Chronic subdural hematoma: a systematic review and meta-analysis of surgical procedures

A systematic review

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Object. In this paper the authors systematically evaluate the results of different surgical procedures for chronic subdural hematoma (CSDH).

Methods. The MEDLINE, Embase, Cochrane Central Register of Controlled Trials, and other databases were scrutinized according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement, after which only randomized controlled trials (RCTs) and quasi-RCTs were included. At least 2 different neurosurgical procedures in the management of chronic subdural hematoma (CSDH) had to be evaluated. Included studies were assessed for the risk of bias. Recurrence rates, complications, and outcome including mortality were taken as outcome measures. Statistical heterogeneity in each meta-analysis was assessed using the $I^2$ (tau-squared), $F$, and chi-square tests. The DerSimonian-Laird method was used to calculate the summary estimates using the fixed-effect model in meta-analysis.

Results. Of the 297 studies identified, 19 RCTs were included. Of them, 7 studies evaluated the use of postoperative drainage, of which the meta-analysis showed a pooled OR of 0.36 (95% CI 0.21–0.60; $p < 0.001$) in favor of drainage. Four studies compared twist drill and bur hole procedures. No significant differences between the 2 methods were present, but heterogeneity was considered to be significant. Three studies directly compared the use of irrigation before drainage. A fixed-effects meta-analysis showed a pooled OR of 0.49 (95% CI 0.21–1.14; $p = 0.10$) in favor of irrigation. Two studies evaluated postoperative posture. The available data did not reveal a significant advantage in favor of the postoperative supine posture. Regarding positioning of the catheter used for drainage, it was shown that a frontal catheter led to a better outcome. One study compared duration of drainage, showing that 48 hours of drainage was as effective as 96 hours of drainage.

Conclusions. Postoperative drainage has the advantage of reducing recurrence without increasing complications. The use of a bur hole or twist drill does not seem to make any significant difference in recurrence rates or other outcome measures. It seems that irrigation may lead to a better outcome. These results may lead to more standardized procedures.

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Key Words • chronic subdural hematoma • review • meta-analysis • traumatic brain injury

Chronic subdural hematoma (CSDH) is a frequently encountered neurosurgical condition, especially in the elderly, with an incidence of 58/100,000 persons a year in people 70 years of age or older.²¹ Although CSDH is one of the most commonly encountered conditions in neurosurgery, no consensus yet exists regarding the optimal surgical technique to treat the CSDH. All surgical strategies aim at decompression of the cerebral hemisphere and to prevent recurrence of CSDH, with minimal morbidity and mortality. Recurrence rates, however, can be high, with reported rates up to 33%.²⁵ It has already been shown by Santarius et al. that drainage after surgical evacuation of the hematoma likely leads to a better outcome.²⁸ Besides drainage, other questions that remain imminent are the use of a regular bur hole or the use of a twist drill, the use of irrigation, the optimal duration of drainage, postoperative posture, and optimal location of the catheter used for drainage. In the available literature, results are inconsistent. In view of the aforementioned factors we aimed to perform an extensive systematic review addressing these issues.

Methods

Study Inclusion

A systematic search was performed in MEDLINE, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL, The Cochrane Library 2012, Issue 1), LILACS (Latin American and Caribbean Center on...
Health Sciences Information), CMB (Chinese Biomedical Database), and Google Scholar. The last search was conducted on December 1, 2013, and went back as far as data were available. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement was followed. In addition, references of the included studies were scrutinized for additional studies. The Cochrane Highly Sensitive Search Strategy for identifying randomized trials was used.8 No language restrictions were applied. The following search terms were used: “chronic subdural hematoma”[All Fields] OR “hematoma, subdural, chronic”[MeSH Terms] OR (“hematoma”[All Fields] AND “subdural”[All Fields] AND “chronic”[All Fields]) OR “chronic subdural hematoma”[All Fields] OR (“chronic”[All Fields] AND “subdural”[All Fields] AND “hematoma”[All Fields]).

After careful evaluation, only RCTs and quasi-RCTs (pseudo-random) were included. Quasi-RCTs were defined as allocation by date of birth, day of the week, medical record number, and month of the year, among others. The included studies at least had to focus on 2 different neurosurgical procedures to treat CSDH: twist drill or bur hole, drainage or not, irrigation or not, catheter location, duration of drainage, and/or postoperative posture. A bur hole in general leads to a craniostomy opening of approximately 10 mm; a twist-drill craniostomy may be a hole as small as 1 mm up to 5 mm.

Outcome Measures

Recurrence rates, complication rates, and outcome including mortality were used as outcome measures. Chronic SDH recurrence was defined as the presence of symptoms attributable to an ipsilateral hematoma and with the presence of a hematoma on a CT scan, within 6 months after the initial surgical procedure. The following conditions were considered to be complications: surgical site infections (subdural empyema, incision infections, and meningitis), infection in other parts of the body (pneumonia, urinary tract infections, and gastrointestinal infections), intracranial hemorrhage independent from CSDH (parenchymal hemorrhage and acute subdural hematoma), seizure, other organ complications (arrhythmia, myocardial infarction, and renal failure), and electrolyte imbalance. Pneumocephalus was not considered a com-
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A Glasgow Outcome Scale score\textsuperscript{16} of 4–5 or a modified Rankin Scale score of 0–3 was considered a favorable outcome. Operative mortality was defined as any death, regardless of cause, occurring 1) within 30 days after surgery in or out of the hospital or 2) after 30 days during the same hospitalization subsequent to the operation.\textsuperscript{17}

Selection of Studies

We each independently selected trials for inclusion in the review and cross-checked the outcome data. Two authors (W.L. and N.A.B.) independently extracted and cross-checked the outcome data. Disagreements were solved by discussion.

Assessment of Risk of Bias in Included Studies

Two review authors (W.L. and N.A.B.) independently assessed the risk of bias of the included trials according to the Cochrane Handbook for Systematic Reviews of Interventions\textsuperscript{9} based on the following 6 domains with the rating of low risk of bias, high risk of bias, and uncertain risk of bias: random sequence generation, allocation concealment, blinding, incomplete outcome data, selective reporting, and other bias. Other criteria included the prognostic balance between the 2 treatment arms and the completeness and length of follow-up (6 months).

Statistics: Assessment of Heterogeneity and Reporting Biases in Meta-Analysis

Statistical heterogeneity in each meta-analysis was assessed using the $T^2$ (tau-squared), $I^2$, and chi-square tests. Heterogeneity was considered substantial if $T^2 > 0$ or $I^2$ was greater than 30\% or in case of a p value $< 0.10$ in the chi-square test for heterogeneity. When reporting bias was suspected, we attempted to contact study authors, asking them to provide missing outcome data. When this was not possible and the missing data were considered to introduce serious bias, the impact of these studies in the overall assessment of results was analyzed by a sensitivity analysis. In case of 5 or more studies in a meta-analysis, reporting biases (such as publication bias) were analyzed using funnel plots. Publication bias is defined as the phenomenon in which statistically significant results are more likely to be published and cited. When an unbiased sample of trials performed is studied with a funnel plot, the observed effect sizes should range symmetrically around the true effect size, which will be most accurately estimated by the largest trials, resulting in a symmetrical plot shaped like an inverted funnel.

### TABLE 1: Characteristics of included studies\textsuperscript{*}

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Study Type</th>
<th>Included Cases</th>
<th>Follow-Up</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>twist vs bur hole</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muzii et al., 2005</td>
<td>RCT</td>
<td>46</td>
<td>2 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Horn et al., 2006</td>
<td>quasi-RCT</td>
<td>79</td>
<td>3 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Gökmen et al., 2008</td>
<td>RCT</td>
<td>68</td>
<td>6 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Singh et al., 2011</td>
<td>RCT</td>
<td>100</td>
<td>1 mo</td>
<td>no significant difference</td>
</tr>
<tr>
<td>drainage vs no drainage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laumer et al., 1989</td>
<td>RCT</td>
<td>96</td>
<td>3 wks</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Wakai et al., 1990</td>
<td>quasi-RCT</td>
<td>38</td>
<td>1 mo</td>
<td>in favor of drainage</td>
</tr>
<tr>
<td>Tsutsumi et al., 1997</td>
<td>RCT</td>
<td>138</td>
<td>6 mos</td>
<td>in favor of drainage</td>
</tr>
<tr>
<td>Erol et al., 2005</td>
<td>RCT</td>
<td>70</td>
<td>1 mo</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Santarius et al., 2009</td>
<td>RCT</td>
<td>215</td>
<td>6 mos</td>
<td>in favor of drainage</td>
</tr>
<tr>
<td>Javadi et al., 2011</td>
<td>RCT</td>
<td>40</td>
<td>6 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Ahmed et al., 2011</td>
<td>RCT</td>
<td>51</td>
<td>6 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>irrigation vs no irrigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gurel et al., 2007</td>
<td>RCT</td>
<td>80</td>
<td>8 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Zakaria et al., 2008</td>
<td>quasi-RCT</td>
<td>82</td>
<td>6 mos</td>
<td>no significant difference</td>
</tr>
<tr>
<td>Ishibashi et al., 2011</td>
<td>RCT</td>
<td>92</td>
<td>NR</td>
<td>in favor of irrigation</td>
</tr>
<tr>
<td>catheter location</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nakaguchi et al., 2000</td>
<td>quasi-RCT</td>
<td>63</td>
<td>3 mos</td>
<td>catheter in frontal convexity better than other location</td>
</tr>
<tr>
<td>Kaliaperumal et al., 2012</td>
<td>RCT</td>
<td>50</td>
<td>6 mos</td>
<td>subperiosteal better than subdural</td>
</tr>
<tr>
<td>drainage duration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sindou et al., 2010</td>
<td>RCT</td>
<td>65</td>
<td>48-hr drainage better than 96-hr drainage</td>
<td></td>
</tr>
<tr>
<td>postop posture (upright vs supine)</td>
<td>RCT</td>
<td>46</td>
<td>6 mos</td>
<td>no difference</td>
</tr>
<tr>
<td>Nakajima et al., 2002</td>
<td>RCT</td>
<td>84</td>
<td>3 mos</td>
<td>in favor of supine</td>
</tr>
</tbody>
</table>

\textsuperscript{*} NR = not reported.
If enough studies on a specific topic were present, a meta-analysis was performed using Review Manager 5.1 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2011). The DerSimonian-Laird method was used to calculate the summary estimate using the fixed-effect model.

Results

Search Results

Overall, the literature searches identified 297 clinical trials addressing CSDH (Fig. 1). Of the titles and abstracts screened, 82 relevant full papers were retrieved and assessed in detail. A total of 27 RCTs and quasi-RCTs were related to CSDH. We excluded 8 RCTs, 1 because of repeated publishing in another language, 1 because not enough data were provided, and 1 because prospectively collected results were compared with historical controls. Four other studies were excluded because different nonsurgical treatments were applied in the control group. Therefore, 19 studies were included in this review (Table 1). Among these trials, 4 compared twist drill with bur hole procedures, 7 compared drainage versus no drainage postoperatively, 3 compared irrigation versus no irrigation, 2 compared catheter location, 2 compared postoperative posture, and 1 compared duration of drainage.

Assessment of Risk of Bias of the Included Studies

Details of assessment of risk of bias in included studies are shown in Fig. 2. Although some trials were declared randomized, their random sequence generation and allocation concealment were not clear. If the study was not complete—length of follow-up was less than 6 months or important data (such as recurrence, complications, outcome, and mortality) were not present—this study was considered incomplete regarding outcome data.

Postoperative Drainage

Seven trials compared drainage versus no drainage after a bur hole procedure. Three of them concluded the use of drainage to be superior. The other 4 trials did not identify significant differences in outcome. In all 7 trials, reoperation rates were considered recurrence rates. However, indications for reoperation were different. Laumer et al. defined recurrent CSDH as either worsening of neurological symptoms or hematoma increase on CT. The other 6 trials used the presence of both worsening of neurological symptoms and hematoma increase on CT as an indication for reoperation. As such, the study by Laumer et al. was excluded from the analysis. The study by Erol et al. used a follow-up of 1 month; the other 5 trials had a follow-up of 6 months.

These 6 trials included 523 patients. There were 23 cases of recurrent CSDH among 273 patients (8.4%) with a closed drainage system in contrast with 54 cases of recurrence CSDH of 259 patients without a closed drainage system (20.8%). A fixed-effects meta-analysis showed a pooled OR of 0.36 (95% CI 0.21–0.60; p < 0.001), indicating a significant benefit for the use of a closed drainage system (Fig. 3A). There was no indication of heterogeneity between the results of the different trials (p = 0.42; I² = 0%). A funnel plot was used to test for publication bias in our meta-analysis. Figure 4 shows that the trials in meta-analysis seem approximately symmetric in both analyses.

The study by Tsutsumi et al. did not report complications, while Wakai et al. reported complications with-
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out subgroup information. The other 5 studies were analyzed regarding complication rates. These 5 trials included 472 patients. There were 37 complications among 237 patients (15.6%) with drainage system compared with 25 complications among 235 patients (10.6%) without drainage. A fixed-effects meta-analysis showed a pooled OR of 1.60 (95% CI 0.92–2.78; p = 0.09, Fig. 3B). No indication of heterogeneity between the results of the different trials was present (p = 0.40; I² = 1%).

Five studies (a total of 410 patients) could be analyzed for mortality. No significant differences were noted (p = 0.98, Fig. 3C). Outcome could not be analyzed because of different outcome measures and follow-up times of the included studies.

**Bur Hole Versus Twist Drill**

Four trials compared bur hole with twist drill procedures in CSDH (293 patients in total). Among these 4 studies, the twist procedures were different. Singh et al.32

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**Fig. 3.** Summary of the meta-analysis comparing the use of a closed drainage system in relation to recurrence of CSDH (A), complications (B), and mortality (C). Each horizontal line represents results of a single study. The square marks the OR estimate for the study and the size of the square is proportionate to the weight given to the information from the trial. The left and right endpoints of the horizontal line mark the ends of the CI for the individual trial’s OR estimate. In panel A, the diamond represents the pooled estimate from the meta-analysis; its center lies on the left side, showing significant difference between 2 groups (p < 0.001).

**Fig. 4.** A funnel plot evaluating publication bias in comparing with or without a closed drainage system in relation to recurrence of CSDH. The plot shows that the 6 included RCTs in this meta-analysis seem approximately symmetrically ranged around the overall effect size estimate, shown by the dashed line in the center.
TABLE 2: The procedural differences among studies comparing twist drill and bur hole craniostomy

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Type</th>
<th>No. of Cases</th>
<th>Type of Anesthesia</th>
<th>No. of Irrigation</th>
<th>Catheter</th>
<th>Drainage System</th>
<th>Drainage Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gökmen et al., 2008</td>
<td>twist</td>
<td>37</td>
<td>local or general</td>
<td>1</td>
<td>12-Fr drain catheter</td>
<td>bagged soft drains</td>
<td>remove 2nd day of surgery</td>
</tr>
<tr>
<td></td>
<td>bur hole</td>
<td>31</td>
<td>local or general</td>
<td>yes</td>
<td>12-Fr drain catheter</td>
<td>bagged soft drains</td>
<td></td>
</tr>
<tr>
<td>Horn et al., 2006</td>
<td>twist</td>
<td>55</td>
<td>NR</td>
<td>1</td>
<td>ventriculostomy catheter</td>
<td>NR</td>
<td>blood adequately drained (on CT)</td>
</tr>
<tr>
<td></td>
<td>bur hole</td>
<td>24</td>
<td>NR</td>
<td>yes</td>
<td>ventriculostomy catheter</td>
<td>NR</td>
<td>blood adequately drained (on CT)</td>
</tr>
<tr>
<td>Muzii et al., 2005</td>
<td>twist</td>
<td>22</td>
<td>local</td>
<td>1</td>
<td>subdural expansion catheter</td>
<td>100-ml suction reservoir</td>
<td>drainage ceased, average 65.3 hrs</td>
</tr>
<tr>
<td></td>
<td>bur hole</td>
<td>24</td>
<td>local</td>
<td>1 or 2</td>
<td>a catheter</td>
<td>50 cm below head</td>
<td>drainage ceased average 34.8 hrs</td>
</tr>
<tr>
<td>Singh et al., 2011</td>
<td>twist</td>
<td>48</td>
<td>local</td>
<td>2</td>
<td>ventricular catheter</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>bur hole</td>
<td>52</td>
<td>local</td>
<td>yes</td>
<td>ventricular catheter</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

used 2 twist holes for drainage, Muzii et al.24 used 1 or 2 twist holes, and the other 2 trials used only 1 twist hole. Gökmen et al.7 and Muzii et al.24 did not use saline irrigation after twist hole procedures, while the other 2 trials did use irrigation. Three of 4 trials used a ventriculostomy catheter for drainage, while Muzii et al.24 used a subdural expansion catheter. Drainage time was also different: Gökmen et al.7 removed the catheter on the 2nd day after surgery, while Muzii et al.24 and Horn et al.11 removed the catheter when draining stopped. Singh et al.32 did not report on drainage time. The study by Horn et al.11 did not meet our predefined criteria for a clear definition of recurrence of hematoma. As such, this study was not used for the quantitative analysis. The procedural differences among included studies are shown in Table 2.

Because studies did not have a uniform operative procedure, study heterogeneity was analyzed, showing significant heterogeneity (p = 0.11, I² = 54%). As such, Mantel-Haenszel (M-H) random models were used to analyze recurrence rates between the 2 groups. The meta-analysis showed a pooled OR of 0.76 (95% CI 0.26–2.25; p = 0.62 [Fig. 5A]). Outcome was also defined in distinct ways among the included studies, leading to significant heterogeneity (p = 0.20; I² = 36%). Using M-H random models, a pooled OR of 1.10 (95% CI 0.60–2.00; p = 0.76) was observed (Fig. 5B). Regarding mortality, study heterogeneity was acceptable (p = 0.28; I² = 21%). The meta-analysis showed a pooled OR of 1.38 (95% CI 0.55–3.43; p = 0.49 [Fig. 5C]). Complication rates could not be analyzed because too little information was provided in the studies included.

Irrigation During the Operative Procedure

Three of the included studies addressed irrigation during the procedure.8,13,37 These trials compared recurrence rates between studies using drainage with and without irrigation. Data on complications, outcome, and mortality were not available for analysis. These 3 trials included 254 patients. There were 9 recurrences among 112 patients (8.0%) in the irrigation group compared with 20 recurrences among 142 patients (14.1%) in the drainage without irrigation group. A fixed-effects meta-analysis showed a pooled OR of 0.49 (95% CI 0.21–1.14; p = 0.10 [Fig. 6]).

Postoperative Posture

Abouzari et al.1 compared supine and sitting positions for 3 days postoperatively in a study with 84 patients. After follow-up of 3 months, the recurrence rate was 2.3% in the supine position group compared with 19.0% in the sitting position group. However, only 1 patient (1 [12.5%] of 8 total patients in whom there were recurrences) needed a reoperation. According to definitions used in this review, only this case is considered a recurrence. Nakajima et al.25 did not find differences between postoperative positions. When analyzing the trials together, heterogeneity was acceptable (p = 0.49; I² = 0%), with a pooled OR of 0.86 (95% CI 0.21–3.48; p = 0.83 [Fig. 7]).

Position of Draining Catheter

Two studies focused on the position of the catheter used for drainage. One trial was performed by Nakaguchi et al.25 The authors observed significantly fewer recurrences when the tip of the drain was placed in a frontal position (5% recurrences) compared with the temporal (33% recurrences), occipital (36% recurrences), or parietal (38% recurrences) position in a study with 63 patients. Another trial was performed by Kaliaperumal et al.18 In this prospective randomized study including 50 patients, 2 types of drainage were compared: subperiosteal drainage and subdural drainage following bur hole. No significant differences were detected.

Duration of Drainage

One trial including 65 patients could be included to
address the question of duration of drainage. Using a twist drill technique with closed-system drainage, the duration of drainage was compared: 48 hours versus 96 hours. The rate of recurrence and outcome did not differ significantly. The postoperative complication rate was 26.9% in the 96-hour group and 10.7% in the 48-hour group, with mortality rates of 11.4% and 3.8%, respectively (p < 0.001, data not shown).
In recent years, a significant number of controlled trials were performed on different aspects of the surgical treatment of CSDH. Also, some meta-analyses were performed,\(^1^3\)\(^\text{36}\) however, some questions on optimal treatment remain. As such, we aimed to perform a systematic review and meta-analysis of the available literature in a modern fashion, using the PRISMA statement, to provide clarity regarding the evidence for different aspects of surgical procedures to treat CSDH. In the present meta-analysis, it is clearly shown that postoperative drainage is useful in the treatment of CSDH. Drainage reduces recurrence by approximately 60%, without an increase in complications and mortality. This is consistent with most neurosurgeons’ experience in everyday clinical practice. As such, postoperative drainage should be recommended in the treatment of CSDH. Whether irrigation should be performed prior to postoperative drainage is less clear; recurrence rates were 8.0% in the irrigation group and 14.1% in the irrigation-free group \(p = 0.10\). Although not significant, there was a trend in favor of irrigation. This makes sense in our opinion as this provides a washout of blood products and other factors possibly involved in maintaining the hematoma.

Regarding postoperative posture, no definitive conclusions can be drawn from this review. Additional comparative studies are needed to find evidence in favor of one of the positions. Catheter location was only investigated by 2 studies. Although no overall differences were detected between subperiosteal drainage and subdural drainage, it was clearly shown that in case of subdural drainage, the catheter tip should be placed in the frontal position. Only 1 study investigated optimal drainage duration; it was shown that 48 hours of drainage instead of 96 hours led to significantly fewer complications. It is unclear, however, whether a shorter drainage time would also suffice.

Some limitations of this review have to be mentioned. Some of the included trials are quasi-(pseudo) RCTs, in which allocation took place by medical record number or the order of operation. Most of the studies did not report on random sequence generation and allocation concealment. Also, follow-up among the investigated trials varied. Unfortunately, in almost half of the included studies follow-up time was rather short, precluding us from drawing firm conclusions on outcome. Also, differences in recurrence and outcome criteria were present among studies, making it difficult to evaluate the results in a standardized way.

This review clearly demonstrates the benefit of postoperative drainage after treatment of CSDH. The use of irrigation seems to be beneficial, while both a twist drill and a burr hole seem to be reliable treatment options. As such, more studies addressing irrigation, duration of drainage, and postoperative position with uniform follow-up times of at least 6 months are needed.

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