Heart Surgery Forum 2023; 26(3): E303–E310
doi: 10.59958/hsf.5333 https://journal.hsforum.com/

Systematic Review

Thoracic Endovascular Aortic Repair Versus Open Surgery for Stanford Type B Aortic Dissection: A Meta-Analysis and Systematic Review

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Submitted: 30 November 2022 Revised: 9 January 2023 Accepted: 13 January 2023 Published: 29 June 2023

Abstract

Background: Thoracic endovascular aortic repair is a relatively new technique relative to open surgery, and our aim was to assess whether there is a difference in the risk of common postoperative complications between thoracic endovascular aortic repair and open surgery. **Methods**: The PubMed, Web of Science, and Cochrane library were systematically searched for trials comparing thoracic endovascular aortic repair and open surgical repair from January 2000 to September 2022. Primary outcome was death, other outcomes included common associated complications. Data were combined using risk ratio or standardized mean difference with 95% confidence interval. Funnel plot and egger's test were used for assessing publication bias. The study protocol was registered prospectively with PROSPERO (CRD42022372324). **Results**: This trial included 11 controlled clinical studies with 3667 patients. Thoracic endovascular aortic repair had lower risk of death (risk ratio [RR], 0.59; 95% CI, 0.49 to 0.73; $p < 0.00001$; $I^2 = 0$), dialysis (RR, 0.55; 95% CI, 0.47 to 0.65; $p < 0.00001$; $I^2 = 37\%$), stroke (RR, 0.71; 95% CI, 0.51 to 0.98; $p = 0.03$; $I^2 = 40\%$), bleeding (RR, 0.44; 95% CI, 0.23 to 0.83; $p = 0.01$; $I^2 = 56\%$), and respiratory complications (RR, 0.67; 95% CI, 0.60 to 0.76; $p < 0.00001$; $I^2 = 37\%$) compared with open surgical repair. In addition, the length of hospital stay was shorter in the thoracic endovascular aortic repair group (SMD, –0.84; 95% CI, –1.30 to –0.38; $p = 0.0003$; $I^2 = 80\%$). **Conclusions**: Thoracic endovascular aortic repair has significant advantages over open surgical repair, in terms of postoperative complications and survival in Stanford type B aortic dissection patients.

Keywords

thoracic endovascular aortic repair; stanford type B aortic dissection; open surgery

Introduction

Aortic dissection (AD) is a tear in the intima and media of the aorta, due to various reasons, and blood enters the media through the tear [1]. The annual incidence of AD is about 2.8–6.0/100,000, 37.3% had Stanford type B aortic dissection (TBAD). Associated risk factors include hypertension, smoking, or atherosclerosis [2–4].

TBAD refers to the tearing of the intima of the aorta beyond the aortic arch, and blood enters the middle layer of the aorta and develops along the longitudinal axis of the aorta, dividing the aorta into a true lumen and false lumen [5]. Although TBAD is slightly milder than Stanford type A aortic dissection, it also is an emergency aortic surgery, which also can cause aortic rupture and cause death of patients. Therefore, TBAD also needs to be actively treated. Optimal management of uncomplicated TBAD currently is an area of debate.

For complicated TBAD, immediate surgical treatment with endovascular repair or open repair is required. For many years, open surgical repair has been the only therapeutic option for surgical intervention in patients with complicated TBAD. Although it has been used worldwide for decades, there still are some serious postoperative problems, such as renal failure, spinal cord ischemia, blood transfusion, and death [6,7]. Currently, in the treatment of complicated TBAD, thoracic endovascular aortic repair (TEVAR) is considered an attractive alternative because it is less invasive than open surgical repair [8]. Although studies have shown that TEVAR has the advantages of low mortality and short operation time, it has been suggested that TEVAR is more prone to related postoperative complications than open surgical repair [9,10]. In addition, the difference in survival between TEVAR and open surgical repair has been controversial [11,12]. TBAD is a relatively urgent clinical problem, due to its acute onset and high mortality. Clarifying the difference between TEVAR and open surgical repair in terms of prognosis and survival in TBAD patients to start treatment as soon as possible is expected to improve the prognosis of TBAD patients.

Methods

This study was conducted, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA) statement [13]. We also registered this protocol in the International Prospective Systematic Reviews Registry database (CRD42022372324).

Data Sources and Search

The Web of Science, PubMed, and the Cochrane Library were searched between January 2000 and September 2022. The main search terms were as follows: [(Aneurysm, Dissecting) OR (acute type B aortic dissection)] AND [(thoracic endovascular aortic repair) OR (Endovascular repair of thoracic aorta)] AND [(open adrenalectomy) OR (Open surgery)] in the title/abstract. In addition, references of relevant articles were searched as supplement relevant studies not included in the initial literature search results. In addition, references of relevant articles were searched as a complement to relevant studies not included in the initial literature search results. Detailed search strategies are presented in the **Supplementary Material**.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were developed, according to PICOS principles. Inclusion criteria included (I) Studies must include comparisons of TEVAR and open surgery; (II) Only patients diagnosed with Stanford type B aortic dissection were included; (III) Types of included studies included randomized controlled trials or controlled clinical trials. Exclusion criteria were: (I) Reviews, conference papers, abstracts, letters, case reports and other types of papers were not included; (II) Clinical study of aortic dissection diagnosed but not Stanford type B; (III) Lack of relevant analyzable outcomes or data that could be translated into usable form. Based on the above inclusion and exclusion criteria, two authors screened independently and consulted another author for disagreements.

Data Collection and Quality Assessment

Data extraction independently was performed by two authors, and when disagreements were encountered, a third author was consulted. The extracted data included baseline data such as first author, year of publication, sample size, age, history of diabetes, history of chronic obstructive pulmonary disease, etc. In addition, relevant outcome measures also were extracted for data pooling. The included studies were assessed for bias, according to the "Cochrane Risk of Bias Assessment Tool" in the Cochrane Handbook [14]. The evaluation content includes allocation hiding, randomization method, blinding method between investigator and subject, blinding method of result evaluator, and selective reporting of results, data completeness, and other possible biases in seven areas.

Outcomes and Definitions

The primary outcome measure was death. Secondary outcomes included TEVAR and common complications after open surgical repair. We chose dialysis caused by renal failure, neurological complications, such as stroke, paraplegia, hemorrhage, and respiratory complications to reflect the patient's prognosis. In addition to this, we also analyzed the length of the patient's hospital stay.

Statistical Analysis

All statistical analyses were performed using Review Manager (RevMan) version 5.4 (The Cochrane Collaboration, Copenhagen, Denmark) and Stata SE 16.0 (Stata Corporation, College Station, TX, USA). The risk ratio (RR) with 95% confidence intervals (CI) were used for dichotomous data, and standard mean difference (SMD) with 95% CI for continuous data. The Q-test and I^2 statistic were calculated to assess the heterogeneity of studies. Significant heterogeneity was considered when $p < 0.1$ or $I^2 > 50\%$. The fixed-effects model was used when $I^2 < 50\%$; otherwise, we would use random-effects model. Meta-regression analysis was conducted to explore the source of heterogeneity. Risk of publication bias for studies were assessed using funnel plots, and the egger's test when there were at least 10 studies. Sensitivity analysis was used to assess whether the results were stable and also to assess sources of heterogeneity.

Results

Study selection results: A total of 1687 articles were retrieved from the database, and 1219 articles remained after deduplication. After reviewing the titles and abstracts, 1176 articles were excluded from the preliminary screening. The remaining 43 papers were read in full-text for final inclusion. Finally, 11 controlled clinical trials were included in this study [11,12,15–23]. The detailed screening process is shown in Fig. 1.

Study characteristics and quality assessment: Table 1 [11,12,15–23] summarizes the basic characteristics of the included study patients, including some comorbidity history. The sample size of each trial varied from 24 to 1982. A total of 3667 patients participated in the study, with an average age of 61.2 years. All patients were TBAD patients.

Fig. 2 is risk of bias graph, and Fig. 3 shows each risk of bias item for each included study. Four trials were classified as having low risk of bias, seven trials considered unclear risk of bias, and one trial was considered high risk of bias.

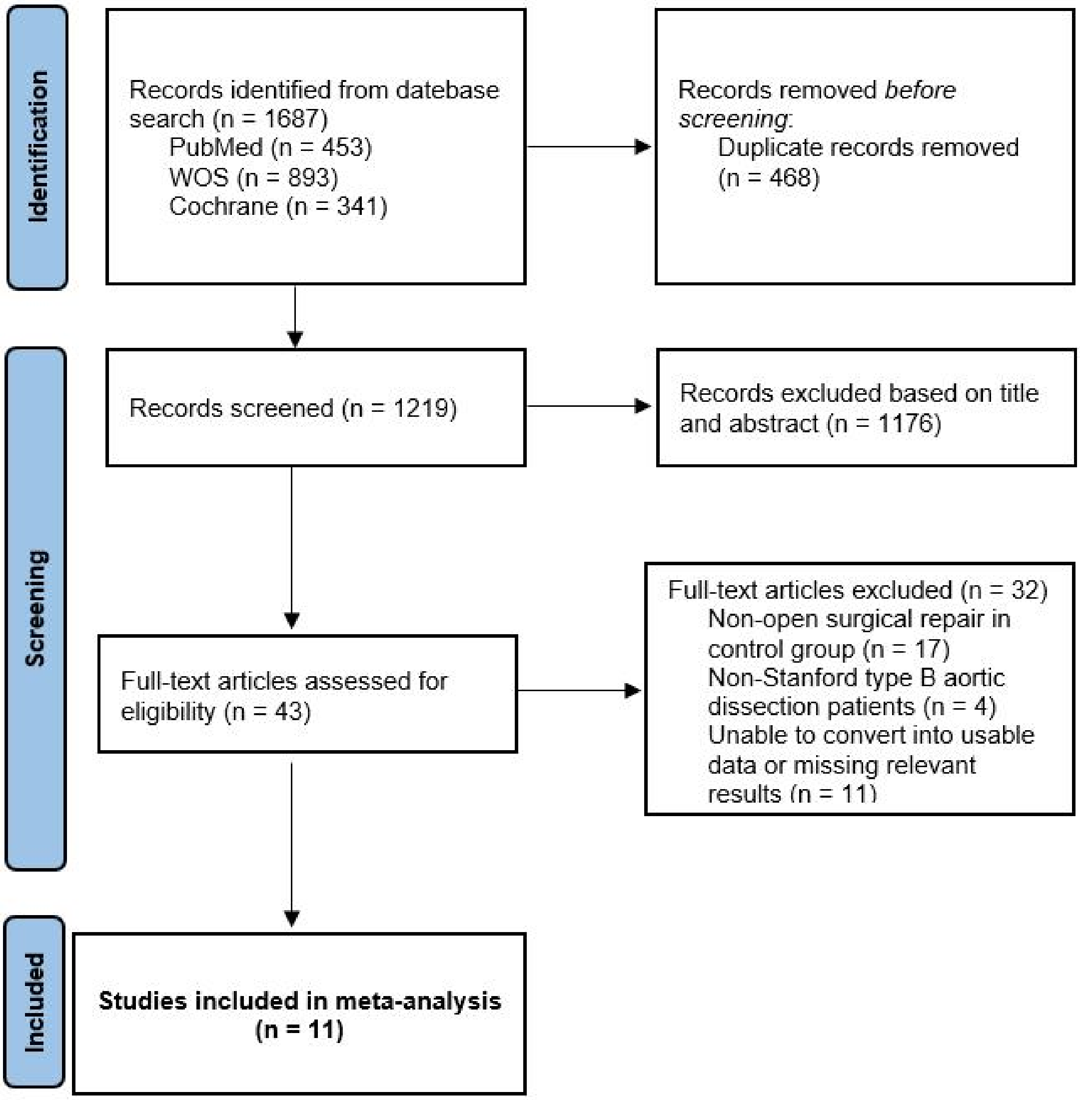

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flowchart of selection.

Table 1. Patient baseline data and history of relevant comorbidities.

Reference	Country	N	Age (year)	Male (%)	Smoke (%)	HT (%)	DM (%)	CAD (%)	COPD (%)
Afifi 2015 [15]	America	442	60.2	153 (57.1)	NA	NA	NA	NA	96 (35.8)
Andersen 2014 [16]	America	107	56.0	77 (72)	64 (60)	100 (94)	7 (7)	18 (17%)	18 (17)
Brunt 2011a [17]	America	1982	61.5	1230 (62.1)	NA	1310 (66.1)	225 (11.4)	361 (18.2)	489 (24.7)
Brunt 2011b [17]		564	61.4	399 (70.7)		417 (74)	70 (12.4)	92 (16.3)	124 (22)
Garbade 2010 [11]	Germany	51	64.5	35 (68.6)	NA	45 (88.2)	10 (19.6)	NA	10 (19.6)
Lee 2012 [18]	Korea	68	58.0	16 (23.5)	37 (54.4)	49 (72.1)	3 (4.4)	19 (27.9)	NA
Leshnower 2013 [19]	America	89	60.5	62 (69.7)	NA	78 (87.6)	5 (5.6)	NA	32(36.0)
Mastroroberto 2010 [20]	Italy	24	72.4	15 (62.5)	NA	19 (79.2)	3 (12.5)	2 (8.3)	15 (62.5)
Nozdrzykowski 2013 [21]	Germany	80	62.3	59 (73.7)	NA	79 (98.8)	NA	17 (21.3)	16 (20)
van Bogerijen 2015 [22]	America	122	59.8	85 (69.7)	78 (63.9)	111 (91.0)	11 (9.0)	19 (15.6)	10 (8.2)
Wilkinson 2013 [12]	America	73	66.3	46 (63.0)	42 (57.5)	59 (80.8)	8 (11.0)	19 (26.0)	12 (16.4)
Zeeshan 2010 [23]	America	65	58.1	48 (73.8)	31 (47.7)	50 (76.9)	9 (13.8)	8 (12.3)	10 (15.4)

Data are expressed as mean or number (percent). N, number; HT, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; NA, not acceptable.

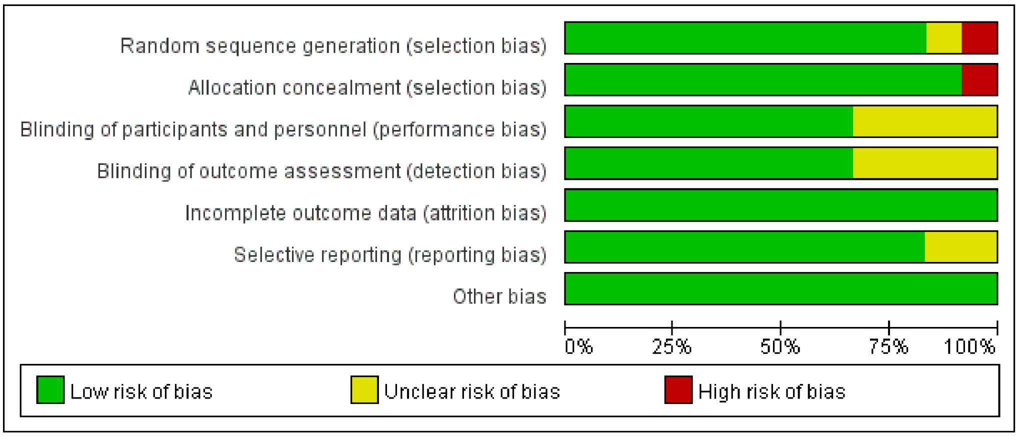

Fig. 2. Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies.

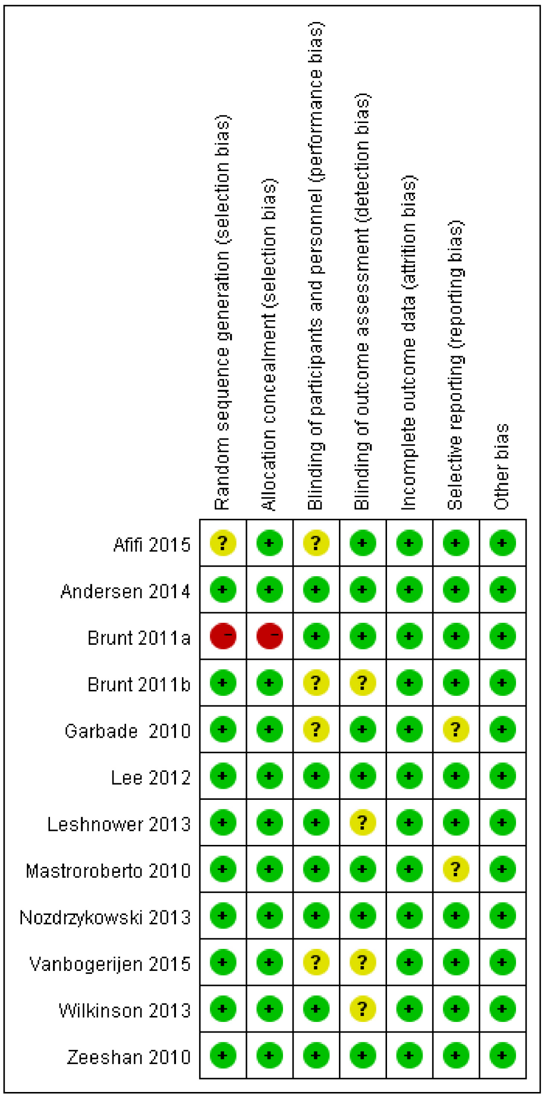

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

Main outcomes: Our results found a lower risk of death (Fig. 4A) (RR, 0.59; 95% CI, 0.49 to 0.73; $p < 0.00001$; $I^2 = 0$), dialysis (Fig. 4B) (RR, 0.55; 95% CI, 0.47 to 0.65; $p < 0.00001$; $I^2 = 37\%$) for renal failure, stroke (Fig. 4C) (RR, 0.71; 95% CI, 0.51 to 0.98; $p = 0.03$; $I^2 = 40\%$), bleeding (Fig. 4D) (RR, 0.44; 95% CI, 0.23 to 0.83; $p = 0.01$; $I^2 = 56\%$), and respiratory complications (Fig. 5A) (RR, 0.67; 95% CI, 0.60 to 0.76; $p < 0.00001$; $I^2 = 37\%$) in the TEVAR group than with open surgical repair. In addition, the length of hospital stay was shorter in the TEVAR group (Fig. 5B) (SMD, –0.84; 95% CI, –1.30 to –0.38; $p = 0.0003$; $I^2 = 80\%$). And there was no difference in the risk of paraplegia between the TEVAR group and the open surgical repair group (Fig. 5C).

Results of meta-regression: The meta-regression was performed to explore potential possible sources of heterogeneity. Multivariate meta-regression analyses were performed for the three outcomes of postoperative dialysis, stroke, and respiratory complications. Covariates included age, male sex, and history of hypertension, diabetes, coronary heart disease, and chronic obstructive pulmonary disease. The results show that none of the above factors are the main sources of heterogeneity. Detailed results are presented in **Supplementary Material**.

Publication bias assessment and sensitivity analysis: The funnel plot is basically symmetrical, and Egger's tests for death (Egger's $p = 0.336$), dialysis (Egger's $p = 0.233$), respiratory complications (Egger's $p = 0.577$), and stroke (Egger's $p = 0.699$) also show no significant publication bias. The results of the funnel plot and Egger's test are presented in the **Supplementary Material**. Other outcomes were not assessed for publication bias, due to fewer than 10 articles. When the Brunt *et al.* [17] trial was excluded, the result of bleeding was $I^2 = 0$, RR = 0.29, $p < 0.00001$. After excluding the trials of Andersen *et al.* [16] and Zeeshan *et al.* [23], the results of length of hospital stay were $I^2 = 0$, SMD = –0.88, $p < 0.00001$. Sensitivity analysis results show that our results are reliable and robust.

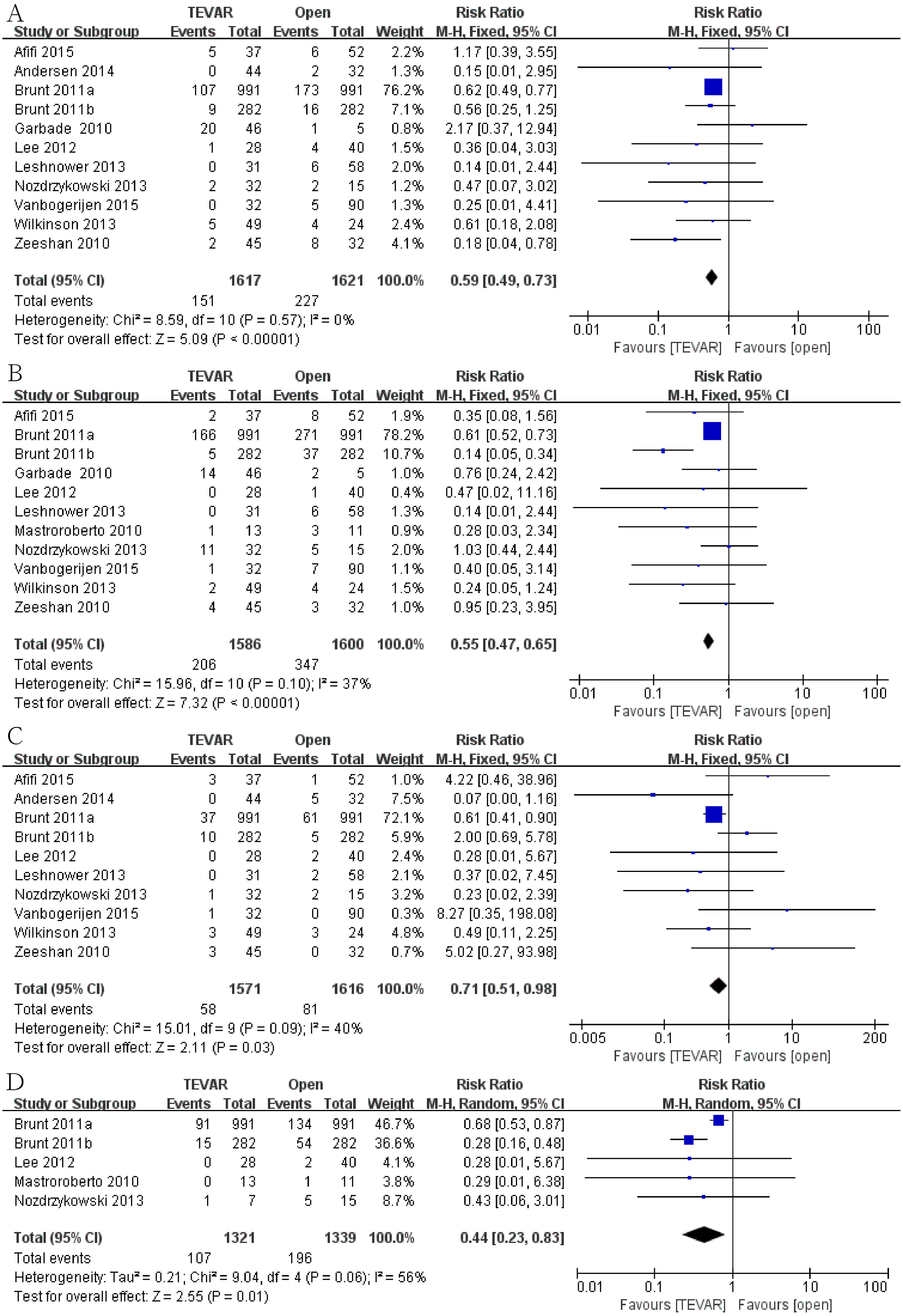

Fig. 4. Forest plot of (A) death; (B) dialysis; (C) stroke; (D) bleeding.

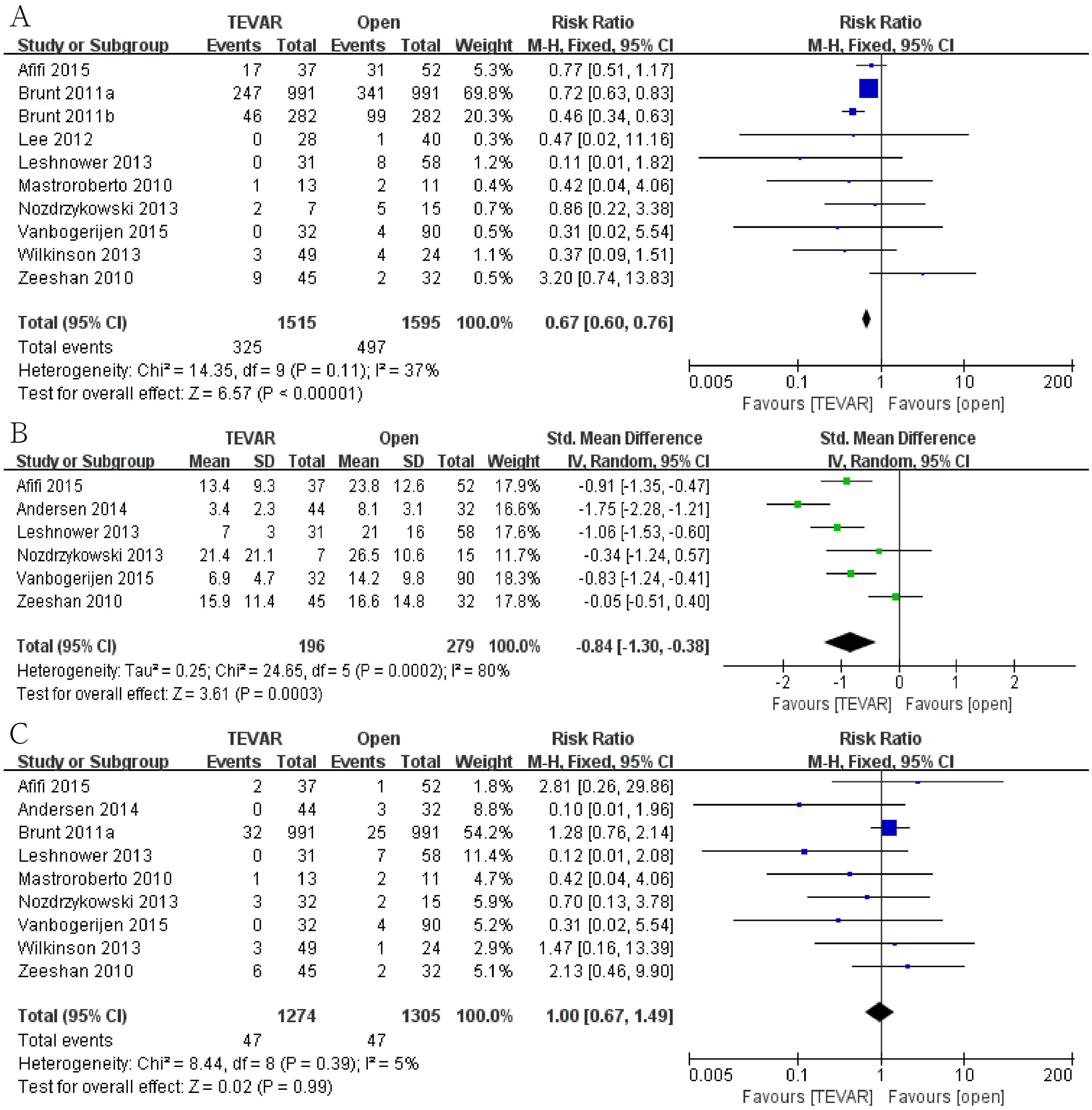

Fig. 5. Forest plot of (A) respiratory complications; (B) length of hospital stay; (C) paraplegic.

Discussion

Management of TBAD has been a clinical challenge due to its acute onset, rapid progression, poor prognosis, and high mortality. At present, there are many treatment methods for TBAD. In addition to open surgical repair, conservative drug treatment usually is recommended for uncomplicated TBAD patients. Compared with surgical repair of large trauma and poor prognosis, TEVAR has been widely used as a minimally invasive and convenient interventional treatment method. Despite the increasing use of TEVAR in recent years, the superior efficacy and safety of TEVAR have not been well evaluated [24]. No randomized trials involving complicated type B dissection with long-term follow up have been performed, the indication for TEVAR has not been established [25]. Even though expert consensus has established the convenience of TEVAR compared with open surgical repair, there still is no high-quality evidence on which approach is best [26]. In conclusion, our research is necessary.

Our results show there was a significant difference in the risk of death and other common complications between the TEVAR and open surgical repair groups. Our study found that compared with TEVAR, patients undergoing open surgical repair had twice the risk of postoperative death, dialysis, stroke, bleeding, and respiratory complications. In addition, patients who underwent TEVAR had a shorter hospital stay. Our results suggest that TEVAR is more beneficial for the prognosis of TBAD patients and significantly reduces the risk of death.

Paraplegia is one of the main concerns in surgical repair of aortic disease. The most common cause of paralysis in TBAD patients is spinal cord ischemia and hypoxia. Ischemia most likely was caused by perioperative hypotension and/or interruption of key intercostal and lumbar arteries. Other mechanism of spinal cord hypoxia is thrombosis or embolism of the costolumbar arteries [27].

The incidence of postoperative paraplegia in patients with early aortic dissection is as high as 38%. With the advancement of technology, this figure currently is controlled at 3.3%–16% [28–31]. The difference may be related to the different surgical methods and severity of the disease. The research results of some scholars show that the incidence of paraplegia is lower in open surgery repair [12,15,23], and the research results of some people show that the risk of paraplegia in TEVAR is lower [16,19,20]. However, our results showed no significant difference in the risk of paraplegia between TEVAR and open surgical repair. At present, there still is no higher level of evidence to show which way will reduce the risk of paraplegia. This cannot be explained from the pathophysiology and pathogenesis of paraplegia, so this also provides a direction for future research.

Our study has the following limitations: (i) There are few studies on TEVAR and open surgical repair, and there is a lack of large-scale randomized controlled trials. Although our included literature is not much, the sample size still has a certain degree of credibility; (ii) As the countries and years of the trials varied, we could not rule out a potential influence on the results due to different equipment; (iii) Due to the limited number of included literature, we were unable to conduct subgroup analysis to draw more detailed conclusions.

After years of development, TEVAR technology has been more and more widely used in aortic lesions, including acute and chronic type B aortic dissection and penetrating atherosclerotic ulcers. Although TEVAR can treat almost all lesions of the descending aorta, it still faces many challenges, such as the risk of a retrograde type-A dissection and how to accurately place the stent at the distal end of the descending aorta. How to reduce the risk of air embolism and paraplegia may also be the main research direction in the next few years. In addition, there still is a lack of specific stents that can be widely used in acute aortic lesions.

Conclusions

The risk of postoperative death, dialysis, stroke, bleeding, and respiratory complications was doubled in the open surgical repair group compared with the TEVAR group. The length of hospital stay also was significantly shorter in the TEVAR group than in the open surgical repair group. However, there was no difference in the risk of postoperative paraplegia between the two groups. Overall, TEVAR is more beneficial for TBAD patients.

Author Contributions

YY and JAW completed most of the statistical work and manuscript writing. BCD does the rest of the statistics and manuscript writing, and organizes the tables and pictures. PPW designed the trial and reviewed and modified it. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.5333.

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