Introduction

Traumatic brain injury (TBI) is one of the major causes of mortality and permanent disability around the world. TBI is a spectrum of conditions ranging from a cerebral contusion to large intracranial hematoma [1]. Acute subdural hematoma (ASDH) is one of the major problems in TBI [2]. It is diagnosed with head CT scan as an extra-axial, crescentic hyperdense lesion between dura mater and brain parenchyma [2]. ASDH is a space-occupying lesion that increases intracranial pressure and usually accompanies with diffuse injuries, cerebral contusion, and edemas. Because of this, the mortality of ASDH remains high [2].

Management of ASDH is including operative and non-operative treatment. Non-operative management correlates with significantly higher mortality if compared to surgical management [3]. Surgical techniques for treating ASDH are varied. They include craniotomy and followed by cranioplasty, decompressive craniectomy, trephination/craniotomy, or combination of these procedures. Principally, the aim of the surgery is to relieve the brain from intracranial hypertension because of space-occupying lesion by the hematoma [4], [5]. Large craniotomy with hematoma evacuation could be a perfect choice to treat ASDH. However, when intraoperative brain swelling develops, decompressive craniectomy may be a better choice. However, based on a recent study in animals, bony decompression of the brain results in a reduction of intracranial pressure but enhances cold injury brain edema [4].

Based on what has been described, the superiority of craniectomy and craniotomy for treating ASDH is still controversial. This study aimed to compare the clinical outcome between craniectomy and craniotomy for treating traumatic ASDH through systematic review and meta-analysis.
Methods

**Eligibility criteria**

Eligibility criteria were created based on the PICO framework. PICO criteria are shown in Table 1.

Table 1: PICO criteria of the study

| Patient            | Traumatic ASDH |
|--------------------|----------------|
| Intervention       | Decompressive craniectomy |
| Comparator         | Craniotomy |
| Outcome            | Glasgow Outcome Scale |

This review included all studies comparing decompressive craniectomy and craniotomy in traumatic ASDH patients. We exclude review, animal, anatomic, cadaveric, qualitative, and economic studies. Articles made by the same author in the same institution were performed sample evaluation to prevent sample duplication. We included studies published in Indonesian and English. Other languages were translated using Google translate and decided by author whether to include or not. There was no restriction regarding the year of publication.

This review included studies with adult participants (age 18 years or older) of both genders who have suffered traumatic SDH. ASDH was defined as a hematoma in potential space between dura mater and arachnoid that was confirmed by a crescentic hyperdense lesion in head CT scan following trauma. Participants of all nationalities and setting were included. Participants with other head injury or focal lesions were excluded from this review.

The reviewed surgical interventions were decompressive craniectomy and craniotomy. Decompressive craniectomy was defined as a procedure removing a portion of skull temporary after clot evacuation. A craniotomy was defined as a procedure to evacuate clot and followed by cranioplasty. We excluded studies that did not describe the surgical procedure and combine the technique of interest with other technique.

The investigated outcome in this review was the Glasgow Outcome Scale (GOS) after the surgical procedure. GOS was dichotomized into favorable and poor outcomes. They were calculated for risk ratio (RR) and were analyzed.

**Data collection process**

An electronic data collection form was used to collect data from each author. The collected data by each author will be merged and be managed with software Review Manager 5.3.

**Data items**

The data items were the author's name, year of publication, method, sample size, diagnosis of the participant, age, surgical technique, and GOS. GOS was dichotomized into favorable and poor outcomes. They were calculated for risk ratio (RR) and were analyzed.

**Assessment of quality of a study**

Studies that complied with inclusion and exclusion criteria were assessed for their quality to ensure the validity and reliability of the studies. This process was done independently by two authors using a standardize critical appraisal tool to minimize the possibility of bias in study selection. The critical appraisal tool in this study was the Joanna Briggs Institute (JBI) critical appraisal tool based on study design. A decision of the third and fourth authors was used when a disagreement occurred.

The cutoff point was used to determine the quality of the study. The cutoff point in this review was half of the total score in each JBI critical appraisal checklist. The low-quality study was defined as a score below the cutoff point while conversely was termed as a high-quality study.

**Synthesis of result**

The RR of outcome was pooled and analyzed. Meta-analyses were performed using software Review Manager 5.3. The random-effect model was used because of high heterogeneity among studies.

**Results**

The systematic searching method resulted in six articles that met our inclusion and exclusion criteria...
All six articles were observational cohort studies. We did not find any randomized clinical trial study comparing craniotomy and craniectomy. All six articles were considered as good quality based on our judgment. The summary of finding and complete characteristic of the study is shown in Tables 2 and 3.

From random-effect model analysis with high heterogeneity ($I^2 = 77\%; X^2 = 21.98$), pooled RR between craniectomy and craniotomy on poor outcome was $1.41$ ($p = 0.02; 95\% CI: 1.06–1$) (Figure 2).

**Table 2: Summary of findings of the study sources**

| Study author       | Type of study, prospective cohort | Level of evidence | Subject condition                                                                 | Intervention | n  | Control n | Outcome                      |
|--------------------|----------------------------------|-------------------|-----------------------------------------------------------------------------------|--------------|----|-----------|-------------------------------|
| Tsermoulas et al., 2016 | Observational study, prospective cohort | 1b                | Patients above 16 years old with traumatic acute subdural hematoma                 | CR           | 69 | CO 30     | CR: 41 poor outcome, CO: 11 poor outcome |
| Chen et al., 2011   | Observational study, retrospective cohort |  | Patients with GCS score 4–8 and subdural hematoma with thickness >10 mm or a midline shift >5 mm on CT scan | CR           | 60 | CO 42     | CR: 27 poor outcome, CO: 16 poor outcome |
| Vilcinis et al., 2017 | Observational study, prospective cohort | 1b                | All adult patients diagnosed with acute subdural hematoma causing brain compression on pre-operative CT scan | CR           | 249| CO 384    | CR: 212 poor outcome, CO: 176 poor outcome |
| Woertgen et al., 2006 | Observational study, retrospective cohort |  | Patients with traumatic acute subdural hematoma range 15–91 years old              | CR           | 69 | CO 111    | CR: 41 poor outcome, CO: 59 poor outcome |
| Li et al., 2012     | Observational study, retrospective cohort |  | All traumatic acute subdural hematoma patients who underwent craniotomy or craniectomy | CR           | 50 | CO 38     | CR: 29 poor outcome, CO: 21 poor outcome |
| Wong et al., 2010   | Observational study, retrospective cohort |  | All traumatic acute subdural hematoma patients who underwent craniotomy or craniectomy | CR           | 19 | CO 22     | CR: 12 poor outcome, CO: 7 poor outcome |

**Discussion**

Traumatic ASDH is a major neurotrauma problem in the world. It causes primary brain damage because of direct compression to the brain and secondary damage mainly because of brain edema and ischemia due to compression. ASDH has been known for its high mortality rate. Several studies reported that initial GCS score, age, midline shift, and hematoma size are important clinical predictors of mortality [6], [7], [8], [9], [10].

The main objective of the surgical treatment is to relieve intracranial pressure by evacuating the hematoma with craniotomy followed by cranioplasty procedure. However, brain swelling can be uncontrolled during surgery, and cranioplasty cannot be done. Decompressive craniectomy seems to provide a better solution in that case because, in this procedure, the defect on the skull is kept open to provide “additional room” for the uncontrolled brain swelling, so the intracranial pressure remains normal. However, there is still debate which procedure provides a better outcome for traumatic ASDHs. At present, the surgical technique is based on the surgeon’s preference.

From the pooled RR, we found that craniectomy provided worse outcomes compared to craniotomy as surgical treatment of traumatic ASDH. The pooled RR was $1.41$ ($p = 0.02$), with high heterogeneity among studies. The result of this study is similar to other systematic reviews conducted by Phan et al. In their study, they found that craniectomy was associated with worse post-operative outcomes compared to craniotomy [11]. Based on our analysis of included studies, there are several factors that may contribute to the more unsatisfactory outcome of craniectomy for treating traumatic ASDH.

In a study by Tsermoulas et al., patients who were performed decompressive craniectomy tend to
Comparison of craniotomy and decompressive craniectomy in severely head injured patients with acute subdural hematoma. (Chen et al., 2011)

Methods Retrospective cohort
Participants Inclusion criteria: Patient with GCS score of 4–8
Subdural hematoma with thickness > 10 mm or midline shift >5 mm
Exclusion criteria: Patient older than 70 years
Had preexisting illness that limited life expectancy of less than 1 year after ictus
Renal failure
Liver cirrhosis
Bleeding tendency
Penetrating injury
Hemodynamic instability
Injury >24 h before admission
Bilateral pupillary dilatation
Previous neurologic condition
Underwent surgery for contralateral lesion
Patient with intracerebral hematoma larger than 2 cm in diameter
Intervention Intervention group: Decompressive craniectomy: 60 patients
Comparison group: Frontotemporoparietal craniotomy: 42 patients
Outcomes Primary outcomes are GOS at minimum 1 year after surgery.

The Association of Surgical Method with Outcomes of Acute Subdural Hematoma Patients: Experience with 643 Consecutive Patients. (Vilcinis et al., 2017)

Methods Prospective cohort
Participants Inclusion criteria: Adult patients diagnosed with acute subdural hematoma causing brain compression on pre-operative CT scan
Require emergent surgical evacuation of acute subdural hematoma
Exclusion criteria: Underwent secondary decompressive craniectomy after evacuation of acute subdural hematoma
Intervention Intervention group: Lateral or bifrontal decompressive craniectomy: 249 patients
Comparison group: Osteoplastic craniotomy: 394 patients
Outcomes Primary outcomes are GOS

Surgery for acute subdural hematoma: Replace or remove the bone flap? (Tsromoulas et al., 2016)

Assessing the neurological outcome of traumatic acute subdural hematoma patients with and without primary decompressive craniotomies. (Wong et al., 2010)

Methods Retrospective cohort
Participants Inclusion criteria: All patients with traumatic acute subdural hematoma who underwent craniotomy or craniectomy
Exclusion criteria:
Intervention Intervention group: Decompressive craniectomy: 19 patients
Comparison group: Craniotomy: 22 patients
Outcomes Primary outcomes are GOS at 6 months after injury

Table 3: Characteristics of the studies

| Study                                                                 | Methods          | Participants                                                                                                               | Outcomes                                                                                     |
|---------------------------------------------------------------------|------------------|---------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Chen et al., 2011                                                    | Retrospective    | Inclusion criteria: Patient with GCS score of 4–8, subdural hematoma with thickness > 10 mm or midline shift >5 mm, etc. | Primary outcomes are GOS at minimum 1 year after surgery.                                      |
| Vilcinis et al., 2017                                                | Prospective      | Adult patients diagnosed with acute subdural hematoma causing brain compression on pre-operative CT scan                   | Primary outcomes are GOS                                                                     |
| Tsromoulas et al., 2016                                              | Retrospective    | Inclusion criteria: All patients with traumatic acute subdural hematoma who underwent craniotomy or craniectomy          | Primary outcomes are GOS at 6 months after injury                                             |

Table 3: (Continued)

Comparison of craniotomy and craniectomy in patients with acute subdural hematoma. (Li et al., 2012)

Methods Retrospective cohort
Participants Inclusion criteria: All patients with traumatic acute subdural hematoma who underwent craniotomy or craniectomy
Exclusion criteria: Non traumatic cases of acute subdural hematoma
Mini craniotomies
Intervention Intervention group: Decompressive craniectomy: 50 patients
Comparison group: Craniotomy: 38 patients
Outcomes Primary outcomes are GOS at 6 months

Our meta-analysis result showed that craniectomy has a poorer outcome. However, this result should be interpreted cautiously because of high heterogeneity between studies, no randomized clinical trial study was included, and the possibility of baseline characteristic bias.

Based on our analysis, we suggested not to perform decompressive craniectomy as the primary first-line choice to treat ASDH. However, if brain edema is developing intraoperatively, the surgeon should perform a decompressive craniectomy immediately to prevent reoperation. Pre-operative midline shift, initial GCS, and presence of intraventricular hemorrhage can be predictors of post-craniectomy edema. The first surgical planning for treating ASDH should be...
done with craniotomy technique; however, the surgeon should make preparation to perform decompressive craniectomy when severe brain edema occurred.

**Conclusion**

Craniectomy increases the risk of poor clinical outcomes in treating traumatic ASDHs. However, the interpretation should be done cautiously because of high heterogeneity between studies, no randomized clinical trial study was included, and the possibility of baseline characteristic bias. We suggest that the first surgical planning for treating ASDH should be done with craniotomy technique; however, surgeons should make preparation to perform decompressive craniectomy when severe brain edema occurred.

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