

# Burr-Hole Evacuation of Chronic Subdural Hematoma: Biophysically and Evidence-Based Technique Improvement

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**ABSTRACT**

Chronic subdural hematoma (CSDH) is one of the most common neurosurgical conditions. Despite ongoing efforts, recurrence and reoperation rates after surgical treatment remain high. We synthesize scientific evidence on the treatment of CSDH with biophysical principles and then propose a simple and effective surgical technique aiming to reduce the recurrence rate. Under local anesthesia, one burr hole is placed in the area above the maximum hematoma thickness. One drain is inserted into the dorsal direction to the deepest point of the hematoma cavity, and a second drain is inserted frontally into the highest point. Next, saline is gently instilled to the dorsal drain to eliminate air from the hematoma cavity through the frontal drain. Once saline has filled the frontal drain, the frontal drain is removed. The dorsal drain is left *in situ* for 48 h, and the pressure within the cavity may be adapted hydrostatically. We implemented evidence-based conclusions of previous studies and modified the classical burr-hole technique to reduce the recurrence rate. As a result, we developed a straightforward surgical procedure that is possible to perform under local anesthesia, suitable for everyday practice in rural and remote areas while working with limited resources. The novelty of this technique is in the purposeful reduction of postoperative pneumocephalus, a known independent factor of recurrence. Subdural air is eliminated during surgery using a two-drain system. Safety and efficacy of the technique need to be evaluated in future clinical trials.

**KEYWORDS:** *Chronic subdural hematoma, evidence-based medicine, head trauma, neurosurgery, pneumocephalus*

## INTRODUCTION

Chronic subdural hematoma (CSDH) is among the most common neurosurgical conditions. Although CSDH is usually not a life-threatening condition, its clinical course is not benign.<sup>[1]</sup> Perioperative morbidity ranges from 0% to 25% and mortality from 0% to 32%.<sup>[2,3]</sup> The generally accepted mortality rate is usually 8%. Furthermore, even after a successful evacuation of CSDH, the excess mortality rate can be seen up to 1 year after surgery.<sup>[4]</sup>

Three principal surgical procedures are commonly used as follows: twist-drill craniostomy, burr hole, and craniotomy. Many modifications of these procedures have been described; however, none have solved the main problem of CSDH surgery, namely a high

recurrence rate. Recurrence of CSDH is usually defined as reaccumulation of hematoma fluid that needs reoperation; defined in this way, the recurrence rate ranges from 0.4% to 33.3%.<sup>[5]</sup> In most studies, the recurrence rate is around 10%.

The literature offers evidence on the effectiveness of certain surgical nuances. Systematic reviews have shown the superiority of irrigation and placing a drain in the hematoma cavity to decrease the recurrence rate.<sup>[6-8]</sup> Another independent factor of recurrence that might

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be impacted during surgery is the amount of air that enters the hematoma cavity (i.e., pneumocephalus).<sup>[9-13]</sup> Reduction of pneumocephalus is often disregarded during surgery, and most surgical techniques do not address this issue at all.

This paper aimed to synthesize scientific evidence on the treatment of CSDH with biophysical principles and to propose a simple and effective surgical technique, suitable for everyday practice in rural and remote areas while working with limited resources.

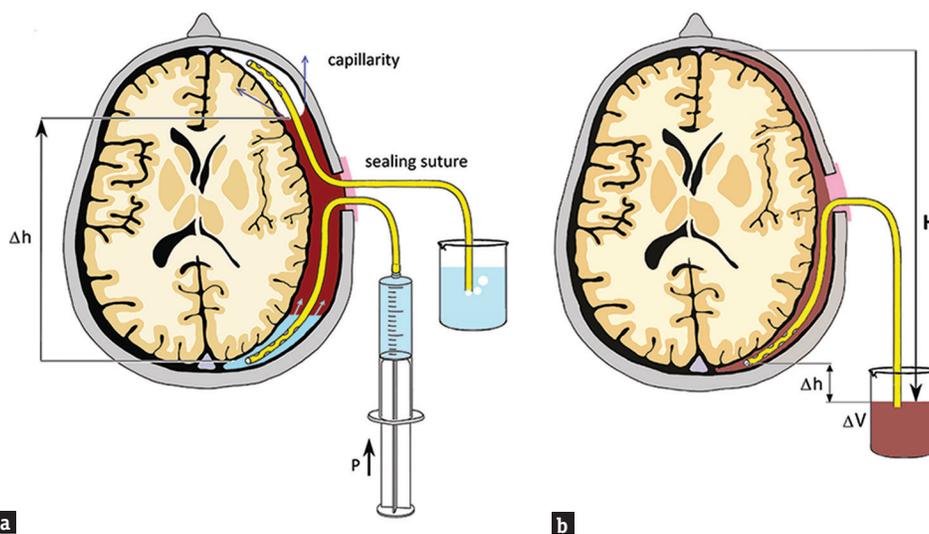
## TECHNIQUE DESCRIPTION

The surgery is generally performed under local anesthesia and is usually well tolerated. The patient's head is rotated approximately 45° away from the side of the hematoma and fixed by a tape in a horseshoe headrest. One burr hole is made in the area above the maximum hematoma thickness. In the event of a large holo-hemispheric CSDH, the burr hole is placed approximately at the coronal suture to avoid potential motor cortex injury. One drain is inserted into the dorsal direction to the deepest point of the hematoma cavity, and the other one is inserted frontally into the highest point [Figure 1a]. The exact distance from the burr hole to the deepest point and to the highest point is measured by computed tomography (CT) scan before surgery, and this distance is marked on each drain.

The hematoma cavity is irrigated copiously until the drainage fluid runs clear. Thereafter, the wound is closed in a two-layer fashion to prevent any

hematoma-atmosphere communication. Then, the saline is gently instilled to the dorsal drain to eliminate air from the hematoma cavity by the way of the frontal drain [Figure 2]. When saline fills the frontal drain, the frontal drain is removed and air bubbles, if present, stop to appear in the effluante [Figure 1b]. The patient is left on strict bed rest for 2 days. The hydrostatic level between the intracranial and extracranial ends of the dorsal drain (hence the pressure within the cavity) may be set according to the volume and composition of the effluante. A CT scan is performed on the 2<sup>nd</sup> postoperative day, and the dorsal drain is removed [Figure 3].

So far, the proposed technique was used in 18 patients with good postoperative outcome and no recurrence. About 56% of the patients were on antiplatelet medication and 28% on oral anticoagulants preoperatively. The most common symptom was hemiparesis (78%), followed by a decreased level of consciousness (22%), headache (17%), and aphasia (6%). The mean maximum hematoma thickness was 23.0 mm ± 5.3 mm; mean operative time was 36 ± 8 min; and the mean postoperative pneumocephalus volume was 3.8 ± 2.1 ml on CT scan performed on the 2<sup>nd</sup> postoperative day. The mean postoperative follow-up was 9.3 months ± 3.6 months. No reoperation was performed, and no complication occurred in these patients during the follow-up. Modified Rankin Scale (mRS) measured at the follow-up period was 0 in 16 cases, 1 in one case, and 2 in one case.



**Figure 1:** (a) Schematic depiction of intraoperative saline irrigation using two drains (frontal drain and dorsal drain). Note the tip of the frontal drain in the air bubble trapped in the subdural cavity. The air is eliminated from the subdural cavity through the frontal catheter.  $\Delta h$  shows the height difference attributed to hydrostatic pressure. (b) Postoperative situation showing no subdural air. Only the dorsal drain is left in place to drain the residual fluid under the hydrostatic pressure ( $\rho g H$ ). The outflow  $\Delta V$  (and indirectly the intracavity pressure) may be controlled by the hydrostatic levels of the internal and external ends of the drain ( $\Delta h$ )



**Figure 2:** Intraoperative photo after wound suturing showing two drains (frontal drain and dorsal drain). Analogous situation is depicted in Figure 1a

## DISCUSSION

### How to reduce the recurrence rate?

Despite efforts, the recurrence rate in surgery for CSDH remains high. When defined as symptomatic reaccumulation of hematoma fluid that needs reoperation, the recurrence rate ranges (widely) from 0.4% to 33.3%.<sup>[5]</sup> Whereas some factors of recurrence cannot be influenced (age, comorbidities, severe neurological deficit, volume and internal structure of hematoma, and bilaterality), others can.

Factors of recurrence that can be influenced are mainly certain operative nuances and postoperative measures such as the type of trepanation, intraoperative irrigation, drain insertion and position, air that enters the subdural space, and postoperative patient position. Procedures available for CSDH patients include twist-drill craniostomy, burr hole, and craniotomy. A burr hole seems to have the best cure-to-complication

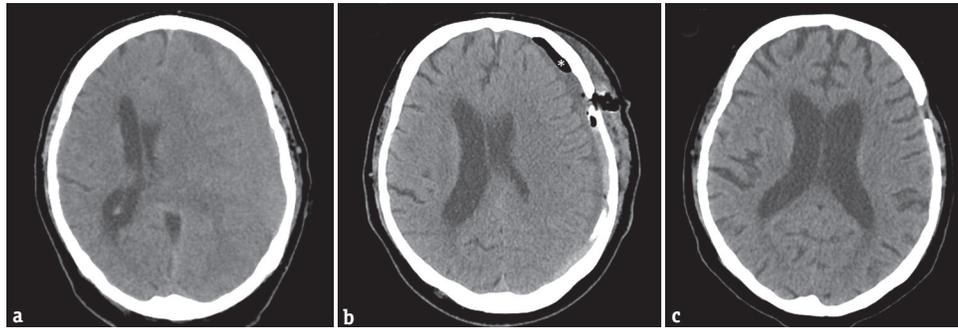
ratio when compared with the twist-drill craniostomy and craniotomy,<sup>[2,3,7,8,14]</sup> which was confirmed by Monte Carlo simulation techniques and decision analytical methods.<sup>[15]</sup> Evidence favors intraoperative irrigation of sterile saline to wash out the hematoma, despite potential risks associated with the introduction of air and infection.<sup>[16-18]</sup> Meta-analyses show that inserting a drain into the hematoma cavity and leaving it in place for 24–48 h to drain residual hematoma fluid is beneficial in reducing recurrence without increasing risk of acute bleeding or infection.<sup>[6-8]</sup> Santarius *et al.* performed a randomized trial that demonstrated not only a decrease in recurrence when using the drain but also a decrease at a 6-month mortality rate.<sup>[19]</sup> Leaving postoperatively two drains instead of one was studied by Gernsback *et al.* and showed no additional benefit.<sup>[20]</sup> Another important independent factor of recurrence is postoperative pneumocephalus, i.e., the amount of air that enters the hematoma cavity during surgery.<sup>[9-13]</sup> Only a few papers, which were mainly technique descriptions, have examined reducing postoperative pneumocephalus. We discuss this issue more in depth in a separate paragraph (see below). The optimal postoperative posture of the patient was examined in only a few studies, with results indicating no meaningful differences between sitting and supine postoperative positions regarding the recurrence rate.<sup>[21-23]</sup> Concerning our technique, we assume that the supine position and bed rest for 48-postoperative hours are needed to ensure hydrostatic pressure gradients as described above.

When developing our technique, we included all the above-mentioned measures that are supported by the scientific evidence.

### How to reduce postoperative pneumocephalus?

The most important technique is to position patient's head on a horseshoe headrest with burr hole at the highest point if possible. Several other techniques have been proposed to reduce postoperative pneumocephalus, with some being quite complicated and invasive. Pioneers in this research are mostly Japanese investigators. Intraoperative intrathecal injection of saline for cerebral reexpansion was described in two papers.<sup>[24,25]</sup> The authors used Ringer's solution and Ringer's lactate solution that were introduced through a lumbar needle to the subarachnoid space until the brain reexpanded to the inner table of the skull and thus subdural air eliminated. In the study by Grisoli *et al.*, the amount of fluid ranged from 40 to 300 ml.<sup>[24]</sup>

Another approach to avoid air collection in the hematoma cavity is replacing air by another gas that is absorbed into the circulation faster than air. Kitakami *et al.* used



**Figure 3:** Computed tomography scan of the patient with chronic subdural hematoma before surgery (a). Early postoperative computed tomography (b) showing minimal residual subdural air (asterisk). After 1 month, complete resolution of chronic subdural hematoma and subdural air (c)

carbon dioxide to fill the hematoma cavity after blood evacuation.<sup>[26]</sup> Carbon dioxide is absorbed 250 times faster than air, which is one of the reasons for its use in abdominal surgery to create pneumoperitoneum during laparoscopy. The authors observed almost complete absorption 24 h after surgery and the recurrence rate was 5.2%. Similar techniques using oxygen instead of carbon dioxide have been published by Aoki *et al.* and Takeda *et al.*<sup>[27,28]</sup>

The direction of drain placement to reduce pneumocephalus has been examined in only a few studies. Nakaguchi *et al.*, for instance, found a significant reduction in both postoperative pneumocephalus and in the recurrence rate in patients with the frontal direction of the drain when compared with patients with a drain placed parietally and occipitally.<sup>[12]</sup> The authors explained their results by easier evacuation of the air collection by a frontally placed drain when patients were lying in a supine position. Shiomi *et al.* observed a significantly longer time to recurrence in patients with frontal drain direction and a trend toward a lower recurrence rate.<sup>[10]</sup> On the other hand, Ohba *et al.* did not find a statistically significant difference between the frontal and dorsal position of the drain.<sup>[9]</sup>

A conservative measure to resolve postoperative pneumocephalus is administration of supplemental oxygen. The rationale for this approach is that an increase in  $\text{FiO}_2$  decreases the concentration of nitrogen within the blood and brain tissue and thereby increases the nitrogen concentration gradient for absorption. Gore *et al.* performed a randomized trial on 13 patients that underwent elective craniotomy (non-CSDH patients) with a mean initial air volume of 50 ml.<sup>[29]</sup> The results showed that 24-h administration of 100% normobaric oxygen significantly increased the absorption rate of postcraniotomy pneumocephalus as compared with breathing room air. The potential use of this treatment in CSDH patients is limited because the usual volume

of air is higher than 50 ml, and longer administration of concentrated oxygen is linked to the risk of pulmonary toxicity.

### Advantages of the present technique

Our technique combines the aforementioned scientific evidence (i.e., intraoperative irrigation, reduction of pneumocephalus, and one drain for 48-h placement) with basic physical principles. In our technique, postoperative subdural air accumulation is avoided by replacing it with saline using two drains during surgery. The air is pushed upward by the ascending level [ $\Delta h$  in Figure 1] of the inflowing fluid. The superficial tension at the air-fluid interface facilitates the coalescence of bubbles into one that is finally expelled by the frontal drain. When air is eliminated, the frontal drain is removed in the operating room, and the dorsal drain is left in place for 48-h postsurgery. We leave in place dorsal drain despite the fact, that some studies showed better outcome in frontally placed drain. The superiority of the frontal drain placement was explained in the studies by easier air elimination when the patient is postoperatively in the supine position allowing the air to migrate passively frontally and to form a bubble around the tip of the frontal drain. In our technique, this process is active due to pressure [ $P$  in Figure 1] and is thus accelerated. Therefore, the use of the frontal drain is not necessary. On the contrary, the remaining dorsal drain improves the removal of the residual fluid thanks to hydrostatic pressure gradient setup [ $H$  in Figure 2]. The outflow which facilitates expansion of the brain tissue may be controlled by the level between the intracranial and extracranial ends of the drain [ $\Delta h$  in Figure 2].

Cecchini described a similar technique to ours with one important difference. The drain that is left in place is introduced through the parietal burr hole and faces frontally.<sup>[30]</sup> The tip of the drain is at the highest point of the CSDH cavity when the patient is in the supine position. Therefore, this setting does not benefit from the maximum hydrostatic pressure as compared with our technique see Figure 1a. In addition, we consider the

placing of the burr hole at the parietal eminence as more difficult to perform under local anesthesia and riskier regarding potential injury of the motor cortex. A similar technique was described by Weigel *et al.*,<sup>[31]</sup> however, these authors left the postoperatively frontal drain in place, which we consider less effective.

### Limitations

This paper has several limitations that need to be addressed. First, it is only a technique description, and therefore, clinical trials are required to clarify its efficacy. We consider the present development of technique as Stage 2a according to IDEAL framework,<sup>[32]</sup> and next stages are going to begin. Second, the technique demands the specific placement of subdural drains, which might be challenging. During insertion of the drain, it may move to an undesired direction even without the neurosurgeon's awareness. Proper positioning of the drain might be checked by an endoscope; however, it requires additional equipment.<sup>[33]</sup> Third, placing two drains instead of the usual one, even temporarily, might potentially increase the risk of bridging vein and brain surface damage. Meta-analyses did not show higher complication rate associated with single drain use.<sup>[6,7]</sup> Therefore, we speculate that two drains use do not increase complication rate either. Fourth, the presented technique is the best suitable for homogenous hematomas without compartmentalization. Hematoma with at least two compartments needs to be evacuated with membrane opening. Furthermore, we do not use the presented technique for hematomas with acute component because complete irrigation is not possible.

### CONCLUSION

A high recurrence rate is a major concern of CSDH surgery. We implemented evidence-based conclusions of previous studies to reduce recurrence while keeping the surgical procedure straightforward and feasible to perform under a local anesthesia. The novelty of the present technique consists of the purposeful reduction of postoperative pneumocephalus, which has been shown to be an independent factor of recurrence. Subdural air is eliminated during surgery using a two-drain system (frontal drain and dorsal drain). The frontal drain is removed at the end of the surgical procedure while the dorsal drain is left *in situ* for 48 h to allow the evacuation of residual hematoma fluid. Obviously, the future clinical trials are needed to establish the safety and efficacy of the technique.

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### Conflicts of interest

There are no conflicts of interest

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