Chronic Subdural Hematoma Management

A Systematic Review and Meta-analysis of 34829 Patients

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Objective: To compare the efficacy and safety of multiple treatment modalities for the management of chronic subdural hematoma (CSDH) patients.

Background: Current management strategies of CSDHs remain widely controversial. Treatment options vary from medical therapy and bedside procedures to major operative techniques.

Methods: We searched MEDLINE (PubMed and Ovid), EMBASE, CINAHL, Google scholar, and the Cochrane library from January 1970 through February 2013 for randomized and observational studies reporting one or more outcome following the management of symptomatic patients with CSDH. Independent reviewers evaluated the quality of studies and abstracted the data on the safety and efficacy of percutaneous bedside twist-drill drainage, single or multiple operating room burr holes, craniotomy, corticosteroids as a main or adjuvant therapy, use of drains, irrigation of the hematoma cavity, bed rest, and treatment of recurrences following CSDH management. Mortality, morbidity, cure, and recurrence rates were examined for each management option. Randomized, prospective, retrospective, and overall observational studies were analyzed separately. Pooled estimates, confidence intervals (CIs), and relative risks (RRs) were calculated for all outcomes using a random-effects model.

Results: A total of 34,829 patients from 250 studies met our eligibility criteria. Sixteen trials were randomized, and the remaining 234 were observational. We included our unpublished single center series of 834 patients. When comparing percutaneous bedside drainage to operating room burr hole evacuation, there was no significant difference in mortality (RR, 0.69; 95% CI, 0.46–1.05; $P = 0.09$), morbidity (RR, 0.45; 95% CI, 0.2–1.01; $P = 0.05$), cure (RR, 1.05; 95% CI, 0.98–1.11; $P = 0.15$), and recurrence rates (RR, 1; 95% CI, 0.66–1.52; $P = 0.99$). Higher morbidity was associated with the adjuvant use of corticosteroids (RR, 1.97; 95% CI, 1.54–2.45; $P = 0.005$), with no significant improvement in recurrence and cure rates. The use of drains following CSDH drainage resulted in a significant decrease in recurrences (RR, 0.46; 95% CI, 0.27–0.76; $P = 0.002$). Craniotomy was associated with higher complication rates if considered initially (RR, 1.39; 95% CI, 1.04–1.74; $P = 0.01$); however, craniotomy was superior to minimally invasive procedures in the management of recurrences (RR, 0.22; 95% CI, 0.05–0.85; $P = 0.003$).

Conclusions: Percutaneous bedside twist-drill drainage is a relatively safe and effective first-line management option. These findings may result in potential health cost savings and eliminate perioperative risks related to general anesthetic.

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Chronic subdural hematoma (CSDH) is an abnormal collection of liquefied blood degradation underneath the dura matter that may result in brain tissue compression and subsequent neurological sequelae. It is a disease of increasing frequency, especially among the elderly. The annual estimated incidence is 13.5 per 100,000 individuals per year. This may reach up to 58.1 per 100,000 persons for patients 65 years of age or older.[1] Recent advances in imaging techniques in addition to the wide availability of computed tomography scanners have led to an increase in diagnosis. The widespread use of antiplatelet and anticoagulant medications was described as risk factors.[2] Increased recognition of this condition was attributed to an improved awareness among medical professionals given our aging population.

CSDH might be found incidentally on brain imaging. Surgical intervention is considered when mass effect on the surrounding brain tissue results in symptomology. Relatively simple, safe, and effective procedures have been used to manage this condition. Percutaneous twist-drill bedside drainage, operative theater burr holes, or craniotomy are widely used main treatment options. The differences between each are not simply related to surgical techniques, however, are also reflected in potential cost savings in light of operating room resources, involvement of multiple health professionals, and perioperative risks associated with general anesthesia. Moreover, these surgical interventions differ in their degree of invasiveness, where minimally invasive approaches would be incrementally favored for the elderly patients with multiple medical comorbidities. Following CSDH management, the reported estimates of recurrence, mortality, morbidity, and cure rates are highly variable across each of the 3 main treatment modalities. The use of corticosteroids alone for milder cases and their role as forms of adjuvant therapy require further studies. In addition, the value of drain insertion, irrigation of the hematoma cavity, single or multiple burr holes, bed rest after surgical evacuation, and management of recurrent cases remains debatable. Despite the fact that CSDH is a common and known presentation, there is no established standard of care for first-line treatment and there is a lack of management consensus. The available wealth of data from the literature pertinent to this disease demonstrates a highly variable practice of management. The aim of this systematic review and meta-analysis is to perform a comprehensive comparison of treatment options to evaluate their efficacy and safety for patients presenting with symptomatic CSDH. We also aim to describe the outcomes of each management modality and stratify separately the evidence from randomized, prospective, and retrospective observational studies.

METHODS

We undertook a systematic review and meta-analysis and reported our findings in accordance with recommendations made by the Meta-analysis Of Observational Studies in Epidemiology (MOOSE),[3] the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA),[4] the Cochrane handbook,[5] and the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE)[6] working groups' guidelines.

Search Strategy

Four independent reviewers (S.A.A., C.H., B.Y., and S.S.) performed a detailed electronic search of MEDLINE (PubMed and Ovid), EMBASE, CINAHL, Google scholar, and the Cochrane library for studies published between January 1970 and February 2013 written in the management of CSDH without language restriction. Key words and MeSH (Medical Subjective Headings) terms pertaining the condition (ie, *CSDH, chronic subdural, hematoma, haematoma, hemorrhage, haemorrhage,* or *bleed*) were cross-referenced with terms pertinent to treatment (ie, *burr hole, twist drill, percutaneous, craniotomy, steroid, management, treatment, surgery, evacuation, irrigation, drainage,* or *conservative*) in relevant combinations. The full-text versions of all studies that the reviewers considered relevant were obtained. References of studies with potential relevance and relevant reviews were screened manually to identify any applicable studies that were not previously identified.

Selection Criteria

Studies were included if they stated and evaluated a treatment modality for clinically symptomatic patients with radiological findings of CSDH and reported one or more of the management outcomes on follow-up. Articles with a sample size below 15 consecutive patients were excluded. In addition, we excluded duplicate references, studies that did not specify the treatment of choice, and resources that mixed the management outcomes of acute with chronic subdural hematomas. Papers with more than 1 treatment were considered eligible if outcomes of each management were separated. We excluded reports that examined only infantile CSDH. Abstracts presented in conferences and letters to editors were excluded if studies were not published as full reports. We included non-English articles if they presented the previously discussed selection criteria in a translated English abstract. Moreover, the current authors included their own unpublished observational study as it is one of the largest series in the literature with multiple cohorts and comparisons (for description of the single center series see the Supplemental Digital Content, available at: http://links.lww.com/SLA/A452). Any disagreement between the 4 reviewers concerning the decision to include or exclude a study was solved by discussion and consensus with a fifth reviewer (N.M.).

Data Extraction

Data were abstracted by 6 investigators (S.A.A., C.H., B.B., B.M., P.A., and N.M.). We developed a system to ensure accuracy by having each reference abstracted and reviewed by 3 investigators independently, including the principal reviewer (S.A.A.). Discrepancies were settled by consensus and discussion. We gathered information from eligible articles using data abstraction forms to include title, first author, year of publication, study design, number of cohorts, total number of managed patients, total number of CSDHs (including bilateral cases), number of patients with previous use of antiplatelet or anticoagulant therapy, main treatment modality (percutaneous twist-drill drainage, burr holes, craniotomy, and corticosteroids), use of drains, duration of drainage, irrigation of the hematoma cavity, adjuvant use of steroids, the value of bed rest after surgical management, bed rest duration, single or multiple holes, recurrence rates, mortality, morbidity, types of complications, cure rates, treatment of recurrence, and recurrences following the second intervention (see the Supplemental Digital Content, available at: http://links.lww.com/SLA/A452).

Definition of Variables

Although the definition of percutaneous drainage is a relatively smaller skull puncture (usually <0.5 cm) made by a handheld twist-drill done at the bedside under local anesthetic, burr hole craniostomies are wider openings through the skull created using larger operating room drills. Craniotomy mostly requires intubation under general anesthetic and is defined as the creation of a cranial flap to access the hematoma cavity. The use of corticosteroids included dexamethasone and prednisone. We examined steroid usage as a nonsurgical conservative therapy and its use as adjuvant treatment. The definition of recurrence (primary outcome of success) was variable among the included articles. It was generally defined as reoccurrence of CSDH radiological and clinical findings warranting further treatment. Mortality, morbidity (secondary outcomes of safety), and improvement rates were reported at the time of discharge. The documented timing of recurrence rates was variable among included studies (up to 1, 3, or 6 months) based on reoccurrence of patients' symptomology that required management. Cure rates (tertiary outcome of efficacy) were assessed using multiple scales. The most commonly used was Markwalder classification system.[7] We adopted the improved neurological outcomes as reported by the authors of included papers.

Quality Assessment

Methodological quality assessment was done by 2 reviewers (S.A.A. and W.A.). We used the Cochrane collaborations tool[8] to assess the risk of selection, performance, detection, attrition, and reporting biases of randomized trials. The Newcastle-Ottawa Scale (NOS)[9] was used to measure comparability, selection of cohorts, and assessment of outcomes (for quality assessment results see the Supplemental Digital Content, available at: http://links.lww.com/SLA/A452).

Statistical Analyses

We performed separate analyses of randomized, comparative, and single cohort studies of prospective and retrospective designs. For each treatment option, we examined the outcomes of recurrence rate, mortality, morbidity, and cure rates. We reported the overall outcome estimates following CSDH management per 100 patients per year of the included studies separately for each of the previously discussed study designs. A comparison was made between percutaneous drainage, burr holes, craniotomy, and corticosteroids as main first-line treatment options. The adjuvant use of steroids to surgical management was evaluated. For burr holes, the roles of drainage, irrigation, and number of holes were analyzed. We did not perform similar analyses of percutaneous twist-drill drainage, because in all randomized and 80% of observational studies this procedure was described as the creation of a single skull puncture and insertion of a drain with no irrigation. The effect of bed rest following surgical management was examined. We compared percutaneous drainage, burr holes, and craniotomy as treatment options for recurrent cases. Randomized trials with similar comparisons were analyzed separately (Table 1). When appropriate, we pooled data from cohort studies reporting similar outcomes (Table 2). Moreover, we undertook separate meta-analyses of comparative cohort studies with similar arms of intervention (Fig. 1).

We undertook sensitivity analyses of high-quality observational studies, defined as prospective study designs with high scores using The Newcastle-Ottawa Scale assessment (>4 points). Heterogeneity among studies was investigated using the Q test and quantified by the I^2 statistic, which represents the percentage of total variation across studies with a predefined $I^2 > 50\%$ as the cutoff point of statistical heterogeneity. We used the DerSimonian and Laird random-effects model[10] to calculate weighted pooled proportions due to a priori that variable studies with different designs are prone to

TABLE 1. Meta-Analyses Results of Randomized Trials

	Outcome	No. Studies	Total No. Participants	Estimate % (95% CI) per 100 Person per Year of Included Studies	I^2 Heterogeneity (%)	RR (95% CI)	*P*
Overall treated chronic subdural hematoma patients	Mortality	11	974	4.0 (2.0–7.0)	77.1	—	—
	Morbidity	13	1,202	11.0 (5.0–19.0)	93.7	—	—
	Cure rate	9	702	82.0 (75.0–89.0)	83.1	—	—
	Recurrence	16	1,407	11.0 (9.0–14.0)	67.5	—	—
Percutaneous bedside drainage vs operative theater burr holes†	Mortality	3	216	5.0 (2.0–10.0) vs 3.0 (1.69–11.0)	0	1.13 (0.24–5.19)	0.88
	Morbidity	3	216	6.0 (4.7–17) vs 4.0 (8.5–16.0)	0	1.17 (0.46–2.95)	0.75
	Cure rate	3	216	84.0 (75.0–91.0) vs 83.0 (67.0–95.0)	54	1.01 (0.84–1.21)	0.94
	Recurrence	4	296	8.0 (4.0–12.0) vs 11.0 (3.0–23.0)	30	0.65 (0.22–1.91)	0.43
Drain use following hematoma evacuation vs no drainage‡	Mortality	4	524	5.6 (0.5–15.5) vs 5.8 (1.9–11.5)	14	0.96 (0.39–2.37)	0.94
	Morbidity	5	688	9.2 (1.6–22.2) vs 12.8 (2.3–29.4)	0	0.79 (0.52–1.19)	0.26
	Cure rate	3	302	75.7 (62.7–86.6) vs 68.0 (52.2–82.0)	49	1.11 (0.89–1.37)	0.36
	Recurrence	5	688	10.2 (5.7–15.8) vs 21.5 (15.6–28.0)	34	0.46 (0.27–0.76)*	0.002
Irrigation of the hematoma cavity vs no irrigation	Recurrence	2	119	12.7 (5.6–22.2) vs 15.0 (5.1–29.0)	59	0.75 (0.12–4.66)	0.75
Bed rest following surgical drainage vs activity as tolerated	Recurrence	2	130	8.7 (0.3–26.1) vs 18.4 (10.0–28.6)	70	0.42 (0.05–3.93)	0.45

Data obtained from less than 2 studies were not included in the table.
*Statistically significant result.
†Detailed results obtained from individual studies are presented in Figure 3.
‡Detailed results obtained from individual studies are presented in Figure 4.

inherent heterogeneity. Weights were calculated using the Mantel-Haenszel method. Publication bias was evaluated visually by funnel plots, and quantified by Egger regression[11] and Begg-Mazumdar tests.[12] We used GRADE profiler 3.6 to stratify the level of evidence of variable outcomes (see the Supplemental Digital Content, available at: http://links.lww.com/SLA/A452). We calculated relative risks (RRs) and 95% confidence intervals (CIs) and generated forest plots for all outcomes. An alpha error of <0.05 was considered a criterion for statistical significance. We used RevMan (version 5.1) and StatsDirect (version 2.7.9) for statistical analyses.

RESULTS

Our search of the literature yielded 3584 studies. By screening of the articles' title, abstract, or both and removing duplicates, 3178 studies were excluded. After reviewing full-text versions of the remaining publications, we excluded 156 articles (Fig. 2). Resources that met our eligibility criteria numbered 250, totaling 34,829 patients with 38,395 CSDHs, including bilateral presentations (for eligible studies description and their references see Supplemental Digital Content, available at: http://links.lww.com/SLA/A452). No related reviews were found upon searching the Cochrane library, and no additional studies were included from screening the references of potential resources and reviews. Sixteen of the eligible studies were randomized trials, and the remaining 234 were observational. We included the current authors' unpublished series of 834 managed CSDH patients with multiple cohorts (see the Supplemental Digital Content, available at: http://links.lww.com/SLA/A452). As expected, studies varied in terms of potential risk of bias with a substantial statistical heterogeneity detected in some outcomes. However, heterogeneity was investigated by conducting sensitivity analyses of higher quality observational studies and examining resources for potential risk of bias. Forty-nine of the included studies reported outcomes on percutaneous drainage, 203 on burr holes, 25 on craniotomy, 5 on corticosteroids as main management plan, 22 on steroids as adjuvant therapy, 128 on drain usage, 123 on irrigation, 96 on number of holes, 51 on bed rest following surgical management, and 52 studies examined the treatment of recurrent cases. Among the cohorts, 146 reported on mortality, 132 on morbidity, 138 on cure, and 208 on recurrence rates. All extracted data were available as actual numbers. The calculated overall estimates following management of CSDH patients per 100 individuals per year of included studies were 4% (95% CI, 2–7) mortality, 11% (95% CI, 5–19) morbidity, 82% (95% CI, 75–89) cure, and 11% (95% CI, 9–14) recurrence rates in 16 randomized trials (Table 1); and 3.5% (95% CI, 2.9–4.2) mortality, 7% (95% CI, 5.6–8.5) morbidity, 86.5% (95% CI, 84–89) cure, and 10.7% (95% CI, 9.5–12) recurrence rates in 234 observational studies (Table 2).

We undertook meta-analyses comparing percutaneous twist-drill bedside drainage and operating room burr holes craniostomy to evaluate morbidity, mortality, neurological improvement, and recurrence rate. Comparisons were done separately for randomized trials, pooled prospective, retrospective, and combined observational studies. The results pertinent to variable levels of evidence did not show significant differences between both treatment modalities for all outcomes (Tables 1 and 2). Analyses of 4 randomized trials (Fig. 3) resulted in no evidence of difference pertaining to the primary outcome of recurrence rate (RR, 0.65; 95% CI, 0.22–1.91; $I^2 = 30\%$; $P = 0.43$). Furthermore, we analyzed 10 higher quality observational studies, each including both arms of intervention (ie, percutaneous compared with burr holes drainage) resulting in no statistical difference in mortality (RR, 0.69; 95% CI, 0.46–1.05; $I^2 = 0\%$; $P = 0.09$), morbidity (RR, 0.45; 95% CI, 0.2–1.01; $I^2 = 63\%$; $P = 0.05$), cure (RR, 1.05; 95% CI, 0.98–1.11; $I^2 = 70\%$; $P = 0.15$), and recurrence rates (RR, 1; 95% CI, 0.66–1.52; $I^2 = 49\%$; $P = 0.99$). Nonstatistically significant trend was found favoring lower complication rates in patients managed with percutaneous twist-drill drainage when compared with burr hole craniostomy (Fig. 1).

No randomized trials were found reporting the role of craniotomy or the value of corticosteroids in management of CSDHs. Pooled results of 74 observational studies comparing craniotomy to percutaneous drainage showed higher morbidities (RR, 1.39; 95% CI, 1.04–1.74; $I^2 = 76.9\%$; $P = 0.01$) and lower recurrence rate (RR, 0.25; 95% CI, 0.2–0.3; $I^2 = 93.5\%$; $P = 0.009$) in patients managed with craniotomy. Similar results were obtained from sensitivity analyses of prospective studies showing higher morbidity (RR, 2; 95% CI,

TABLE 2. Pooled Meta-Analyses Results of Cohort Studies

Outcome		Prospective No. Cohorts	Prospective Total No. Participants	Prospective Estimate % (95% CI) per 100 Person-Years	Prospective RR (95% CI)	Retrospective No. Cohorts	Retrospective Total No. Participants	Retrospective Estimate % (95% CI) per 100 Person-Years	Retrospective RR (95% CI)	All Cohorts No. Cohorts	All Cohorts Total No. Participants	All Cohorts Estimate % (95% CI) per 100 Person-Years	All Cohorts RR (95% CI)
Overall treated CSDH	Mortality	27	1,622	3.5 (2.3–4.9)	—	118	20,991	3.5 (2.9–4.2)	—	145	22,613	3.5 (2.9–4.2)	—
patients	Morbidity	24	1,419	6.3 (4.0–9.0)	—	107	17,611	7.2 (5.6–9.0)	—	131	19,030	7.0 (5.6–8.5)	—
	Cure rate	24	1,143	90.2 (85.6–94.0)	—	113	18,126	85.7 (83.0–88.3)	—	137	19,269	86.5 (84.0–89.0)	—
	Recurrence	41	2,961	11.5 (8.7–14.7)	—	166	27,786	10.5 (9.3–12.0)	—	207	30,747	10.7 (9.5–12.0)	—
Percutaneous drainage	Mortality	9	437	4.4 (1.4–9.0)	1.11 (0.60–2.03)	20	2,123	3.4 (2.2–4.9)	1.0 (0.77–1.30)	29	2,560	3.6 (2.4–5.0)	1.03 (0.8–1.30)
	Morbidity	8	401	5.2 (1.5–10.8)	1.46 (0.95–2.24)	26	2,552	5.7 (2.5–10.0)	1.1 (0.95–1.24)	34	2,953	5.5 (2.9–9.0)	1.1 (0.96–1.23)
	Cure rate	7	367	87.6 (76.4–94.5)	0.96 (0.91–1.01)	25	2,508	91.3 (87.4–94.3)	1.03 (0.92–1.06)	32	2,875	90.2 (87.8–93.4)	1.02 (0.94–1.05)
	Recurrence	9	437	17.0 (10.0–25.0)	1.24 (0.96–1.60)	31	3,087	14.0 (11.3–17.0)	1.3 (0.92–1.65)	40	3,524	14.5 (12.0–17.0)	1.31 (0.95–1.58)
Burr hole craniostomy	Mortality	19	1,317	3.7 (2.2–5·6)	0.90 (0.49–1.66)	101	15,702	3.5 (2.8–4.2)	0.99 (0.76–1.28)	120	17,019	3.5 (2.9–4.2)	0.97 (0.76–1.22)
	Morbidity	15	860	5.8 (3.4–8.7)	0.68 (0.44–1.05)	84	14,527	7.4 (5.6–9.5)	0.91 (0.80–1.04)	99	15,387	7.2 (5.6–9.1)	0.92 (0.81–1.04)
	Cure rate	17	618	90.1 (85.5–95.1)	1.05 (0.99–1.11)	89	12,396	85.0 (82.2–87.5)	0.97 (0.85–1.10)	106	13,014	86.0 (83.4–88.2)	0.97 (0.87–1.08)
	Recurrence	33	2,658	12.0 (8.9–15.3)	0.80 (0.62–1.04)	139	21,091	10.3 (9.1–11.5)	0.76 (0.49–1.06)	172	23,749	10.5 (9.4–11.7)	0.76 (0.50–1.04)
Craniotomy	Mortality	3	132	4.0 (0.06–10.3)	0.98 (0.37–2.56)	12	2,769	7.6 (0.3–14.5)	0.80 (0.47–1.18)	15	2,901	6.8 (2.9–12.0)	0.81 (0.48–1.15)
	Morbidity	3	132	12.6 (2.6–31.4)	2.0 (1.20–3.30)*	7	522	9.1 (4.8–14.5)	1.42 (1.08–1.76)*	10	654	10.2 (6.0–15.7)	1.39 (1.04–1.74)*
	Cure rate	3	132	90.3 (69.0–100)	0.99 (0.90–1.08)	11	2,747	77.8 (53.4–93.8)	1.07 (0.87–1.28)	14	2,879	80.3 (62.3–93.5)	1.06 (0.96–1.17)
	Recurrence	3	132	3.2 (0.1–14.3)	0.22 (0.09–0.52)*	17	3,227	6.8 (2.6–12.8)	0.28 (0.17–0.38) *	20	3,359	6.2 (2.6–11.2)	0.25 (0.2–0.30)*
Corticosteroid use	Mortality	1	26	3.8 (0.1–18.9)	1 (0.17–5.32)	4	289	2.2 (0.1–7.0)	0.65 (0.27–1.55)	5	315	2.6 (0.3–6.8)	0.69 (0.31–1.52)
	Morbidity	1	26	3.8 (0.1–18.9)	0.48 (0.08–2.45)	2	113	10.5 (5.0–21.1)	1.07 (0.49–2.17)	3	139	9.1 (4.0–16)	0.88 (0.43–1.73)
	Cure rate	1	26	88.5 (71.0–96.0)	0.88 (0.43–1.73)	4	289	94.0 (88.0–98.0)	1.08 (0.93–1.23)	5	315	93.3 (87.4–97.0)	1.04 (0.95–1.11)
	Recurrence	1	26	3.8 (0.1–18.9)	0.23 (0.04–1.14)	3	214	16.7 (7.5–28.7)	1.22 (0.85–1.71)	4	240	13.1 (5.0–24.2)	1.07 (0.75–1.49)
Drain usage	Mortality	20	963	5.0 (2.7–7.8)	1.32 (0.63–2.80)	68	10,119	3.0 (2.2–3.9)	1.09 (0.78–1.52)	88	11,082	3.3 (2.5–4.1)	1.09 (0.81–1.49)
	Morbidity	14	535	7.9 (3.3–14.3)	0.93 (0.57–1.30)	62	9,866	6.4 (4.4–8.7)	0.85 (0.61–1.12)	76	10,401	6.6 (4.7–8.7)	0.87 (0.67–1.08)
	Cure rate	15	528	91.0 (83.6–96.3)	1.02 (0.95–1.11)	62	9,207	84.2 (79.0–88.9)	0.98 (0.93–1.03)	77	9,735	85.4 (80.8–89.5)	0.98 (0.94–1.02)
	Recurrence	25	1,590	13.6 (10.1–17.6)	1.27 (0.90–1.82)	102	14,145	11.2 (9.5–13.0)	1.14 (0.97–1.32)	127	15,735	11.6 (10.0–13.2)	1.15 (0.98–1.30)
Irrigation of hematoma	Mortality	13	802	3.5 (2.0–5.3)	0.54 (0.08–1.01)	68	11,847	3.0 (2.4–3.7)	0.67 (0.30–1.04)	81	12,649	3.1 (2.5–3.7)	0.66 (0.31–1.02)
	Morbidity	12	784	5.6 (3.1–8.7)	0.90 (0.19–5.19)	60	11,094	7.4 (5.1–10.0)	0.94 (0.67–1.33)	72	11,878	7.1 (5.1–9.4)	0.93 (0.67–1.31)
	Cure rate	11	502	91.5 (85.3–96.1)	0.98 (0.9–1.08)	61	9,419	85.5 (81.7–89.0)	0.97 (0.90–1.05)	72	9,921	86.6 (83.3–89.6)	0.97 (0.91–1.03)
	Recurrence	25	1,884	11.6 (8.3–15.4)	0.45 (0.24–1.08)	96	15,565	10.1 (8.6–11.8)	1.14 (0.93–1.40)	121	17,449	10.4 (9.0–12.0)	1.12 (0.92–1.37)
Single burr hole	Mortality	10	489	4.7 (2.0–8.7)	0.69 (0.24–1.51)	49	8,000	4.6 (3.2–6.3)	0.82 (0.49–1.06)	59	8,489	4.3 (3.0–5.8)	0.78 (0.51–1.05)
	Morbidity	8	381	6.2 (1.1–15.2)	1.07 (0.32–1.82)	49	8,852	10.5 (5.5–17.0)	1.06 (0.47–1.65)	57	9,233	9.8 (5.3–15.5)	1.06 (0.48–1.62)
	Cure rate	9	339	89.5 (78.6–96.8)	1.03 (0.82–1.24)	41	6,296	88.4 (84.7–91.2)	1.05 (0.93–1.18)	50	6,635	88.5 (85.1–91.5)	1.05 (0.94–1.16)
	Recurrence	16	1,343	13.0 (9.1–17.3)	0.83 (0.65–1.09)	78	11,684	10 (8.0–12.0)	1.21 (0.93–1.50)	94	13,027	10.4 (8.6–12.3)	1.15 (0.94–1.37)
Adjuvant use of steroid	Mortality	4	345	2.9 (0.3–10.0)	1.43 (0.33–2.54)	10	2,261	6.3 (4.6–8.3)	1.20 (0.83–1.72)	14	2,606	6.0 (4.4–7.9)	1.32 (0.93–1.88)
	Morbidity	6	366	6.8 (0.7–12.5)	1.74 (1.15–2.33)*	11	1,944	15.4 (13.0–17.9)	1.98 (1.52–2.45)*	17	2,310	12.4 (8.0–17.6)	1.97 (1.54–2.45)*
	Cure rate	5	160	95.7 (83.1–100)	1.01 (0.93–1.13)	10	1,448	83.3 (71.2–92.6)	0.96 (0.86–1.06)	15	1,608	90.0 (79.6–97.0)	0.97 (0.90–1.04)
	Recurrence	7	436	9.1 (3.6–16.8)	0.64 (0.23–1.71)	13	2,688	11.2 (8.9–13.7)	0.93 (0.72–1.14)	20	3,124	9.7 (6.9–13.0)	0.92 (0.71–1.13)
Bed rest	Mortality	9	458	8.7 (0.5–25.4)	1.13 (0.94–1.4)	24	4,381	6.0 (3.6–9.1)	1.25 (0.96–1.54)	33	4,839	6.5 (3.8–9.9)	1.24 (0.97–1.51)
	Morbidity	10	522	6.1 (2.2–12.0)	0.76 (0.32–1.88)	28	4,983	9.5 (4.5–16.2)	1.00 (0.79–1.26)	38	5,505	8.7 (4.6–14.0)	0.98 (0.78–1.23)
	Cure rate	10	577	96.8 (93.5–99.0)	1.18 (0.97–1.41)	24	3,911	83.8 (76.2–90.1)	0.97 (0.87–1.07)	34	4,488	88.3 (82.5–93.1)	0.97 (0.88–1.06)
	Recurrence	12	587	11.3 (4.8–20.2)	1.70 (1.23–2.18)	37	6,308	12.8 (9.0–14.9)	1.29 (0.92–1.67)	49	6,895	12.5 (10.1–15.1)	1.29 (0.90–1.67)
Percutaneous drainage	Second recurrence	5	37	22.1 (11.0–35.7)	1.54 (0.63–3.77)	4	45	7.4 (1.8–16.4)	0.43 (0.14–1.20)	9	82	13.0 (5.7–22.8)	0.88 (0.50–1.54)
Burr hole craniostomy	Second recurrence	7	50	15.4 (7.3–25.8)	0.64 (0.26–1.58)	25	466	15.3 (10.2–21.2)	2.79 (1.83–3.76)*	32	516	15.2 (10.7–20.2)	2.67 (1.84–3.5)*
Craniotomy	Second recurrence	3	15	22.1 (11.0–35.7)	0 (0–1.51)	8	58	6.4 (1.8–13.6)	0.51 (0.10–2.5)	11	73	11.6 (6.2–18.2)	0.22 (0.05–0.85)*

Pooled RR was calculated by comparing burr hole craniostomy, craniotomy, and corticosteroid to percutaneous twist-drill bedside drainage. Drain use was compared with no drainage, irrigation to no irrigation, single burr hole to 2 burr holes, adjuvant use of steroid to no corticosteroid usage, and bed rest to activity as tolerated following surgical intervention.

CSDH indicates chronic subdural hematoma.

*Statistically significant result.

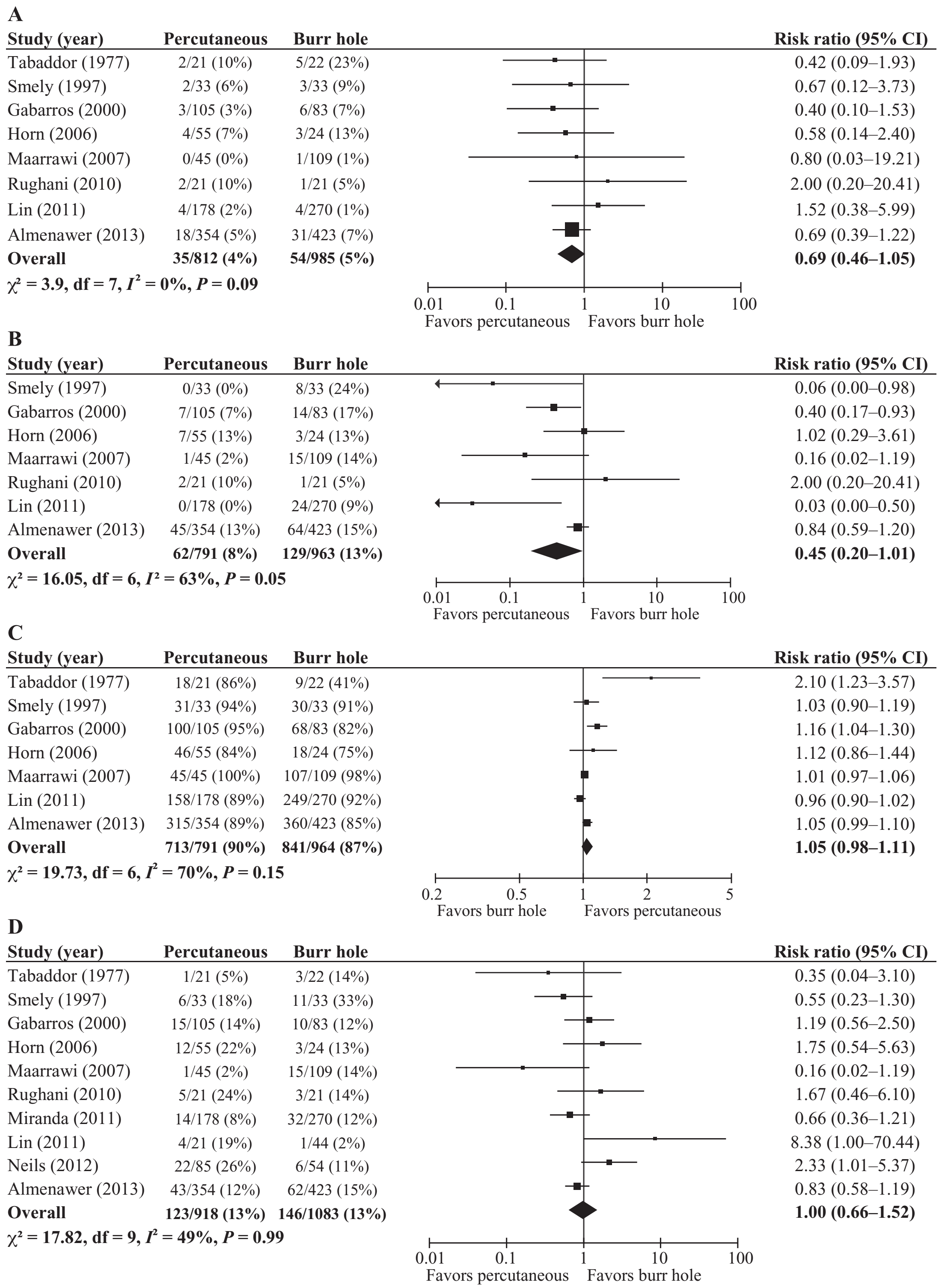

FIGURE 1. Meta-analyses of high-quality observational studies comparing percutaneous twist-drill bedside drainage versus operative theater burr hole craniostomy. Outcomes evaluated are mortality (A), morbidity (B), cure (C), and recurrence rates (D).

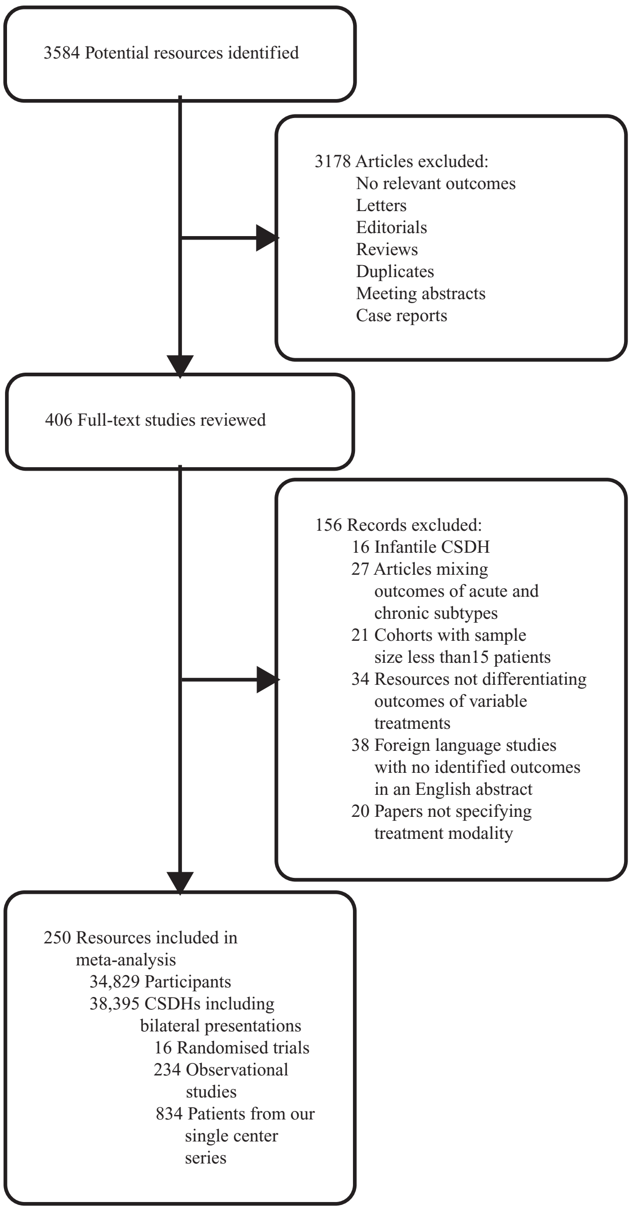

FIGURE 2. Flowchart of study selection process. CSDH indicates chronic subdural hematoma.

1.2–3.3; $I^2 = 84.5\%$; $P = 0.04$) and lower recurrence rates (RR, 0.22; 95% CI, 0.09–0.52; $I^2 = 81.6\%$; $P = 0.02$). Medical conservative therapy of CSDHs using steroids was reported only in 5 included cohorts and when compared with surgical management; this therapy did not result in reduction of mortality (RR, 0.69; 95% CI, 0.31–1.52; $I^2 = 61.4\%$; $P = 0.27$) or morbidity (RR, 0.88; 95% CI, 0.43–1.73; $I^2 = 83.2\%$; $P = 0.56$) with improvement in neither cure (RR, 1.04; 95% CI, 0.95–1.11; $I^2 = 55.4\%$; $P = 0.21$) nor recurrence rates (RR, 1.07; 95% CI, 0.75–1.49; $I^2 = 71.2\%$; $P = 0.39$). These findings should be interpreted cautiously, as data were scarce and abstracted from a small number of observational studies. Seventeen studies were analyzed to evaluate the role of steroids as adjuvant therapy. Mortality, cure, and recurrence rates were not statistically different; however, higher morbidities were associated with the use of corticosteroids combined to surgical management of CSDHs (RR, 1.97; 95% CI, 1.54–2.45; $I^2 = 75.4\%$; $P = 0.005$).

Meta-analysis of 2 randomized trials comparing bed-rested patients to individuals assuming upright positions as tolerated following surgical management showed no statistical benefit for recurrence rate (RR, 0.42; 95% CI, 0.05–3.93; $I^2 = 70\%$; $P = 0.45$). We examined the effect of irrigating the hematoma cavity, and no clear statistical evidence suggested an improvement in the outcomes of mortality, morbidity, cure, and recurrence rates. Meta-analysis of 5 randomised trials (Fig. 4) resulted in significant reduction in recurrence rates when drains were inserted following hematomas evacuation (RR, 0.46; 95% CI, 0.27–0.76; $I^2 = 34\%$; $P = 0.002$). These results were not duplicated through pooling of the data from 127 observational studies (RR, 1.15; 95% CI, 0.98–1.3; $I^2 = 92.3\%$; $P = 0.17$). However, this may be explained by the high level of heterogeneity and the evidence of publication bias detected by the asymmetry of the funnel plot (Egger test, $P = 0.001$; Begg-Mazumdar test, $P = 0.006$). Moreover, we pooled the data of 94 cohorts, resulting in no difference in recurrence rates related to the number of burr holes (RR, 1.15; 95% CI, 0.94–1.37; $I^2 = 88.2\%$; $P = 0.62$). A total of 52 studies were pooled to examine the efficacy of percutaneous drainage, burr holes, and craniotomy in the management of recurrent cases. Craniotomy was associated with lower secondary recurrence rates (RR, 0.22; 95% CI, 0.05–0.85; $I^2 = 0\%$; $P = 0.003$) compared with higher rates when using burr hole craniostomy (RR, 2.67; 95% CI, 1.84–3.5; $I^2 = 47\%$; $P = 0.007$).

DISCUSSION

Results of the current meta-analyses yielded several findings. The main finding is the statistical evidence of similar efficacy and safety obtained from bedside drainage of CSDH compared with the most commonly practiced procedure (ie, operating room burr hole evacuation). Findings from this comprehensive systematic review and meta-analyses were based on a total of more than 34,000 participants from 250 resources comparing multiple CSDH treatment modalities at variable levels of evidence. Analyses were performed separately of randomized, higher quality and prospective, retrospective, and combined observational studies to generate several results. In addition, multiple outcomes were investigated to evaluate the safety and efficacy of the overall treated CSDH patients and detailed individual management options. The presence of 4 recently published questionnaires (French,[13] Canadian,[14] British,[15] and Dutch[16]) concerning CSDH therapy is reflective of the existing variability in current management, despite the vast amount of literature addressing this common condition. Critical appraisal of the literature and evaluation of current treatment strategies based on valid research methodologies is essential to improve the quality of care offered to this group of patients.

The differences between percutaneous twist-drill bedside drainage and operating room burr hole craniostomy for CSDH management are not limited to surgical techniques alone. The associated potential cost savings related to operative theater resources and the involvement of multiple health professionals differentiate these 2 procedures. Given that CSDHs are more frequent among the elderly, these treatments diverge regarding the perioperative risks related to general anesthesia, as burr holes are frequently performed under general sedation,[17] whereas a local anaesthetic is usually sufficient with percutaneous drainage. Moreover, the amount of tissue cut and the size of skull hole favor percutaneous drainage as a more minimally invasive procedure. For these reasons alone, the idea of considering the latter option as a first-line surgical management plan would be logical even if both interventions were otherwise equally safe and effective. A systematic review published in 2003[18] pooling the data from 48 references followed by a decision analysis study[19] resulted in higher recurrence rates associated with the use of percutaneous

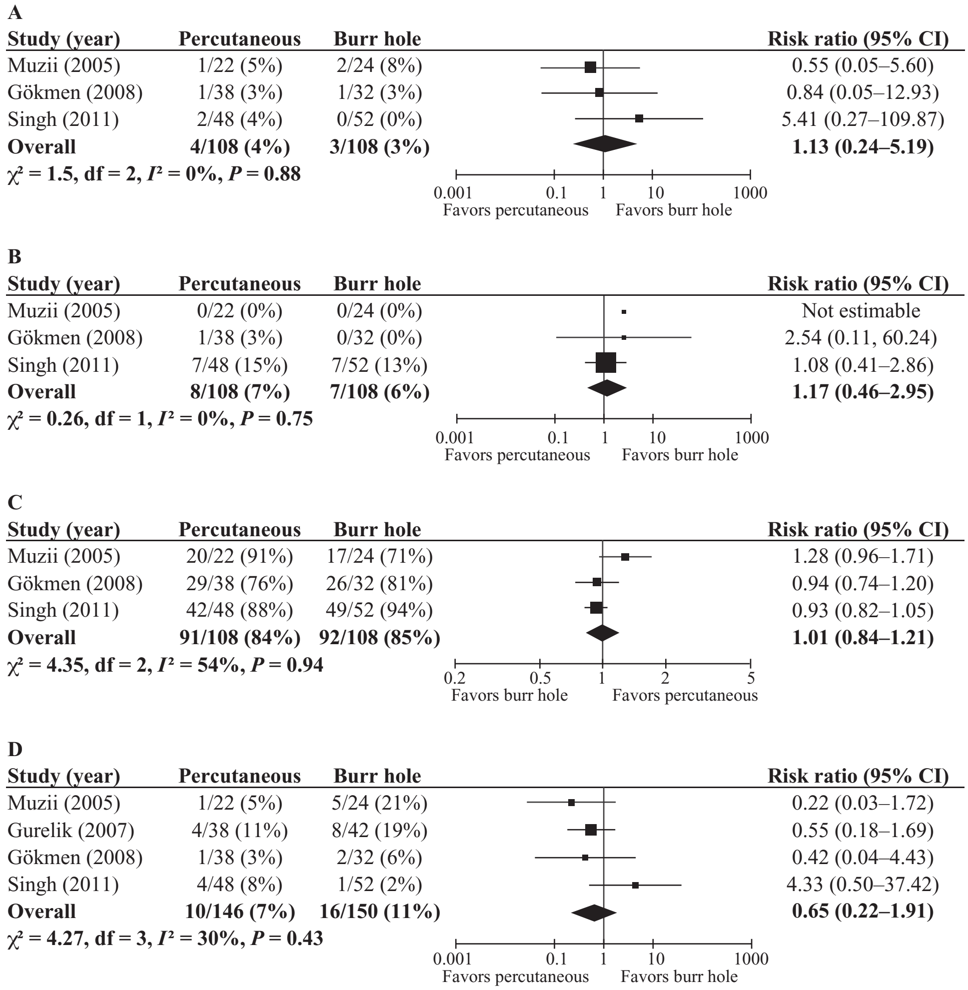

FIGURE 3. Meta-analyses of randomized trials comparing percutaneous twist-drill bedside drainage versus operative theater burr hole craniostomy. Outcomes evaluated are mortality (A), morbidity (B), cure (C), and recurrence rates (D).

drainage. In addition, several surveys[14–16] found burr hole craniostomy to be the most commonly used method for CSDH management, as it was the initially described procedure in 1935 that incurred a major paradigm shift in treatment from craniotomy,[20] whereas percutaneous drainage was only introduced 30 years later.[21] In this meta-analysis, a comparison was made between both interventions, stratifying the evidence separately for randomized, pooled prospective, retrospective, all cohorts, and observational studies with both arms of treatment resulting in no evidence of difference in the outcomes of mortality, morbidity, cure, and recurrence rates. These results are consistent with some previously published smaller scaled studies. Whereas, findings of our meta-analysis are based on a larger group of patients compiled from higher, updated, and comprehensive resources in accordance with recently improved methodological principles.[3–6] A proposed advantage of relatively major operative techniques over percutaneous bedside drainage is the ability to perform membranectomy of CSDH patients presenting with image characteristics demonstrating multiple membranes or multiloculated hematoma.[22] This theoretical advantage is not supported by strong evidence as the majority of included studies that examined twist-drill craniostomy have managed patients with such presentation.[23] To some extent, this difficulty applies to burr holes as well.[24] Moreover, the primary mechanism of the residual incompletely drained hematoma healing occurs after membranes maturations which prevent rebleeding from the immature fragile membranes.[25] This spontaneous resolution can be achieved through bedside drainage after relieving the pressure by draining the bulk of the hematoma.[26]

The use of corticosteroids in CSDH management has been posited as both an anti-inflammatory and an antiangiogenic agent.[27] It was described as a main treatment option for relatively milder cases lacking major structural compressive features, which would warrant surgical evacuation.[28] Pooled analyses from 5 nonrandomized studies did not result in outcomes differences when compared with surgical management. These results and the scarce data in the literature may be explained by the effective, safe, and rapid relieve obtained from minimally invasive surgical procedures.[29] Corticosteroids were proposed to improve outcomes as a form of adjuvant therapy to surgical drainage.[30] Meta-analyses of 17 pooled cohorts resulted in no evidence supporting favorable outcomes when using steroids in addition to surgeries; however, there were higher rates of morbidity. Although these results can be explained by the sicker presentation among patients treated with steroids, our findings are in keeping with the current CSDH management practices,[14–16] the known side effects of corticosteroids, and the reported efficacy of surgical intervention alone.

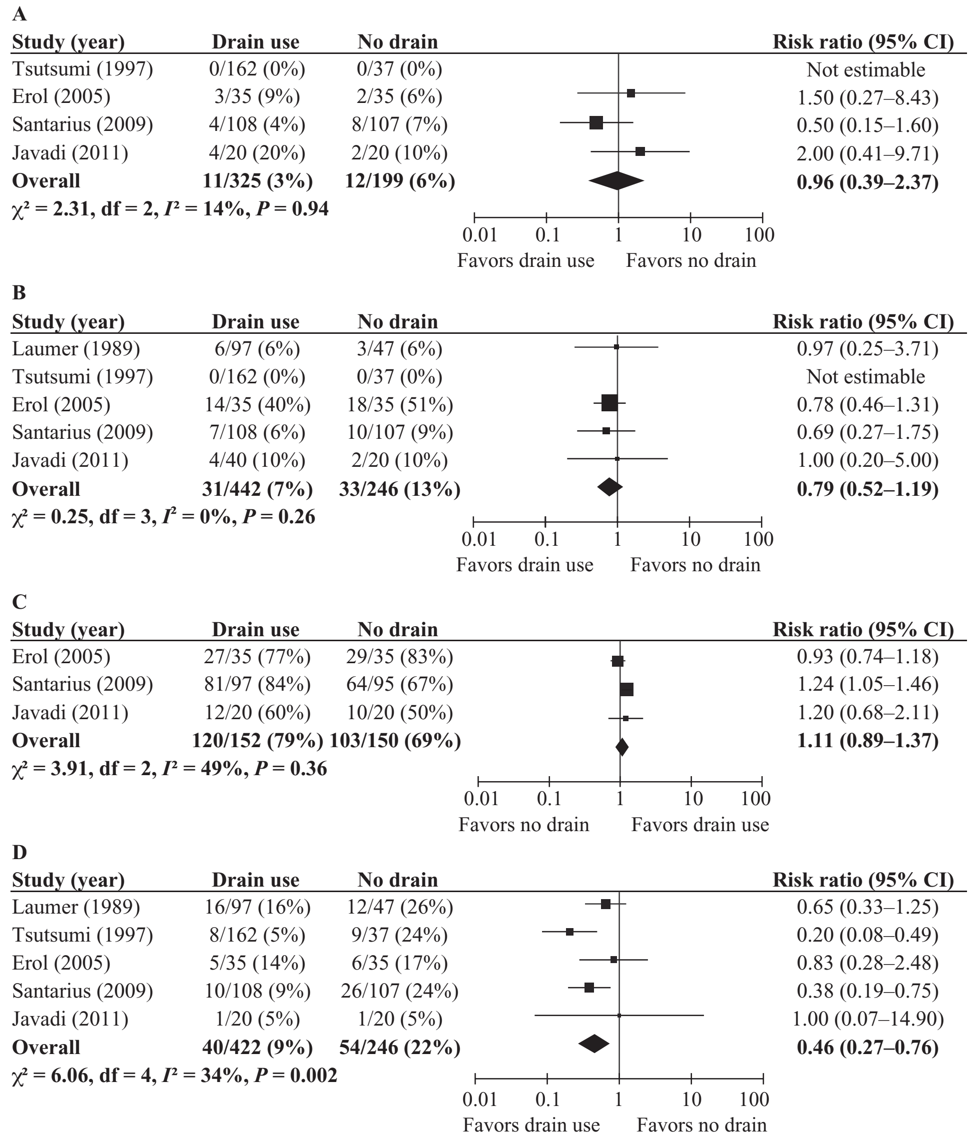

FIGURE 4. Meta-analyses of randomized trials examining the role of drain insertion following burr hole drainage. Outcomes evaluated are mortality (A), morbidity (B), cure (C), and recurrence rates (D).

In 1883, Hulke[31] reported the first successful craniotomy for inflammatory fluid (CSDH) management.[20] Since then, this procedure remained the treatment of choice until less invasive procedures were introduced. The review conducted by Markwalder in 1981 summarizes the current use of craniotomy, in that it should be reserved for those instances in which the subdural collection reaccumulates, the brain fails to expand, or there is solid hematoma[32]; hence, the low numbers of neurosurgeons preferring this operation in the previously discussed questionnaires.[14–16] The current meta-analysis statistically confirms its efficacy; however, craniotomy was associated with higher rates of morbidity as it is a more invasive procedure with accompanying perioperative risks for a mostly elderly population. Pooling of the results from cohort studies demonstrates the superiority of craniotomy when it is used for patients with CSDH recurrences.

Santarius and colleagues[33] stopped a well-conducted randomized controlled trial because of a significant benefit in reducing recurrence rates following the use of drains after burr hole evacuation of CSDH. Our meta-analysis of 5 randomized trials resulted in a similar significance with no higher complication rates associated with drains use. Bed rest following surgical drainage has been proposed to facilitate brain expansion and accordingly decrease the risk of recurrence.[34] This would arguably result in higher risk of postoperative complications, such as pneumonia and thromboembolism among the elderly group. A randomized trial conducted by Nakajima and co-workers[35] showed no benefit favoring patients' posture following CSDH drainage. Our analyses resulted in similar outcomes when comparing bed-rested patients to individuals assuming an upright position after surgical evacuation. Several adjuvant techniques have been suggested to increase the efficacy of surgical drainage. The number of burr holes (1 vs 2) and irrigating the subdural space to facilitate rinsing the hematoma are arguably beneficial in decreasing the risk of recurrences.[36] Neither factor was found statistically beneficial in altering mortality, morbidity, cure, or recurrence rates in this meta-analysis.

The current meta-analysis is a critical assessment and comprehensive examination of more than 40 years of the literature. As an expected limitation of including resources with variable qualities, definitions, follow-ups, and diagnostic criteria, inevitable heterogeneity was detected in some outcomes. Therefore, we undertook sensitivity analyses, investigated studies for potential risk of bias, examined each of the several outcomes multiple times, and reported all findings separately based on the underlying level of evidence in accordance with recent methodological guidelines.[3–6] Several comparative outcomes were examined in this study to evaluate the efficacy and safety of percutaneous twist-drill drainage, burr hole craniostomy, craniotomy, corticosteroids as main therapy, number of holes, use of drains, irrigation of the hematoma cavity, bed rest following surgical management, adjuvant use of steroids, and treatment of recurrences. Another limitation of this study is the relatively small number of patients involved in some of the analyses and that raw data were used in other studies. Unfortunately, owing to insufficient data provided by studies, detailed differences among management options including variable minor techniques, durations, different instruments, and advances in imaging techniques were not evaluated in this study.

CONCLUSIONS

Our findings suggest that percutaneous twist-drill bedside drainage is a relatively safe and effective yet less-invasive method for CSDH management. When it is considered as a first-line treatment option, we believe that this may result in potential cost savings without compromising patient care. Although our meta-analysis is not a cost-effective study, cost benefits may be concluded when considering the associated operating room expenses and multiple involvements of health professionals. Indeed, this option may eliminate the associated risks related to general anesthesia. Evidence from this study also supports the use of drains following hematoma evacuation as they were found to decrease the risk of recurrence. Moreover, craniotomy is a relatively major procedure that should be reserved for recurrent scenarios. Finally, the available studies describing corticosteroids use as adjuvant therapy to surgical management demonstrated significantly higher morbidities with no added benefits. Stronger evidence is needed to further investigate the role of steroids as a sole treatment for milder presentations.

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