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Surgical Treatment of Chronic Subdural Hematoma Based on Intrahematomal Membrane Structure on MRI

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Summary

Background. To determine the optimal surgical management of chronic subdural hematoma (CSDH), we assessed which operative procedure, burr holes or small craniotomy, was more effective on 49 consecutive patients. *Method.* We retrospectively classified all cases into two groups according to the intrahematomal membrane structure of CSDH on T_2^*-weighted magnetic resonance (MR) imaging. The first group, labeled type B, included hematomas which had no intrahematomal membrane and/or were monolayer multilobule. The second group, labeled type C, consisted of hematomas which were divided into multiple layers by the intrahematomal membrane. *Findings.* The outcome of type C patients treated with burr holes was significantly inferior to that of those who underwent a small craniotomy in terms of the relative outcome of neurological grading, re-operation ratio, and postoperative hospital stay ($p < 0.05$). Type C hematomas treated with burr holes also had inferior outcome compared with a small craniotomy in terms of the duration of hematoma until disappearance on postoperative CT ($p < 0.05$). *Interpretation.* We concluded that a considerable number of cases appeared to need craniotomy and resection of intrahematomal membrane for complete recovery in CSDH, and that T_2^*-weighted MR imaging could be used as a basis for selecting the operative procedure for CSDH.

Keywords: Chronic subdural hematoma; small craniotomy; T_2^*-weighted magnetic resonance imaging.

Introduction

The treatment of chronic subdural hematoma (CSDH) has evolved through a vast variety of methods and techniques. Despite general agreement concerning the indication for operative treatment, the optimal surgical treatment of CSDH is still controversial [4, 6, 12, 13, 16, 20]. Recently, the literature has supported the use of burr holes or twist-drill holes, as a less invasive surgical tactic than craniotomy [1, 2, 8, 10, 11]. The rationale for this has been based on the assumption that management with burr holes offers at least equivalent satisfaction as compared to craniotomy, but with much lower mortality and morbidity and a shorter postoperative hospital stay. However, the outcome of management with burr holes varies widely, with the percentage of re-operation ranging from 3.1–33.3% [2, 4, 6, 8, 11, 13, 16, 21]. By contrast, craniotomy is thought by some to be a safe and efficacious method for decompressing CSDH, and many surgeons feel that craniotomy is superior to burr holes for the management of this condition [6, 16]. In fact, although there were many cases for which burr holes were effective, burr holes have by no means led to complete improvement in all patients with CSDH. Thus, it is clear that criteria need to be established to determine whether CSDH should be initially treated by burr holes or craniotomy.

On T_2^*-weighted magnetic resonance (MR) imaging obtained from gradient-echo sequence, dephasing of magnetization by the presence of static field inhomogeneities results in decreasing the apparent transverse relaxation time (T_2^*). Thus, artifacts appear influenced by changes of magnetic susceptibility of the tissue [3]. We have established previously that the intrahematomal structure of CSDH was successfully demonstrated by reversely utilizing this artifact, which was produced by changes of intrahematomal membrane magnetic susceptibility influenced by deposition of hemosiderin, which is superparamagnetic [unpublished data].

In this study, we used this radiological technique for CSDH, and divided patients into two groups according to the intrahematomal findings retrospectively. To assess which operative procedure was suitable for CSDH in individual T_2^*-weighted MR imaging groups, we compared outcomes of the two operative procedures concerning patients' score, re-operation ratio, time in hospital, and time until the disappearance of the hematoma on CT.

Methods and Patients

Between December 1995 and December 1998, 49 consecutive patients with CSDH received surgical treatment at the Department of Neurosurgery, Nagoya City University Hospital after having received T_2^*-weighted MR imaging preoperatively. The median age was 69.8 years, with a range from 29–95 years. The male/female ratio was 32/17. Clinical data of all 49 patients concerning medical history, physical examination, investigations, treatment, morbid events, outcome, and duration of hospital stay from the initial operation were retrospectively obtained from the records of the Department of Neurosurgery.

Operations were performed with neuroleptanalgesia and local anesthesia in all patients. Initial surgical procedure included burr holes which were made in two regions adjacent to hematoma in 33 patients and small craniotomy ranging from 40–50 mm in diameter in 16 patients. Subdural blood was evacuated by repeated irrigation with physiological saline solution. In cases of small craniotomy, the outer and intrahematomal membrane was resected as widely as possible. All patients received a closed-system drain for 1–3 days. The selection of the operative technique was made solely by the attending neurosurgeon's policy. Two neurosurgeons always took burr hole surgery, and the other two took small craniotomy. The decision was not affected by MRI findings. Hematoma recurrence was considered to have taken place when neurological deficits re-appeared and hematoma re-accumulated within 6 months after surgery. In cases in whom both criteria were fulfilled, cases who underwent repeated operations were counted as re-operated cases.

Patients' scores were classified by comparing the preoperative and postoperative status confirmed a week after the first operation. We used the most common neurological grading system for CSDH as proposed by Markwalder [11]: Grade 0: no neurologic deficits; Grade 1: mild symptoms such as headache, absent or mild neurological deficits such as reflex asymmetry; Grade 2: drowsiness or disorientation with variable neurological deficits such as hemiparesis; Grade 3: stupor, but appropriate responses to noxious stimuli, severe focal signs such as hemiplegia; Grade 4: coma with absence of motor response to painful stimuli, decerebrate or decorticate posturing.

The patients were hospitalized at least until marked regression of residual hematoma cavity and disappearance of symptoms and signs due to CSDH, such as headache or hemiparesis. Hospital stay was defined as the duration from the initial operation to discharge. In re-operated cases, the duration from the second or further operation was also added to hospital stay if the patients were re-admitted.

Postoperative computerized tomography (CT) was performed 24 hours, one, two weeks, one, three, and six months after the first operation. With these findings, duration until the disappearance of subdural hematoma after the first operation was established.

Gradient-echo T_2^*-weighted MR imaging (TR 550 msec, TE 34 msec, flip angle of 40°) was performed by using a 1.5-tesla MR system (Gyroscan ACS-II, Philips, Netherlands). Retrospectively, we divided all cases into two groups according to intrahematomal membrane structure on T_2^*-weighted MR image (Fig. 1). The first group, labeled type B, included subdural hematoma which had no intrahematomal membrane, or had monolayer multilobuli. The second group, labeled type C, had hematoma which was divided into multiple layers by the intrahematomal membrane.

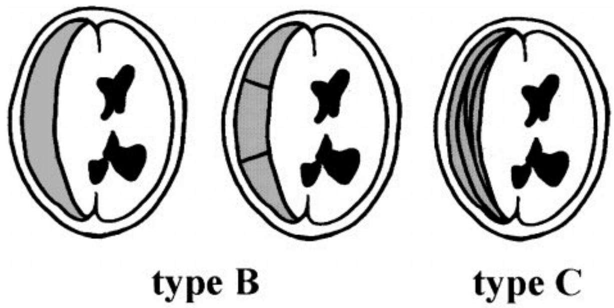

Fig. 1. Schema of the intrahematomal structure confirmed by T_2^*-weighted MR image; (left) type B hematoma: no intrahematomal membrane, (center) type B hematoma: monolayer multilobule hematoma, (right) type C hematoma: multilayer hematoma

Table 1. *Clinical Data Correlated to the Extent of Surgery in 49 Patients with CSDH*

Operation	Burr Holes		Craniotomy	
Number	33		16	
Mean age	69.3 ± 14.9		70.3 ± 9.3	
Grade[a]	preop	postop	preop	postop
0	0	21	0	12
1	14	6	7	3
2	14	4	8	1
3	4	1	1	0
4	0	0	0	0
Relative outcome[b]				
Better	27		16	
Constant	4		0	
Worse	1		0	
Death	1		0	
Reoperation[c]	4		0	
Hospital stay (days)	22.4 ± 15.1		16.8 ± 3.6	

[a] Using the Markwalder's score [11]. [b] Statistical analysis was performed using Mann-Whitney's U test, regarding better, constant, and worse as 3, 2, and 1, respectively. [c] Statistical analysis was performed using Mann-Whitney's U test, regarding no re-operation and re-operated as 0 and 1, respectively.

All values were presented as mean ± S.D. Statistical analysis was performed using Mann-Whitney's U test. Statistical significance was assumed if probability was measured at less than 0.05.

Results

Patients Characteristics

There were 40 unilateral hematomas, 21 (42.9%) on the right and 19 (38.8%) on the left. Nine (18.8%) of the hematomas were bilateral. There were no significant differences in clinical data between bilateral and unilateral cases. Among 49 cases, 33 patients received burr holes and 16 a small craniotomy (Table 1). The mean ages of the burr holes and small craniotomy group were 69.3 ± 14.9 and 70.3 ± 9.3, respectively. According to retrospective neurological grading using the Markwalder's score [11], the postoperative neurological status of 27 patients (81.8%) in the burr holes group and all patients in the small craniotomy group improved in comparison with the preoperative status. Four (14.8%) patients in the group treated with burr holes had no changes and one (3.7%) patient had deterioration in neurological status. Four of the 33 patients (12.1%) after burr holes and no patients after small craniotomy required re-operation. Only one patient died within the early postoperative period in the burr holes group. The death did not relate to cerebral decompensation but to accompanying disease. The case was excluded from this analysis, because the patient on admission had already suffered from severe pneumonia and nutritional deficiency, both of which deteriorated and resulted in systemic infection and multiple organ failure. There were no other patients with local or systemic postoperative complications. Mean hospital stay after the initial operation was 22.4 ± 15.1 days in the burr holes group and 16.8 ± 3.6 days in the small craniotomy group. There was no statistically significant difference between the burr holes group and the small craniotomy group in mean age, relative outcome of neurological grading, rate of re-operation, or hospital stay.

Classification of Hematomas Based on T_2^*-weighted MR Image

To address the controversy concerning which operative procedure, burr holes or craniotomy, is optimal for CSDH management, we retrospectively divided cases into two groups according to membrane structure based on T_2^*-weighted MR image as described in Methods and Patients section. All the CSDH displayed mixed hyperintense and hypo-intense signals on T_2^*-weighted MR image. Furthermore, hematoma membrane was clearly visualized as an extremely hypo-intense structure. Although the hematoma membrane was also demonstrated on T_1 and T_2-weighted images which were obtained by the spin-echo technique, a more distinct image of hematoma membrane was acquired on T_2^*-weighted image (Figs. 2 and 3). Figure 2 shows a representative of type B hematoma consisting of homogeneous and/or monolayer multilobule hematomas. This case received burr holes initially, and had a good postoperative course. Type C

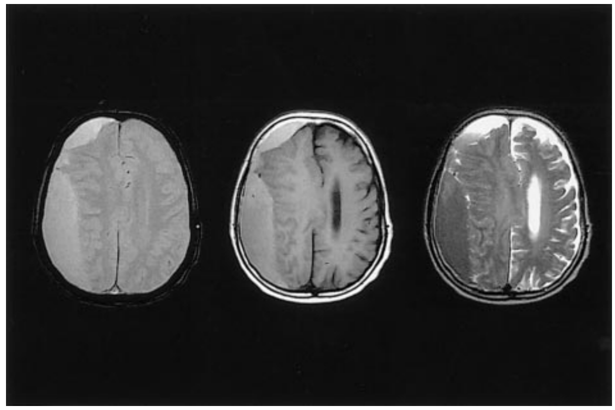

Fig. 2. MR image of a 75-year-old man with homogenous and monolayer multilobule hematoma classified as type B; (left) T_2^*-weighted image, (center) T_1-weighted image, (right) T_2-weighted image

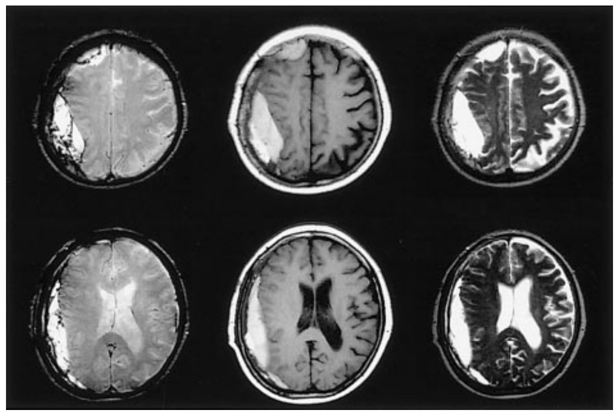

Fig. 3. MR image of a 67-year-old woman with what was considered to multilayer hematoma and classified as type C; (left) T_2^*-weighted image, (center) T_1-weighted image, (right) T_2-weighted image

hematoma was confirmed as multilayer hematoma by T_2^*-weighted MR image. One of this type of hematoma is displayed in Fig. 3. The patient was a 67-year-old woman. No improvement of her neurological deficits and residual or re-accumulated hematoma were found after three burr-hole operations. Finally, craniotomy and resection of hematoma membrane led to her complete recovery.

The Relation Between Operative Outcome and Hematoma Type Based on T_2^*-Weighted MR Image

Of the 49 patients, nine had bilateral hematomas. Coincidentally, all of these patients had the same type of hematoma bilaterally, and received the same oper-

Table 2. *Clinical Data Correlated to the Extent of Surgery in 20 Patients with Type B CSDH*

Operation	Burr holes		Craniotomy	
Number	20		–	
Mean age	73.6 ± 11.9		–	
Grade[a]	preop	postop	preop	postop
0	0	14	–	–
1	8	5	–	–
2	10	0	–	–
3	1	0	–	–
4	0	0	–	–
Relative outcome				
Better	18		–	
Constant	1		–	
Worse	0		–	
Death	1		–	
Re-operation	0		–	
Hospital stay (days)	17.1 ± 6.4		–	

[a] Using the Markwalder's score [11].

Table 3. *Clinical Data Correlated to the Extent of Surgery in 29 Patients with Type C CSDH*

Operation	Burr holes		Craniotomy	
Number	13		16	
Age	62.7 ± 17.2		70.7 ± 9.3	
Grade[a]	preop	postop	preop	postop
0	0	7	0	12
1	6	1	7	3
2	4	4	8	1
3	3	1	1	0
4	0	0	0	0
Relative outcome[b,*]				
Better	9		16	
Constant	3		0	
Worse	1		0	
Death	0		0	
Re-operation[c,**]	4		0	
Hospital stay (days)***	30.5 ± 20.6		16.8 ± 3.6	

[a] Using the Markwalder's score [11]. [b] Statistical analysis was performed using Mann-Whitney's U test, regarding better, constant, and worse as 3, 2, and 1, respectively. [c] Statistical analysis was performed using Mann-Whitney's U test, regarding no reoperation and reoperated as 0 and 1, respectively. * Statistically significant at $p = 0.0191$. ** Statistically significant at $p = 0.0189$. *** Statistically significant at $p = 0.0362$.

ative procedure during the same period. Consequently, 20 and 29 patients suffered type B and type C hematomas, respectively. All 20 patients who were considered to have type B hematoma received surgical treatment with burr holes. The clinical data of this group is shown in Table 2. Of the 29 patients who were classified into type C, 13 received burr holes, and the remaining 16 underwent craniotomy as the initial operation (Table 3). Their mean age was 62.7 ± 17.2 and 70.7 ± 9.3, respectively. Postoperative neurological status improved in nine (69.2%) and sixteen (100%) patients respectively in comparison with the preoperative status. Four (30.8%) patients needed re-operation in a particular group consisting of patients classified as type C and on whom burr holes were performed. Mean hospital stay was 30.5 ± 20.6 and 16.8 ± 3.6 days, respectively. There was no statistically significant difference in mean age between type C patients treated with burr holes and small craniotomy. The outcome of type C patients treated with burr holes in comparison to type C patients who received craniotomy was unfavorable in the relative outcome of neurological grading, re-operation ratio, and postoperative hospital stay, and these differences were statistically significant ($p < 0.05$).

There were 58 hematomas totally, due to the presence of nine bilateral hematomas. We estimated the duration from the first operation to the disappearance of hematoma on head CT in 54 hematomas that could be followed in our outpatient clinic for at least six months after the initial operation. Among 54 hematomas, there were 33 hematomas classified as type C, of which 15 were treated with burr holes and 18 with craniotomy (table 4). On postoperative CT two weeks, one month, and three months after operation, hematoma disappearance was confirmed respectively in 13.3, 20.0, and 66.7% of type C hematomas initially surgically treated with burr holes, and in 22.2, 66.7, and 94.4% of type C hematomas which underwent craniotomy. It was clear in terms of duration until disappearance of hematoma on postoperative CT that the outcome of type C patients treated with burr holes was unfavorable compared with that of type C patients who received craniotomy, and the difference was statistically significant ($p < 0.05$).

Table 4. *Duration until Disappearance of Type C Hematoma on CT*

Operation	Burr holes	Craniotomy
Number (hematoma)	15	18
Postoperative CT findings* (duration until disappearance of hematoma)		
2 weeks	13.3%	22.2%
1 month	20.0%	66.7%
3 months	66.7%	94.4%

* Statistical analysis was performed using Mann-Whitney's U test, regarding 2 weeks, 1 month, 3 months, and 6 months or more as 2, 4, 12, and 24, respectively. Statistically significant at $p = 0.0129$.

Discussion

Operative Procedures for CSDH

Because chronic subdural hematoma (CSDH) is one of the most common types of intracranial hemorrhage, is relatively easier to cure in most cases, and commonly occurs in older patients, its treatment should be as complete and minimally invasive as possible. It has been widely accepted that when treatment is required, surgical removal is the most efficacious way to deal with a CSDH. Various methods of surgical treatment of CSDH have been reported, ranging from percutaneous subdural tapping to large craniotomy, and all with variable degrees of success [1, 10, 12, 14]. Most of the existing controversy revolves around which technique is optimal for the evacuation of CSDH.

Burr-hole craniostomy with closed-system drainage is the most widely accepted method for evacuation of hematoma. However, not all cases could achieve complete recovery by burr-hole craniostomy, and the outcome reported in the literature varies widely with re-operation required in cases ranging from 3.1–33.3% [2, 4, 6, 8, 11, 13, 16, 21]. In Markwalder's review on CSDH in 1981 [10], he stated that craniotomy is reserved for those cases in whom: 1) the subdural collection re-accumulates; 2) there is solid hematoma; or 3) the brain fails to expand and obliterate the subdural space. Therefore, cases with these features would go through more than two operative procedures.

Craniotomy provides a safer and more beneficial opportunity to deal adequately with the hematoma, its membranes, and occasional bleeding complications, while allowing for the safe and controlled insertion of a subdural drain. Recently, a few reports have attempted to address the controversy over whether treatment with burr holes or craniotomy is optimal for CSDH [4, 6]. No significant differences, however, were identified between the two surgical techniques. Therefore, it is at least evident that craniotomy is not required in all cases.

Recurrences of CSDH

The pathogenic mechanism of CSDH has long been discussed. Recent experimental studies revealed that blood in the subdural space evokes an inflammatory reaction with deposition of fibrin, followed by the organization and formation of subdural neomembranes with ingrowth of neocapillaries. Then, plasminogen in the hematoma is transformed into plasmin by tissue plasminogen activator, which is extremely abundant in the outer membrane. Sequentially, both the breaking down of fibrin and fibrinogen and production of an extra-ordinarily large amount of fibrin and fibrinogen degradation products (FDP) occurs. These result in the liquefaction of blood clot, increase in the permeability of the capillary vessels, interference with the hemostatic mechanism and development and progressive enlargement of chronic subdural hematoma [9, 23]. Thus, the primary reasons for re-operation appear to be thick residual hematoma membranes, concealing residual hematoma, or the same followed by re-accumulation of subdural fluid due to rebleeding from the membranes. We thought that the former category might occur in hematoma that was divided into multiple layers by the intrahematomal membranes. Furthermore, the hematoma with a large amount of intrahematomal membranes appeared to belong to the latter category. It seemed that most of these cases also had hematoma which was split into multiple layers by intrahematomal membranes. Therefore, in such cases, who appear to have a high recurrence rate, the opening and resection of intrahematomal membranes with the opening of different hematoma compartments, in addition to the evacuation and drainage of hematoma fluid, may result in improvement of reabsorption of the subdural fluid, and, consequently, rebleeding and fibrinolysis can be prevented.

Role of T_2^*-Weighted MR Imaging

Recently, a few reports described the utilization of magnetic resonance (MR) imaging for diagnosis of CSDH and the superiority of MR imaging over computerized tomography (CT) [5, 7, 15, 17, 18, 19, 22]. The authors used T_1 and T_2-weighted MR images which were obtained by the spin-echo technique. Tsutsumi *et al.* [19] conducted a prospective study using MRI and concluded that CSDH which exhibited homogenous high intensity on T_1-weighted MR images recurred more frequently. However, they focussed only on the intensity of the whole hematoma cavity on T_1 and T_2-weighted images. On T_2^*-weighted magnetic resonance imaging obtained from a gradient-echo sequence, dephasing of magnetization due to the presence of static field inhomogeneities result in decreasing the apparent transverse relaxation time (T_2^*). Thus, artifacts influenced by changes of tissue magnetic susceptibility develop [3]. Because of the considerable amount of hemosiderin, which is superparamagnetic, deposit on the membrane of CSDH, it is thought that magnetic susceptibility of the membrane may easily change. Thus, the membrane can be seen as an extremely hypo-intense structure on T_2^*-weighted MR imaging due to artifacts. Therefore, T_2^*-weighted MR imaging appears to be effective in demonstrating intrahematomal structure of CSDH [unpublished data]. In fact, in our cases, T_2^*-weighted MR imaging proved to be superior to T_1- and T_2-weighted MR imaging in the visualization of the intrahematomal structure of CSDH.

In this study, we have shown that subdural hematomas which appeared to have a multilayer intrahematomal structure showed a high recurrence rate and were clearly visualized on T_2^*-weighted MR image. In addition, there were a significant number of cases among these hematomas which could not achieve complete recovery by initial burr hole surgery. In contrast, patients treated with small craniotomy achieved equivalent or more favorable results and a significantly shortened hospital stay. Thus, there appeared to be CSDH patients who needed small craniotomy for complete recovery, and the T_2^*-weighted MR image appeared to be efficacious for the preoperative assessment of those patients. Furthermore, complete recovery obtained through a single operative procedure may result not only in reducing the surgical invasion of the patients but also in lowering medical costs.

This study was performed retrospectively. Therefore, we could not completely deny the existence of bias, especially in selection of operative procedure. We believe, however, that this study includes very important preliminary results. To develop the definitive criteria for selection of optimal surgical procedure for CSDH should be achieved by a further study such as prospective, randomized, controlled trial.

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Comments

This is a retrospective study on 49 patients with chronic subdural haematomas comparing the efficacy of burrhole treatment with the results of a small craniotomy. Nine of the patients had bilateral haematomas. Preoperative MRI was used to classify the patients with gradient echo sequence in two groups. Group B (20 patients) had no intrahaematomal membrane and all of them had burr hole treatment only, there was no need for re-operation in any of these patients. Group C (29 patients) had multiple layers divided by intrahaematomal membranes, and 13 of them had burr holes, 16 a small craniotomy. All patients in this group with craniotomy had a satisfactory outcome, out of 13 patients with burrholes 4 needed re-operation. Hospital stay in patients with craniotomy in this group was 17 days, with burr hole treatment 31 days (4 out of 13 re-operated.) The haematoma was totally dissolved in the craniotomy group in 3 months, in the burrhole group at that time in 67.7% of patients.

In monolayer (group B) haematomas the burr hole procedure seems to be satisfactory, even if the hospital stay over 17 days is unusually long by European standards. The real study group in the evaluation are the 29 patients with C-type MRI-finding, 13 had burr holes, and 4 needed a re-operation because of slow recovery, all the 16 craniotomy patients had a smooth outcome.

The important questions here is, should we do routine preoperative MRI in every patient with chronic subdural haematoma to get the information of gradient echo sequence? The authors say yes but accept the weakness of a retrospective study. A new study should be prospective, perhaps even comparing the information given by CT and MRI and giving strict indications for reoperation when needed.

M. Vapalahti

The authors have formed a hypothesis that the varying results of operation for chronic subdural hematomas should be related to differences in the membrane structures of the hematomas, and that these differences can be shown by MRI.

To try and prove their hypothesis, the authors have divided the membrane structures into two groups (for some reason called type B and type C) and compared the results of operation of these two goups. The idea is of course that a pre-operative MRI should be one important criterium for choosing the type of operation – a simple burr hole or a small craniotomy.

In their introduction they stated that the optimal surgical treatment is still controversial, although they admit that craniotomy is thought to be a safe and efficacious method, which many surgeons feel is superior to burr holes. This is of course a crucial point for this study, since it constitutes the whole rationale for it. But even if most studies, including their own, seem to show the superiority of the flap technique, a study like this one could nevertheless be valuable, since it is of course better to restrict the operation to a simple burr hole, whenever this is possible without the higher risk for complications or recurrences.

At the same time it must be noted, however, that it seems to be high time for a mega-analysis, made by EANS, the Cochrane Institute or some other body, in order to show if one surgical method for chronic subdural hematoma has any advanatages over the other.

Having said this, it seems as if the present authors have really shown that, while all patients, irrespective of MRI-apperance of the membranes, can be operated on with good results using a small craniotomy, there seems to be a fairly high rate of recurrence or other complications in their group C, i.e. those where MRI showed multiple layers of hematoma membrane.

The methods used in the study seem acceptable, although it is a pity that the study was not blind. Since it is a retrospective study we can then not exclude that the radiologists at least in some cases were aware of the clinical outcome.

With this reservation the results seem convincing, and so, it seems as if the authors have to a sufficient extent proved their hypothesis to be true.

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