Gen Thorac Cardiovasc Surg (2019) 67:70–76
DOI 10.1007/s11748-017-0845-2

SPECIAL EDITION

Controversies in Surgery for Thoracic Aorta

A systematic review and meta-analysis of mechanical vs biological composite aortic root replacement, early and 1-year results

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Received: 27 July 2017 / Accepted: 3 October 2017 / Published online: 10 October 2017

Abstract

Objective Composite aortic root replacement is a standard procedure for various aortic root pathologies. This systematic review was set to identify the postoperative outcomes for composite mechanical root replacement (mCRR) compared to composite biological root replacement (bCRR).

Methods We systematically reviewed four major databases for all papers assessing outcomes in composite root replacement. Articles selected were chosen by two reviewers. Amongst our inclusion and exclusion criteria, all pediatric populations were excluded as were studies with a cohort less than 50 patients.

Results We identified seven studies that conformed to our inclusion criteria and incorporated 2240 patients. In-hospital mortality was higher but non-significant in the mechanical group (6.1 vs 4.2% respectively). There was no significant difference demonstrated in the risk of in-hospital stroke, late stroke and re-operation in either groups. Additionally, there was no significant difference in: endocarditis, 1-year mortality, 5-year mortality, mean cardiopulmonary or aortic cross-clamp time.

Conclusions Composite mechanical root offers no superiority to composite biological root. There is a significant increase in the perioperative bleeding amongst composite mechanical root cohort. There is a need for further randomized control trail to assess the efficacy of either methods.

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Keywords Aortic root · Aneurysm · Composite root · Valve

Abbreviations

mCRR	Mechanical composite root replacement
bCRR	Biological composite root replacement
CVG	Composite aortic valve graft
RR	Risk ratio
MWD	Mean weighted difference
VSR	Valve sparing replacement

Introduction

Bentall and De Bono described their technique for aortic root replacement in 1968 [1]. They used a mechanical composite graft—consisting of a no. 13 Starr cage-ball valve attached to a crimped Teflon tube—for aortic root replacement with reattachment of the two main coronary arteries. In 1977, Kouchoukos and colleagues [2] published their initial experience of 25 cases using coronary buttons. The Button-Bentall became one of the most significant refinements of the classic procedure. In 1996, Jean Bachet et al. [3] reported on their extensive experience of more than 200 patients, demonstrating the superiority of the Button-Bentall and its successful use for various aetiologies. Moving on, and in the early 1990s, Galla et al. [4] introduced the BioBentall which was a home-made composite graft manufactured intraoperatively using a stented bioprosthesis—enabling root replacement in patients deemed unable to take anticoagulants. The BioBentall provided excellent long-term survival and very low rates of thromboembolism, bleeding complications, and reoperation. Since then, Urbanski et al. [5] reported on the successful use of composite grafts with oversized biologic valves, particularly in patients with a small native annulus

(< 23 mm). They suggested the biologic valve composite graft as an alternative for younger patients because of the ease of reoperative replacement of the biologic valve in the rare case of deterioration. In current experiences, aortic root replacement surgery attained acceptable early mortality, low postoperative stroke rates, and acceptable long-term survival. However, there are less data and head to head comparison on durability between the two-composite root procedures, i.e., mechanical vs biological. Yet, less data are available that describes activity and outcomes outside of specialist centers. We aimed to evaluate outcomes after first-time aortic root replacement with mechanical composite aortic valve graft (CVG) vs biological CVG.

Methods

Literature search strategy

Electronic database searches were performed with PubMed, Ovid Medline, Scopus, and COCHRANE Database of Abstract of Review of Effectiveness (DARE) from database inception to May 2015. Limits were placed on manuscripts written in the English language only. Search terms used included; root replacement, mechanical root, biological root, aortic root surgery, composite root replacement, aorta, aortic surgery, mechanical vs biological, Bentall procedure, Bentall surgery, and aortic root replacement.

To achieve maximum sensitivity, all search terms were combined with Boolean operators and searched as both key words and MeSH terms. Following exclusion of articles based on title or abstract, full-text articles selected had reference lists searched for any potential further articles to be included in this review.

Selection criteria

Studies in which patient cohorts who underwent mechanical or biological aortic root replacement were compared in the same study were included. Studies were excluded if they included a pediatric population, case reports or small case series, reviews, isolated biological or mechanical root replacement or editorials. When institutions published duplicate studies with accumulating numbers of patients or increased lengths of follow-up, only the most complete reports were included for quantitative assessment at each time interval.

Data extraction and critical appraisal

Data extracted included patient demographics, reason for aortic root replacement (type A aortic dissection, aortic aneurysm, infective endocarditis or others), clinical urgency, operative data, concomitant procedures, type of composite, in-hospital mortality, post-operative bleeding, renal failure, stroke, re-operation, and 1-year mortality. The quality of the evidence from each study was assessed using the MOOSE system.

Statistical analysis

This meta-analysis was performed in line with recommendations from the Cochrane Collaboration and Met-analysis of Observable Studies in Epidemiological (QUORUM) guidelines [6]. The effect measures estimated were risk ratio (RR) for dichotomous data which was reported with 95% confidence intervals. The risk ratio (or relative risk) represents the ratio of the risk of an event occurring in the Mechanical Composite Root Replacement (mCRR) group compared to the Biological Composite Root Replacement (bCRR) group.

A risk ratio of less than one favored the mCRR group. The point estimate of the risk ratio was considered statistically significant at the $p < 0.05$ level if the 95% confidence interval did not include the value one.

For continuous variables, the risk ratio was calculated with the Mantel–Haenszel Chi-square method using a "random effects" meta-analytical technique. The random effect model is particularly suitable for surgical research as it assumes that there is natural variation between the studies, and the calculated risk ratios thus have a more conservative value. For continuous variable such as time, statistical analysis using weighted mean difference was considered where appropriate. In reporting the results, square is indicative of point estimates of the treatment effect (RR or MWD) with 95% CIs indicated by horizontal bars. The diamond represents the summary estimate from the pooled studies with 95% CIs.

All analysis was conducted using Review Manager Version 5 (The Cochrane Collaboration, Software Update, Oxford).

Results

Study selection

A total of 1709 potential articles were identified from literature searches (Fig. 1). After elimination of review papers with further limiting the results to English and full text papers, 55 articles remained. After review of title and abstracts, 47 articles were excluded. Of these, 55 articles were selected based on the titles and abstracts, and a full examination of the text was performed. There were seven studies that matched the selection criteria and were suitable for meta-analysis [7–13].

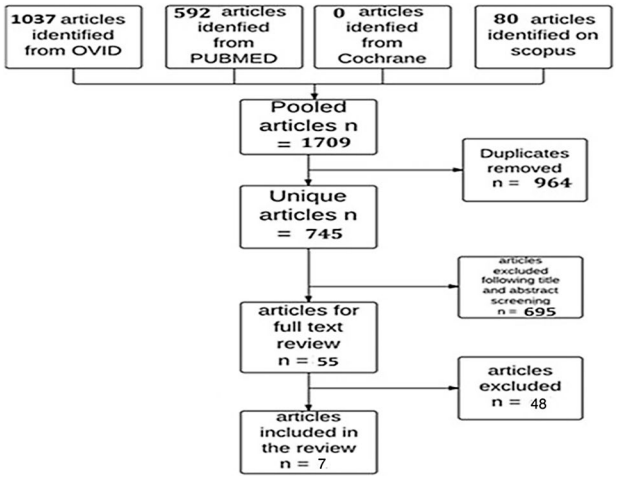

Fig. 1 PRISMA chart of the database search

Study characteristics and results

The characteristics of these studies are summarized in Table 1. All studies were comparative cohort studies between mCRR and bCRR.

A total of 2240 subjects were analyzed, where the average age of the pooled patients was reported 55 years. Around 15% of the population studied presented with acute type A dissection and on average patients were followed up to 10 years. Among the bCRR, 112 patients received cryopreserved homograft, 25 freestyle xenografts, 29 stentless porcine, 220 stented bovine pericardial, 472 stented porcine, 24 Medtronic freestyle and 146 patients were unspecified type of bCRR in the related articles.

Results of meta-analysis

Across the studies reviewed, there was no significance demonstrated for the In-hospital stroke rate between the two groups ($P = 0.90$) (Fig. 2). Additionally, the in-hospital mortality was not significantly higher in any given group ($P = 0.41$) (Fig. 3). Late stroke was not a significant finding in any group and no difference was demonstrated between the mechanical vs biological group ($P = 0.84$) (Fig. 4). Lastly, both reoperation rate and re-operations due to bleeding (Figs. 5, 6) were the same for both groups. It is imperative to mention that the results from these studies reflect early and mid-term outcomes only, while long-term follow-up data were not reported. Heterogeneity among studies was shown to be minimal as assessed by I^2 (ranging between 0–47%).

Discussion

There has been a surge of acceptable outcomes in surgical aortic root and this is seen in literature spanning over the past three decades. The classic Bentall operation is still considered by many authorities as the gold standard surgical approach for aortic root aneurysm disease [1]. The introduction of the exclusion technique improved outcomes and results even further and offered patients yet another line in

Table 1 Perioperative characteristics

Author	Number of patients	Mean age (yrs)	Male (%)	CPB time (mins)	ACx time (mins)	In-hospital mortality (%)	1 year mortality (%)
Mechanical composite root replacement							
Byrne et al. [7]	85	54 ± 10	79	n/a	n/a	2.4	11.8
Etz et al. [8]	476	55 ± 3	80	156 ± 106	100 ± 50	7.1	25
Lehr et al. [9]	51	48 ± 14	94	198 ± 67	141 ± 40	2.0	11
Ehrlich et al. [10]	37	71 ± 13	65	199	135 ± 42	14	n/a
Nakamura et al. [11]	31	55 ± 14	74	261 ± 111	196 ± 77	0	3.1
Zafar et al. [12]	242	53 ± 13	81	160 ± 30	112 ± 19	2.5	7.9
Etz et al. [13]	290	51 ± 11	80	244 ± 60	168 ± 48	2.8	16.9
Biological composite root replacement							
Byrne et al. [7]	136	53 ± 11	74	n/a	n/a	1.5	7.6
Etz et al. [8]	348	56 ± 3	67	151 ± 62	103 ± 29	7.7	20
Lehr et al. [9]	93	61 ± 14	67	221 ± 59	165 ± 44	2.2	16
Ehrlich et al. [10]	47	76 ± 22	70	230 ± 62	196 ± 55	4	n/a
Nakamura et al. [11]	33	63 ± 13	76	240 ± 70	179 ± 44	6.9	10.3
Zafar et al. [12]	64	67 ± 11	88	163 ± 28	117 ± 17	4.7	7.8
Etz et al. [13]	307	71 ± 13	73	260 ± 58	183 ± 49	4.9	33.9

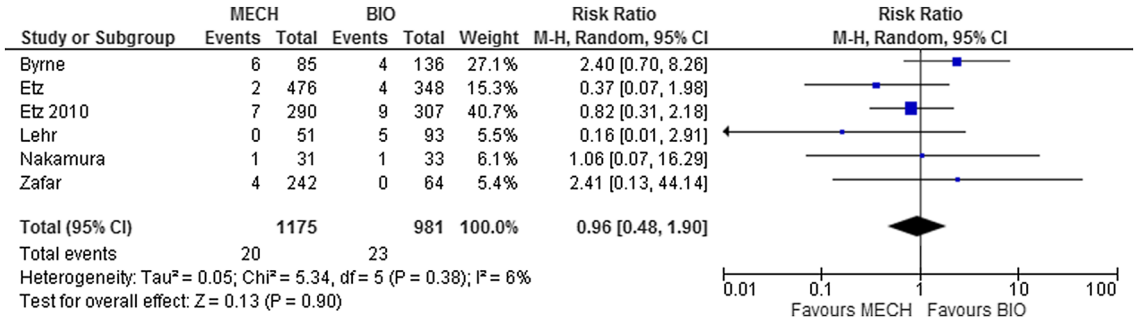

Fig. 2 In-hospital stroke

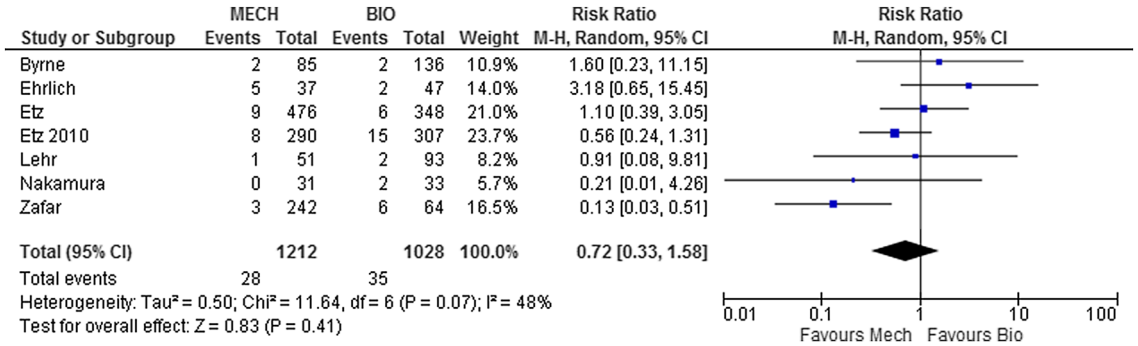

Fig. 3 In-hospital mortality

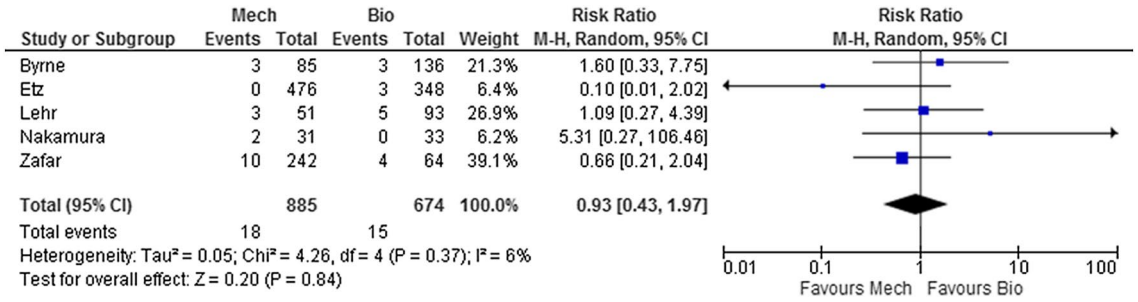

Fig. 4 Late stroke

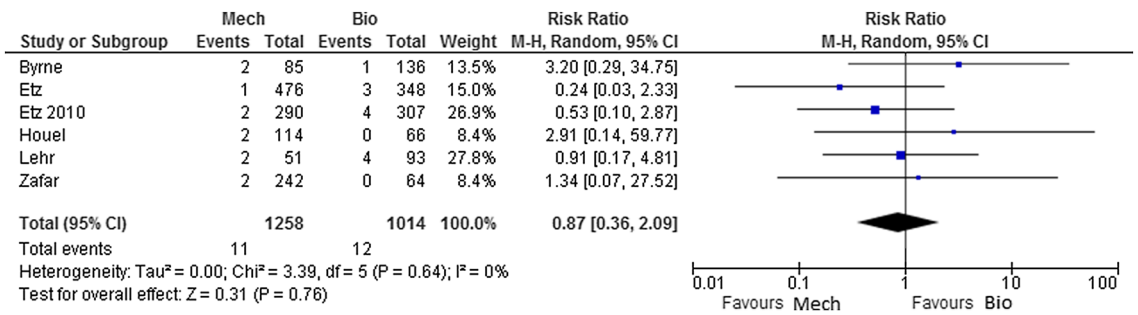

Fig. 5 Reoperation

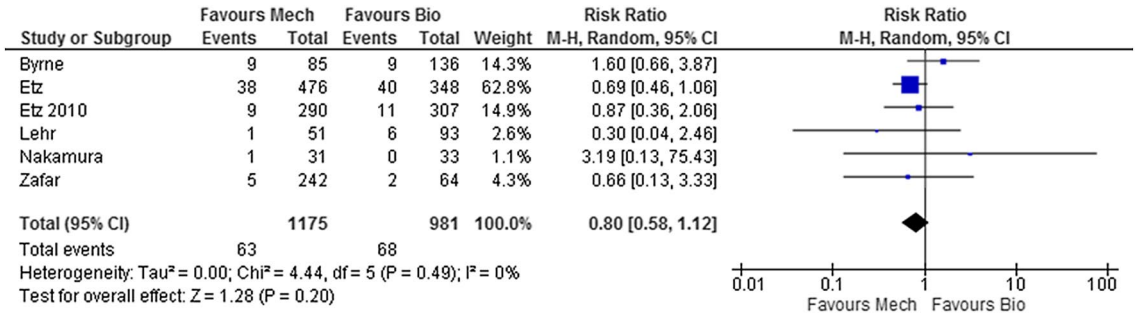

Fig. 6 Perioperative bleeding requiring reoperation

the armamentarium of surgical management of aortic root disease.

Valve-sparing replacement (VSR) has introduced yet another modification to the surgical technique, allowing patients the opportunity for aortic root reconstruction while retaining their native aortic valve [14]. In addition, improved durability of biological aortic valves has allowed the patient to have a composite aortic root replacement without the need for life-long anticoagulation. The improvement in durability of the new generation of the bioprosthetic aortic valves triggered several discussions about the cutoff age for recommendations for the use of mechanical vs biological aortic valves [15, 16], and partly due to above, the recent European guidelines for cardiothoracic surgery recommend the use of mechanical aortic valve replacement in patients aged 60 yrs old or less [17]. This was further supported by several published studies [18–20].

To date, there has been limited comparison regarding which composite aortic root management should be offered to patients. Most of the studies have been confounded by major selection bias or a limited number of patients for comparison and it is difficult to delineate any meaningfulness from those studies. Majority of the studies we pooled out in this review failed to demonstrate better patients' characteristics in current state of aortic root management.

On the contrary, the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database showed a linear increase in proximal aortic surgery in the United States between 2004 and 2009 [21]. We also noted in this review and especially in early years that there was increasingly a high number of root replacements being performed with mCRR operation whilst recently this has shifted and there has been an adoption of the bCRR procedures in the most recent period. This paradox is very difficult to explain and does not seem to be in harmony with current guidelines on aortic root management [17, 22]. However, to date there have been few direct comparisons of the early and long-term results. Kallenbach et al. [23] analyzed a series of 548 patients who underwent mCRR, supracoronary aortic replacement, or VSR. They were unable to show clinically meaningful differences in their early outcomes. Lim et al. [24] reviewed a smaller experience and also found equivalent perioperative outcomes, survival, and intermediate-term valve-related complications. Zehr et al. [25] confirmed these findings in a group of 203 cases, whereas Badiu and colleagues [26] in a series, similar to ours, compared 370 patients who underwent VSR, mCRR, and bCRR. They reported improved 5-year survival among patients undergoing VSR. Similar heterogeneity exists even when looking at the studies that compared mCRR and bCRR. Etz et al. [8] found no difference in early or long-term survival. Freedom from reoperation was similar in 597 patients having 1 of these 2 techniques of CRR.

It is imperative to note that biological aortic root replacement mandates no anti-coagulation. Is also worth noting that although no robust data exist on bCRR structural deterioration and long-term haemodynamic performance, its well perceived that time vs bioprosthesis is important with structural deterioration affecting bCRR which dictates further reoperation which is of course more technically challenging [27]. Yet, several indications for reoperation were observed; while in-hospital; the most common indication was bleeding, however, after discharge the trend shifts toward progressive valvular deterioration either in chronic pattern or acutely in the form of prosthetic valve endocarditis, valve-root dehiscence, and aneurysm. [7]. O'Brien et al. [28] reported a rate of graft degeneration by 9% at 12 years after initial surgery in patients above the age of 20 years old, and thus higher rate of reoperation which surely impacted mortality rate [21]. Nevertheless, if reoperations are required due to degenerative changes of the aortic valve, the valve can be replaced without changing the conduit itself. This was similarly described and performed with placement of the new valve into the neoannulus of homograft [29]. Lehr et al. [9] reported similar results in a smaller series of 144 cases, but Stamou and colleagues [30] in a recent review of data from the STS database including 13.473 cases reported higher in-hospital mortality among patients undergoing bCRR. However, patients undergoing bCRR were older and had a higher incidence of hypertension, chronic lung disease, diabetes,

and urgent operation, making intergroup comparison difficult in particular when aligning all the comparative studies and considering the heterogeneity it was obviated that no supremacy existed between mCRR & bCRR.

Conclusion

In the current systematic review, we find no statistical difference in short- and mid-term outcomes for biological and mechanical valve conduits for aortic root replacement; however, there remain missing data in terms of current valves long-term data, particularly with regard to reoperation rates, considering tissue conduits are not life long lasting as mechanical ones. Therefore, there is a need for multicentre randomized control trial to demonstrate any difference between the two groups at long term.

Compliance with ethical standards

Conflict of interest The authors have declared that no conflict of interest exists.

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