Effectiveness of pelvic packing in hemodynamically unstable patients with pelvic fracture: a meta-analysis

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Abstract

Background

Pelvic packing (PP) has been increasingly used for bleeding control in severe pelvic trauma. However, its effectiveness remains controversial. This meta-analysis was performed systematically to determine the efficiency of PP in pelvic fracture patients with hemodynamic instability.

Methods

Three databases, PubMed, Embase and Cochrane Library were systematically searched to identify studies presenting comparisons between protocol including PP and protocol without PP. Mortality, transfusion requirement and length of hospitalization were extracted and pooled for meta-analysis. Relative risk (RR) or standard mean difference (SMD) with their confidence interval (CI) was used for the pooled statistical indexes included mortality, transfusion requirement and length of hospitalization.

Results

Ten studies involving 560 patients were identified eligible for meta-analysis. A significantly reduced overall mortality (RR = 0.63, 95% CI = 0.50 to 0.79, $p < 0.01$) as well as reduced mortality within 24 h after admission (RR = 0.42, 95% CI = 0.27 to 0.63, $p < 0.01$) and due to hemorrhage (RR = 0.27, 95% CI = 0.15 to 0.49, $p < 0.01$) was shown by PP. The usage of PP also decreased the need for pre-operative transfusion (SMD = -0.44, 95% CI= -0.69 to -0.18, p = 0.001) but had no influence on transfusion during the first 24 h after admission (SMD = 0.04, 95% CI = -0.24 to 0.31, p = 0.215) and length of hospitalization (ICU and total stays).

Conclusions

This meta-analysis indicates that a treatment protocol including PP significantly reduce mortality and transfusion requirement before intervention in pelvic fracture patients with hemodynamic instability. An algorithm in which pelvic packing is performed as first-line treatment was recommended and complemented with angiography and embolization for patients with traumatic pelvic hemorrhage.

Introduction

Pelvic fractures are often caused by high energy trauma with high mortality which is always attributable to bleeding [1, 2]. Hemorrhage is the most common cause of death within the first 24 h after injury [3] and the reported mortality rate of patients with hemodynamic instability due to severe pelvic fracture is as high as 40% [4]. Therefore, early recognition and control of the hemorrhage is vital. Multidisciplinary approaches have been used in managing bleeding including operative managements such as external fixation and pelvic packing (PP), endovascular interventions like angioembolization and resuscitative endovascular balloon occlusion of the aorta (REBOA). Among them, angioembolization and PP are most widely used and of greatest concern.

Angiography and embolization, first discussed in 1972, were reported to have a success rate ranging from 80–100% for arterial hemorrhage [4, 5] but had little effectiveness in controlling venous bleeding [6]. However, arterial bleeding only accounts for 10–15% of cases and in more than 80% of patients, the hemorrhage originates from injured veins or fractured pelvic fragments [7, 8]. Furthermore, the preparation for angiography suite and specialized interventional radiologist is time-consuming and delays have been associated with an increase in mortality [9].

Pelvic packing was originally described in Germany in 1994 by directly addressing the hemorrhage from retroperitoneal space [10, 11]. It is a quick and effective procedure which is most commonly used for venous bleeding. PP can be performed within 20 minutes in emergency room by experienced surgeons [12].

Institutions from different countries have applied PP as part of the treatment algorithm for hemodynamically unstable patients in the 20th century, the results have showed that PP was as effective as AE and patients may benefit from the change of protocol for it showed a reduction of mortality and blood transfusion [6, 11–18]. We performed a quasi-randomized control study in 2014 and our results showed that, compared with angioembolization, pelvic packing had shorter time to intervention and surgical time [3]. However, most studies were just descriptive researches with small to medium cohorts and results varied from different studies so the efficiency of PP remains controversial. Although two meta-analyses regarding PP were found from our search of current literature, one study only included 3 literatures comparing PP with angioembolization [19] and the other was a network meta-analysis with a different aim [20]. We believe a quantitative analysis including large scale of patients would provide more convincing evidences for clinical instruction. The aim of this meta-analysis is to examine the efficacy of early PP in patients with hemodynamic instability due to pelvic fracture. This study hypothesizes that the introduction of PP in the management protocol has a benefit for clinical outcomes that it lowers mortality and transfusion requirement.

Methods

This meta-analysis was performed in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement/Guideline [21].

Design and search strategy

The search process was performed by two investigators, blindly and independently using three databases, PubMed, Embase and Cochrane Library on March 10, 2020 with no language limitations. The complete search terms were: “pelvic packing [All Fields]” AND “pelvic injury [All Fields]” OR “pelvic trauma [All Fields]” OR “pelvic fracture [All Fields]”. Additional eligible studies which were neglected by electronic database searching were retrieved by screening reference lists. Overall mortality was determined as primary outcome. Transfusion requirement and length of hospitalization were secondary outcomes.

Inclusion and exclusion criteria

Included studies had to fulfill all following criteria: a) enrolled patients with pelvic fracture and hemodynamic instability; b) studies comparing clinical outcomes between patients treated with PP and patients without PP or studies presenting a comparison of results between treatment protocol including PP and protocol without PP; and c) articles written in English.

Exclusion criteria were: a) non-original studies including reviews, meta-analyses, case reports, comments, editorials, letters, correspondences and conference addresses; b) enrolled patients < 14 years old; and c) studies with insufficient data.

Data extraction

The following data were extracted from included studies: first author's surname, publication year, country of origin, basic characteristics of the participants (numbers, age and gender), study design, injury severity score (ISS), primary and secondary outcomes. All data were independently extracted from eligible publications by two of the authors and any discrepancies were consulted with an experienced orthopedic surgeon until a consensus was achieved.

Quality assessment

Quality assessment was performed using Newcastle-Ottawa scale (NOS) [22]. The assessment was performed by two authors and disagreements were resolved through discussion between the two assessing authors. We considered a study with a score > 7 to be at low-risk of bias [22].

Statistical analysis

Statistical analysis and production of forest plots were performed by Stata 12.0 (StataCorp, College Station, TX, USA). Heterogeneity was assessed using Chi^2 test and I^2 test. If $p > 0.1$ and $I^2 < 50\%$, the heterogeneity was considered insignificant and a fixed effects model was used. Otherwise a random effects model was used. Relative risk (RR) with 95% confidence interval (CI) was pooled for dichotomous variables and standardized mean difference (SMD) with 95% CI was pooled for continuous variables. To evaluate the stability of results, subgroup analysis according to different factors, publication bias (performed using funnel plot) and sensitivity analysis (conducted by omitting studies one by one) were implemented. A two-tailed p value < 0.05 indicated statistically significant.

Results

Search results and study inclusion

A total of 447 records were retrieved from the three databases after the initial searching. Another 4 records were identified by reviewing citations in the reference. Of the total retrieved studies, 172 were removed because of duplication. Subsequently, 260 articles were excluded after reading titles and abstracts. Then 19 studies were downloaded and assessed for eligibility by reading full texts. Eventually, 10 articles [3, 6, 11, 12, 14-18, 23] were considered to be qualified for this meta-analysis. The detailed selection process is depicted in **Fig. 1**.

Characteristics of included studies and risk of bias

The basic characteristics of the 10 included studies are summarized in **Table 1**. All studies were published from 2009 to 2020, including results from Asia [3, 14-18], Europe [11, 12], the Unites States [6] and Australia [23]. The sample sizes of these studies ranged from 24 to 125, and a total of 560 patients were included. Eight articles [6, 11, 12, 14-18] were retrospective cohort studies and two [3, 23] were prospective studies. Eight studies [11, 12, 14-18, 23] had 9 points and two studies [3, 6] had 8 points using NOS score.

Mortality

All included studies were evaluated for overall mortality. The mortality was 26.30% (71/270) in PP group and 42.41% (123/290) in Non-PP group. Overall mortality was significantly lower in PP group (RR = 0.63, 95% CI = 0.50 to 0.79, $p < 0.05$) (**Fig. 2**). The I^2 statistic was 0%, indicating no heterogeneity among the included studies. No significant publication bias was shown (Fig. 3). Sensitivity analysis was conducted by omitting studies one by one, indicating the results were stable (Fig. 4). Considering that patients from 2 studies [15, 17] were just divided according to the time period whether PP was included in treatment protocol and not all patients in PP group received pelvic packing, subgroup analyses were performed. The patients treated with PP or just protocol including PP all had reduced mortality rate (RR = 0.63, 95% CI = 0.47 to 0.84, $p < 0.05$; RR = 0.63, 95% CI = 0.42 to 0.93, $p < 0.05$). The pooled results from 4 studies and 7 studies showed that PP decreased 24h mortality (RR = 0.42, 95% CI = 0.27 to 0.63, $p < 0.05$) and hemorrhagic mortality (RR = 0.27, 95% CI = 0.15 to 0.49, $p < 0.05$) respectively (Fig. 5). The I^2 statistic was 0% for 24h mortality and hemorrhagic mortality, indicating no heterogeneity among the included studies

Transfusion requirement and length of hospitalization

Blood transfusion was measured by packed red blood cells (PRBC) units. The combined results showed that PP decreased the need for pre-operative transfusion (SMD = -0.44, 95% CI = -0.69 to -0.18, $p < 0.05$; I^2 = 0%) but had no influence on transfusion during the first 24h after admission (SMD = 0.04, 95% CI = -0.24 to 0.31, $p > 0.05$; I^2 = 33.0%, 95% CI = 0% to 76.20%) (**Fig. 6**). Total length of hospital stay and length of stay in ICU weren't changed by PP (SMD = 0.18, 95% CI = -0.30 to 0.66, $p > 0.05$; SMD = 0.14, 95% CI = -0.28 to 0.56, $p > 0.05$, **Fig. 7**). The I^2 statistic was 67.11% (95% CI, 0% to 90.50%) for total length of hospital stay and 59.0% (95% CI, 0% to 86.35%) for length of stay in ICU. the cause of heterogeneity was not allowed to find due to insufficient data and a random effects model was used.

Discussion

Pelvic packing was originally performed using a trans-abdominal approach after laparotomy but with poor results, due to that the disruption of intact peritoneum was attempting to affect tamponade of hemorrhage, leading to aggravation of bleeding [4, 14]. The technique had been changed by Pohlemann et al. [10] in 1994 to packing of retroperitoneum and then modified to ensure direct packing of the pelvic space through a preperitoneal approach [24]. The method is usually performed by making an infra-umbilical midline incision of about 6–8 cm. Skin, subcutaneous tissue and fascia are dissected without violating the peritoneal cavity. Three laparotomy pads are placed below the pelvic brim toward the iliac vessels on each side of bladder [25]. The revision of PP should be done within 48–72 h [26].

After the modification in 1994, PP has been widely used in European trauma centers as a salvage procedure in the management for hemodynamically unstable patients with pelvic fractures [11, 12, 27–29]. Frassini et al. described PP as a life-saving procedure which could be the first step of a multidisciplinary management of pelvic ring disruptions [12]. In the First Italian Consensus Conference, statement agreed the effectiveness of PP and proposed an algorithm in which PP was prior to angiography [30]. Aside from Europe, in the last decade, scholars from China and South Korea reported improved clinical outcomes since adopting PP in the in the initial treatment protocol [11, 15, 17, 18]. World Society of Emergency Surgery (WSES) guidelines in 2017, recommend that PP should always be considered for patients with pelvic fracture-related hemodynamic instability and maximized effectiveness could be achieved when combined with external fixation [26].

However, surgeons in North America seem to be more in favor of angiography and embolization [31]. In guidelines from both Eastern Association for the Surgery of Trauma (EAST) and Western Trauma Association in the Unites States, angiography remains the mainstay of therapy [32–34]. A multicenter, observational study conducted through the American Association for the Surgery of Trauma (AAST) in 2015, enrolling patients from 11 Level I trauma centers, demonstrated that angioembolization and external fixator placement were the most common method for pelvic hemorrhage [35]. The mortality rate was 32% in AAST series of pelvic fracture patients in shock [35]. Another modern series in the US revealed that the mortality rate was 27.8% in patients with hemorrhagic instability and undergoing angiography [31]. Yet in 2016, Burlew et al. in Denver, USA, reported a mortality rate of 21% in an 11-year single-center study with a modified protocol which considered PP as the first intervention for pelvic fracture hemorrhage [36]. Burlew's group had been continuing sharing their results since adopting PP in treatment protocol in 2004 [13, 24, 36]. Their long-term observational study confirmed that PP reduces mortality compared with other series favoring angiography and embolization, recommending that PP should be used for pelvic fracture patients with unstable hemodynamics [36]. The updated algorithm by Western Trauma Association in 2016 also attached more importance to the use of PP [33].

Pelvic packing has the advantage of lowered mortality and reduced time to intervention [15, 17, 18, 36], but results varied in different researches [3, 6, 14]. Its role in the management of pelvic hemorrhage remains controversial and needs more studies with feasible comparison like angiography. This article includes all current comparative studies and to our knowledge, containing the largest number of patients. Only four of the included studies demonstrated that the implementation of PP in management protocol significantly improved survival [11, 12, 15, 17]. The previous relatively small cohorts may lead to results with low credibility. Death within the first 24 h after admission is commonly due to exsanguination, whereas, mortality after 24 h is usually from multiple organ failure [10, 37]. Different groups showed that the improvement through PP in mortality within 24 h or due to hemorrhage might be more marked than the improvement in overall mortality [11, 12, 15, 17]. Our quantitative synthesis confirmed this finding and we believe the early use of PP is a life-saving procedure in management for patients in hemorrhagic shock.

Delay in hemostatic procedures is associated with increased mortality in patients with pelvic hemorrhage [12]. Every 3 minutes of delay in the resuscitation room leads to a 1% mortality increase in a hemodynamically unstable patient with blunt abdominal trauma in the first 90 minutes [38]. Early hemostasis should be done as soon as possible.

Currently, angiography is still considered the first choice of hemorrhage control in most institutional algorithms [23]. However, the time required for transportation of patients, preparation of angiography suite and mobilization of trained interventional radiologists is excessive. In contrast, PP can be quickly accomplished either in operation or emergency room [11, 12]. Osborn et al. reported a mean time to PP of 44 minutes from the emergency department (ED) admission, compared to a mean of 130 minutes to the angiography suite [6]. Average time to operative packing reported from Tai et al. was 79 minutes compared with 140 minutes to angiography [14]. Similar results were shown by Jang et al, with time to intervention in PP group was 55 minutes compared to 194 minutes in Non-PP group [16]. Our previous results also reported that PP had shorter procedure duration than angiography [3]. Recently, a study from Italy demonstrated that the total hemostatic procedure time was sharply reduced for patients in PP group, with a mean time of 49 minutes compared to 156 minutes in the No-PP group [12]. Considering lots of studies have confirmed that PP has the advantage of immediacy and rapidity [3, 6, 12, 14, 16, 17, 23, 36], we didn't perform a quantitative analysis for that.

Except for consuming time, the availability of angiography varies in hospitals. Low-level trauma centers, especially in remote or rural region, may be not equipped with qualified angiography suite. Meanwhile, interventional radiologists are not in-house at all times [3], and interventions are easily to be delayed during nights and weekends [39]. Metcalfe et al. reported that a 24 h formal interventional radiology service was only available at 18% of hospitals in Wales, UK [40]. PP is a fast and easy procedure with a low demand for equipment and short learning curve, deserving a more widespread use. Moreover, the high energy trauma causing pelvic fractures often lead to increased risk of associated injuries. Additionally, three or more procedures are required to address these injuries [36]. The rapid arrestment of hemorrhage by PP facilitates other emergent operative procedures to stabilize polytrauma patients [15].

Pathophysiologically, PRBCs may induce the adverse inflammatory responses by activating inflammatory genes in circulating leukocytes [41]. Wong et al. reported an increased mortality rate by 62% for every one PRBC unit per hour increase of transfusion rate [42]. Since the need of transfusion is associated with increased ICU length of stay, multiple organ failure and mortality, reducing transfusion is a compelling objective [13]. With PP included in protocol, though the total number of transfusions required in the first 24 h after admission wasn't changed, the need of transfusion in ED was significantly reduced. We think the reduced time to intervention for PP is critical to the decreased need of pre-operative transfusion. Osborn et al. reported that packing significantly decreased blood transfusion over the 24 h post-intervention period whereas the angiography demonstrated no such change [6]. Burlew's group also reported a significant reduction in transfusion requirement after PP [13, 36]. This decrease may be attributed to the concurrent management of associated injuries that could otherwise contribute to continuous bleeding [6]. However, our previous study as well as report from Tai et al. demonstrated post-intervention transfusion was similar in patients treated with PP or angiography [3, 14]. On account of inadequate data, we failed to perform a quantitative analysis. Further studies are needed to determine the role PP plays in blood transfusion requirement.

Though most pelvic hemorrhage originates from veins or fractured bones, a combined injury involving both intra-pelvic veins and arteries is not uncommon [28]. Also high rate of arterial injury was found in patients after PP [23]. Despite that the use of PP improves survival; it cannot completely replace angiography and embolization. During initial resuscitation of pelvic trauma, it is difficult to ascertain the accurate source of bleeding [14] so the optimal procedure may be hard to determine in short time. Since the primary source of pelvic bleeding is injured veins or fractured bone and angiography is time-consuming, PP should be considered as the first-line treatment for pelvic fracture patients with unstable hemodynamics. If patients sustained hemodynamically unstable after PP, arterial bleeding should be suspected and angiography is necessary. A complementary association of pelvic packing and endovascular procedures seems to be the best clinical practice based on guidelines from WSES and Western Trauma Association [12]. Suzuki et al. proposed PP as the primary procedure for patients with unstable hemodynamics, whereas angiography could be the first choice in stabilized patients [43]. Totterman et el. reported high rate of arterial injury observed on angiography after PP and suggested that PP should be supplemented with angiography once sufficient hemodynamic stability had been attained [28]. To some extent, PP could be a time-gaining 'bridge technique' to angiography and embolization [12]. It should be pointed out that, based on current evidence, it is unclear whether secondary angiography should be performed on all patients or just on those who still has a manifestation of continuous bleeding after PP.

In recent years, resuscitative endovascular balloon occlusion of the aorta (REBOA) has been proposed as an alternative for temporary bleeding control in hemodynamically unstable trauma patients [26]. REBOA has the advantage of a rapid and effective control of arterial hemorrhage with preservation of cerebral and myocardial perfusion [33]. Its usage in patients with pelvic trauma has been increasing especially in the USA. WSES guidelines and Western Trauma Association suggested that REBOA may act as an effective adjunct in the management of hemodynamically unstable pelvic ring injuries [26, 33]. However, the occlusion time is associated with ischemia-reperfusion injury and amputation. Currently, REBOA is mainly considered as a bridge from emergent hemostasis to secondary procedure [12] and more studies of high quality are needed.

This study has both strengths and limitations. The strength lies in the large member of enrolled patients. Several limitations are listed as following. First, only two of the included studies were prospective study and no randomized controlled trial was included. However, a randomized study was not reasonable in light of ethical and practical reasons. Second, there was limited data for accessing transfusion requirement. Third, Propensity Score Matching (PSM) Analysis was used to adjust the differences in the baseline characteristics between the two groups in two studies [11, 12] and we only enrolled patients after PSM. The neglected data may likely affect the strength of conclusions.

Conclusions

This meta-analysis indicates that a treatment protocol including PP significantly reduce mortality and transfusion requirement before intervention in pelvic fracture patients with hemodynamic instability. We recommend an algorithm in which pelvic packing is performed as first-line treatment and complemented with angiography and embolization for patients with traumatic pelvic hemorrhage.

Abbreviations

PP: Pelvic packing; RR:Relative risk; SMD:standard mean difference; CI:confidence interval; PRISMA:Preferred Reporting Items for Systematic Reviews and Meta-Analyses; ISS:injury severity score; NOS:Newcastle-Ottawa scale; PRBC:packed red blood cells; WSES:World Society of Emergency Surgery; AAST:American Association for the Surgery of Trauma; EAST:Eastern Association for the Surgery of Trauma; ED:emergency department; REBOA:resuscitative endovascular balloon occlusion of the aorta; PSM:Propensity Score Matching

Declarations

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

Not applicable.

Availability of data and materials

All data analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

PYL contributed to the idea of this study and drafted the manuscript. PYL and FXL searched literatures and screened them independently. Any disagreement was solved by consulting the senior authors (JLD and DWW). PYL, FXL and LL screened data from the ten articles and make Tables. QHL and DSZ played an important role in analyzing the outcomes. PYL and FXL conducted the data analyses and make graphs. JLD and DWW revised the manuscript. All the authors have read and approved the final manuscript.

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No.

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Tables

Table.1 Main characteristics of the included studies

Author (year)	Country	Study design	No. of patients			Age (years)		ISS		NOS
			Total	PP	Non-PP	PP	Non-PP	PP	Non-PP	
Osborn (2009)	USA	Retrospective	40	20	20	37.9 ± 18.9	39.5 ±17.4	54.7 ± 12.7	45.9 ± 8.7	8
Tai (2011)	China	Retrospective	24	11	13	51.2 ± 19.0	44.8 ± 24.7	40.0 ± 12.5	42.3 ± 18.8	9
Cheng (2015)	South Korea	Retrospective	125	49	76	45.37 ± 21.02	46.84 ± 21.43	40.10 ± 14.19	45.00 ± 15.71	9
Chiara (2016)	Italy	Retrospective	50	25	25	PSM		PSM		9
Hsu (2016)	Australia	Prospective	24	14	10	49.9 ± 17.5	60.3 ± 23.5	32.0 ± 6.7	23.8 ± 12.7	9
Jang (2016)	South Korea	Retrospective	30	14	16	59.7 ± 15.0	60.9 ± 22.1	38.8 ± 8.3	32.2 ± 4.9	9
Li (2016)	China	Prospective	56	27	29	43 ± 13	40 ± 9	48 ± 6	43 ± 7	8
Lee (2017)	South Korea	Retrospective	79	43	36	53.2 ± 19.8	50.6 ± 19	38.7 ± 12.5	37.2 ± 12.3	9
Shim (2018)	South Korea	Retrospective	58	30	28	62.5 ± 14.4	57.0 ± 22.8	38.4 ± 8.5	38.7 ± 9.2	9
Frassini (2020)	Italy	Retrospective	74	37	37	PSM		PSM		9
PP = Pelvic packing, ISS = Injury severity score, PSM = Propensity Score Matching, NOS = Newcastle-Ottawa scale										

Figures

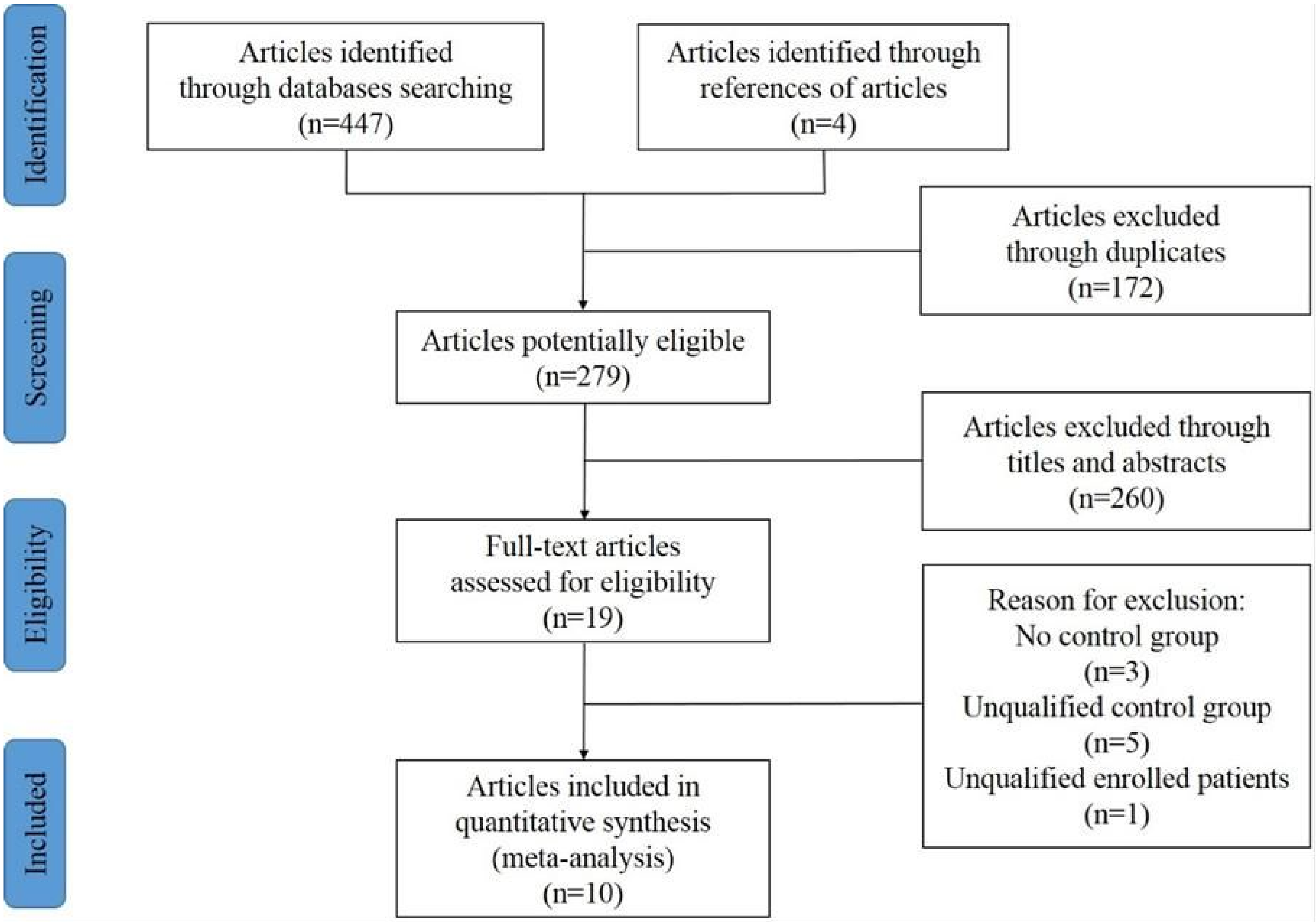

Figure 1

Flow diagram of the selection process for the included studies

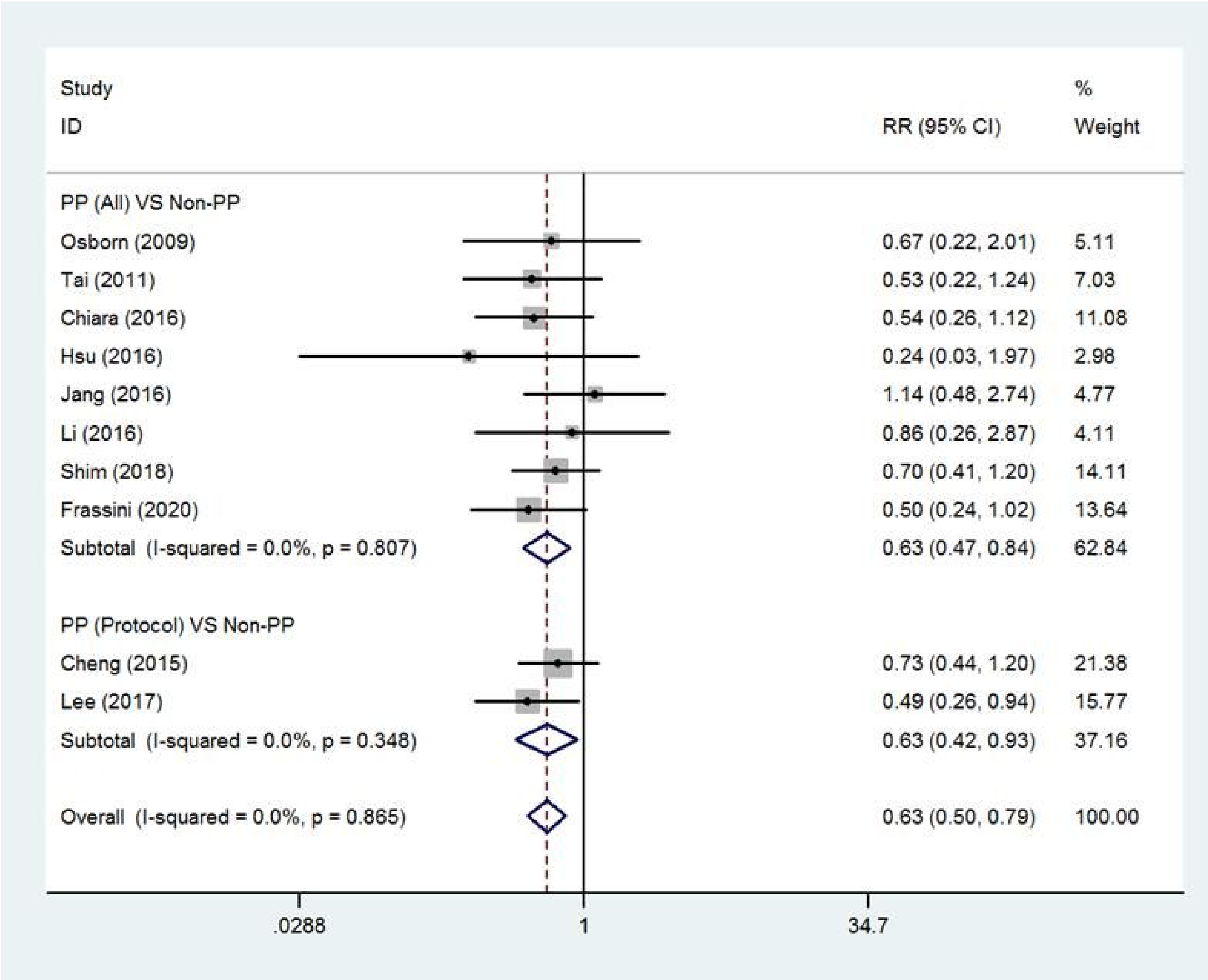

Figure 2

Forest plot involving comparison of overall mortality. RR, relative risk; CI, confidence interval

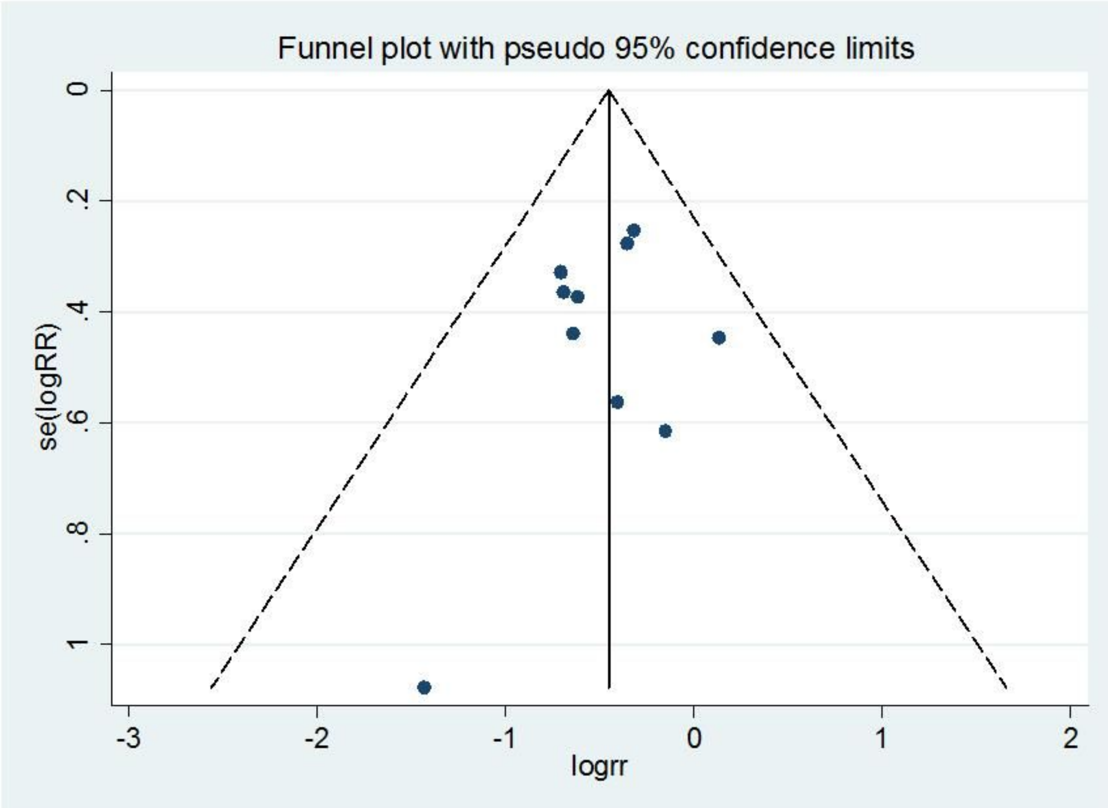

Figure 3

Funnel plot of publication bias.

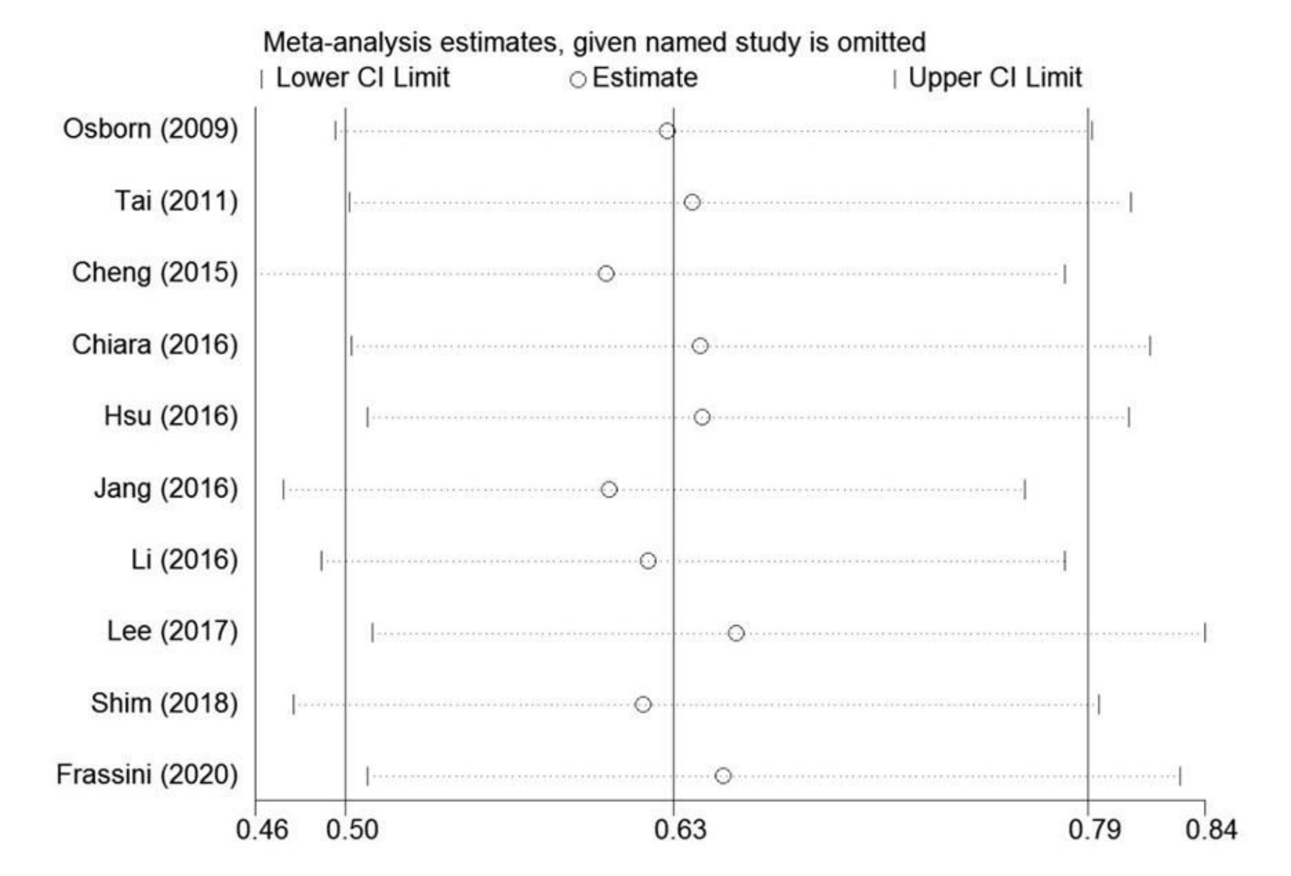

Figure 4

Sensitivity analysis involving overall mortality by omitting studies one by one.

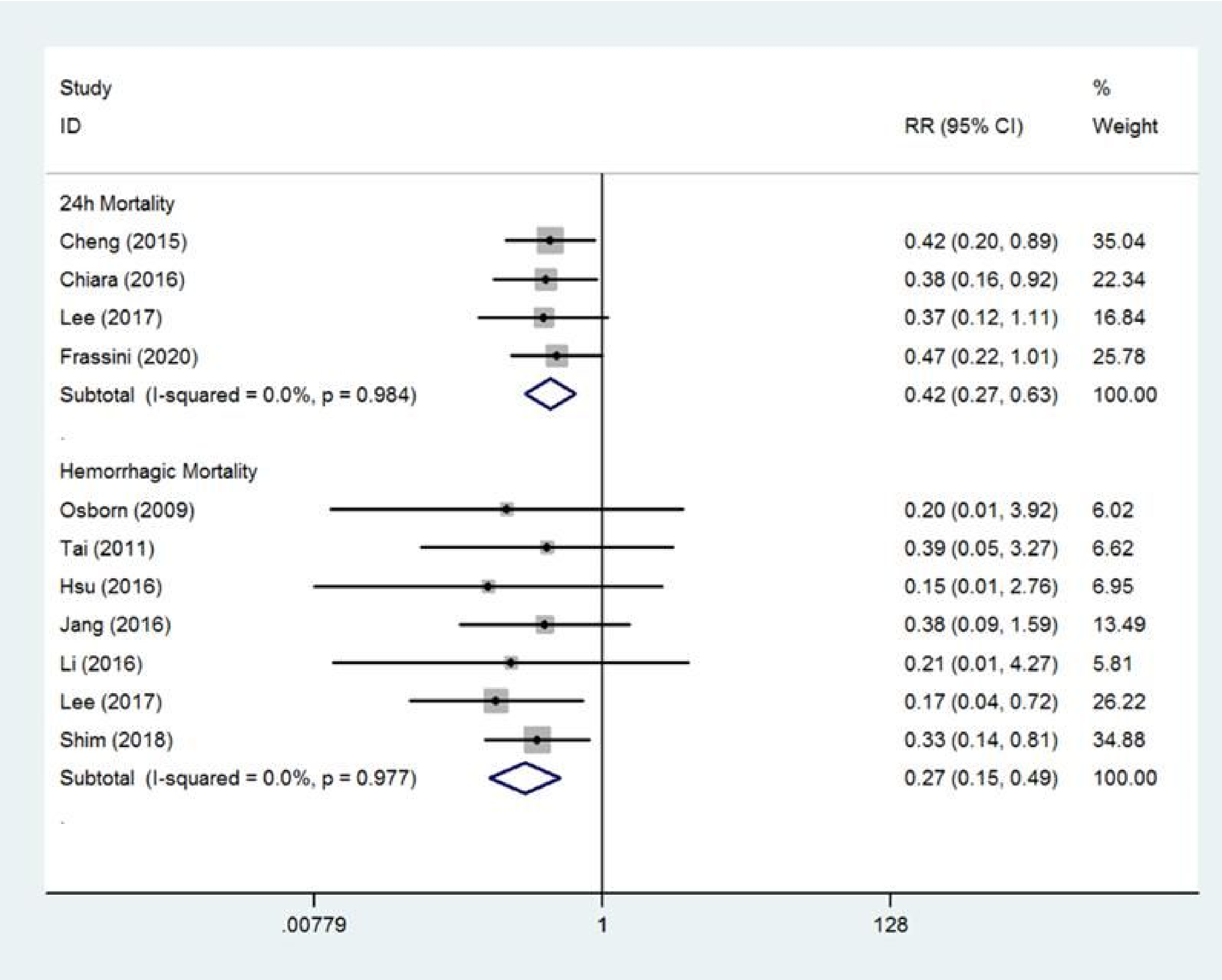

Figure 5

Forest plot involving comparison of early mortality. RR, relative risk; CI, confidence interval.

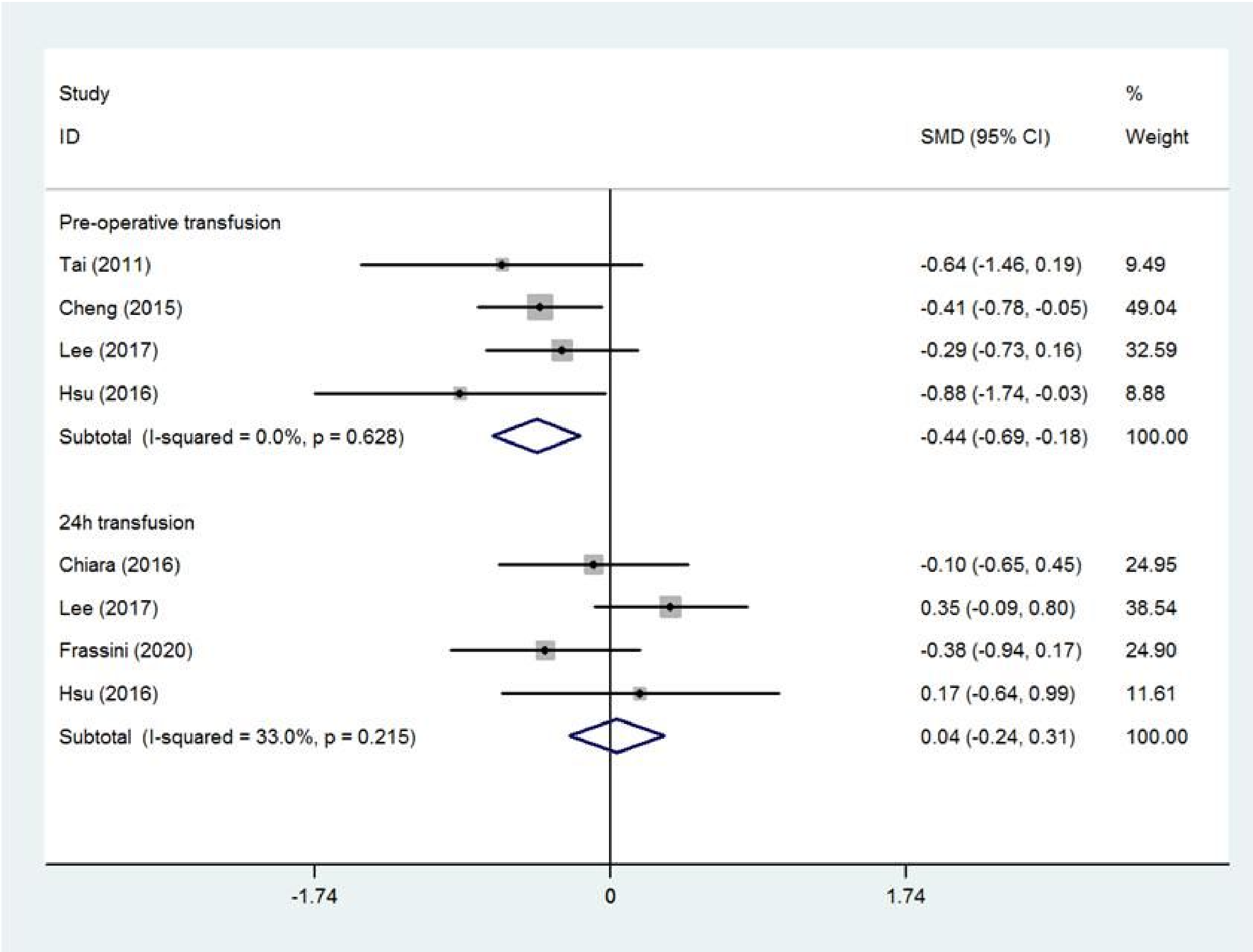

Figure 6

Forest plot involving comparison of transfusion. SMD, standard mean difference; CI, confidence interval.

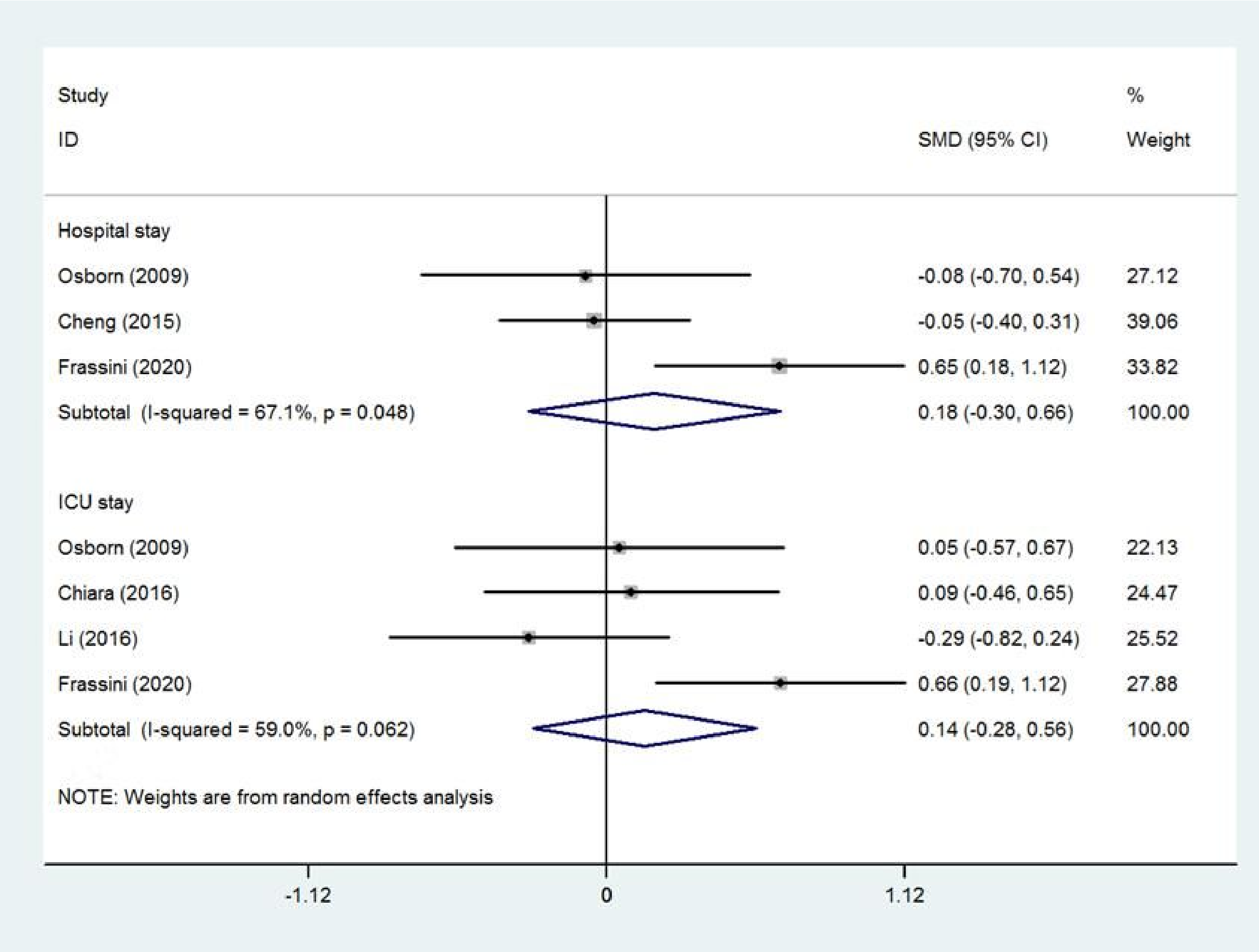

Figure 7

Forest plot involving comparison of length of hospitalization. SMD, standard mean difference; CI, confidence interval