view in the dry field is broader than that in the liquid medium, which is beneficial for comprehensively inspecting and evaluating the actual status of the hematoma cavity. The mean hematoma clearance rates on the first post-operative day in the endoscopic DFT group (98.2%) and non-DFT group (97.4%) were significantly higher than that in the non-endoscopic group (87.1%). (2) For the treatment of separated CSDH, flexible neuroendoscopy with DFT especially affords the advantage whereby it can further identify the actual situation of the separated CSDH shown by CT scan. For real-separated CSDH, the surgeon needs to penetrate and communicate the compartment with related instruments and thoroughly rinse and perform suction in the compartment, which can effectively improve the hematoma clearance rate, avoid post-operative recurrence, and improve the curative effect. The recurrence rates in the endoscopic DFT (6.8%) and non-DFT (9.7%) groups were significantly lower than that in the non-endoscopic group (15.1%). (3) The directional sense in the dry field is much better, which is also conducive to protecting the anatomical structure behind the lens and avoiding secondary damage during surgery. (4) Compared with endoscopic non-DFT the surgeon does not require long-time lavage to guarantee a clear field by the application of DFT. (5) Intraoperative hemostasis is a significant problem in endoscopic neurosurgery.[10] By the application of DFT, the surgeon can more clearly inspect the bleeding site and responsible blood vessel, which helps the surgeon stop bleeding in time. (6) Because it is not necessary to ensure the clear surgical field through pressurized lavage in endoscopic DFT, the integrity of the hematoma capsule is maximally protected and to reduce the incidence of post-operative subdural effusion and CSF leakage. (7) The application of DFT did not require additional instruments and equipment concerning flexible neuroendoscopy in the treatment of CSDH, which is conducive to shortening the learning curve of flexible neuroendoscopy. In summary, flexible neuroendoscopy combined with DFT deserves further endorsement and application in the treatment of CSDH. Because the retrospective study is impossible to rule out all confounding factors and various types of bias, we still need to design a prospective study to prove our conclusion in the following study further.

Declaration of patient consent

The authors have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and outstanding efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Funding

This work was supported by a grant from the Capital Characteristic Clinical Application Research (No: Z131107002213044).

Conflicts of interest

None.

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How to cite this article: Guan F, Peng WC, Huang H, Dai B, Zhu GT, Xiao ZY, Mao BB, Lin ZY, Zhou Q, Wei YP, Hu ZQ. Efficacy analysis of flexible neuroendoscopy combined with dry-field techniques in the treatment of chronic subdural hematoma. Chin Med J 2019;132:1359–1362. doi: 10.1097/CM9.0000000000000249