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Minimally invasive cardiac surgery: A systematic review and meta-analysis

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ABSTRACT

Background: Minimally invasive (MI) cardiac surgery was introduced to reduce problems associated with a full sternotomy. This meta-analysis aimed to investigate the effects of minimally invasive cardiac surgery on a range of clinical outcomes.
Methods: To identify potential studies (randomised/prospective clinical trials) systematic searches were carried out. The search strategy included the concepts of "minimally invasive" OR "MIDCAB" AND "coronary artery bypass grafting" OR "cardiac surgery". This was followed by a meta-analysis investigating cross-clamp time, cardiopulmonary bypass (CPB) time, operation time, ventilation time, intensive care unit (ICU) stay, hospital stay, incidence of myocardial infarction and of stroke/neurologic complications.
Results: Eight studies (9 intervention groups), totalling 596 participants were analysed. MI cardiac surgery was associated with a shorter ICU stay mean difference (MD) −0.7 days (95% confidence interval (CI) −1.23 to −0.18, $p = 0.009$) and longer cross-clamp MD 6.7 min (95% CI 1.24 to 12.17, $p = 0.02$), CPB MD 26.68 min (95% CI 10.31 to 43.05, $p = 0.001$), and operation times MD 55.03 min (95% CI 22.76 to 87.31, $p = 0.0008$). However no differences were found in the ventilation time MD −3.94 h (95% CI −8.09 to 0.21, $p = 0.06$), length of hospital stay MD −1.14 days (95% CI −3.11 to 0.83, $p = 0.26$) and in the incidence of myocardial infarction odds ratio (OR) 1.97 (95% CI 0.49 to 7.9, $p = 0.34$) or stroke/neurologic complications OR 0.67 (95% CI 0.11 to 4.05, $p = 0.66$).
Conclusions: Minimally invasive cardiac surgery is as safe as conventional surgery and could reduce costs due to a shorter period spent in ICU.

1. Introduction

Coronary artery bypass grafting (CABG) was first introduced in the 1960s [1], and, despite the rise of percutaneous coronary intervention, remains the standard of care for high risk patients including those with diabetes and/or complex left main or triple vessel disease [1–2]. The majority of CABG operations still involve a median sternotomy and use cardiopulmonary bypass combined with aortic cross-clamping and cardioplegic arrest. This can represent a frightening prospect for some patients with regard to having the chest 'cracked open' [1]. Minimally invasive cardiac surgery, where access to the heart is typically achieved through a left or right minithoracotomy, may alleviate this problem. The incision is smaller and the risks of wound infection following sternal trauma and problems with sternum healing are avoided [1]. Other possible benefits of minimally invasive cardiac surgery include a reduction in post-operative atrial fibrillation [3], reduced length of hospital stay [4] with earlier mobilisation of patients [5] and cost-effectiveness compared to traditional on-pump CABG [4]. Surgeons have also stated that anastomosing the left internal mammary artery to the left anterior descending artery is easier via minimally invasive cardiac surgery via a left minithoracotomy than a median sternotomy [6].

Minimally invasive cardiac surgery is not without its problems. Inadequacy of heart exposure with a left minithoracotomy may account for an increase in operation time and perioperative complications [7]. In the short term, patients may experience more pain due to involvement of the intercostal nerves [3] and excessive rib retraction [8]. The procedure is also more technically demanding [9]. One study has also reported that minimally invasive surgery increases ventilation time [5], although it should be noted that the majority of cases report shorter ventilation times [9–12].

The aims of this meta-analysis were to: i) investigate the effects of minimally invasive cardiac surgery on a range of clinical outcomes including cross-clamp time, cardiopulmonary bypass time, operation

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time, ventilation time, ICU and hospital stay, incidence of peri-operative myocardial infarction, and incidence of stroke/neurologic complications; and ii) relate these findings to established thresholds of clinical significance and provide an evidence based context for the use of minimally invasive cardiac surgery.

2. Methods

2.1. Search strategy

To identify potential studies systematic searches were carried out using the following databases: EMBASE, PubMed, Web of Science and the Cochrane Central Registry of Controlled Trials (CENTRAL). The search was supplemented by scanning the reference lists of eligible studies. The search strategy included the key concepts of "minimally invasive" AND "coronary artery bypass grafting" OR "MIDCAB" OR "cardiac surgery". All identified papers were assessed independently by two reviewers. A third reviewer was consulted to resolve disputes. Searches of published papers were conducted up until April 1st, 2016.

2.2. Types of studies to be included and excluded

Only randomized controlled trials (RCTs) and prospective trials of patients undergoing minimally invasive cardiac surgery vs. surgery via a median sternotomy were included. There were no language restrictions. Animal studies, review papers and retrospective trials were excluded. Studies that did not have any of the desired outcome measures were excluded. Incomplete data, or data from an already included study, were excluded. Other treatment modalities and interventions for coronary artery disease such as percutaneous coronary intervention were excluded. Other treatment modalities for valvular disease such as balloon valvuloplasty were excluded.

2.3. Participants/population

This meta-analysis analysed RCTs and prospective trials of both male and female adult (≥18 years) patients with coronary artery disease or valvular disease who were undergoing cardiac surgery using either minimally invasive cardiac surgery or cardiac surgery through a median sternotomy.

2.4. Intervention(s), exposure(s)

This meta-analysis considered all RCTs and prospective trials where patients with stable angina or acute coronary syndrome being treated with CABG or patients with valvular disease were exposed to either a median sternotomy or minimally invasive surgery. More specifically, all RCTs and prospective trials where the intervention of carrying out cardiac surgery without the use of a median sternotomy was performed.

2.5. Search results

Our initial search found 4490 articles. Of these 4345 studies were excluded on the basis of title and abstract. 128 studies were excluded as they were not RCTs or prospective trials. Of the RCTs and prospective trials we excluded 9 studies: 6 studies that were retrospective analyses; 2 studies that had no comparator group; and 1 study that had no reported outcomes (see supplementary Fig. S1). Eight studies (9 intervention groups) were included in our analysis [5,8–14].

2.6. Outcome(s)

The primary outcomes analysed were: cross-clamp time; cardiopulmonary bypass time; operation time; ventilation time; length of stay in the intensive care unit (ICU); length of hospital stay; incidence of myocardial infarction; and incidence of stroke/neurologic complications.

2.7. Risk of bias (quality) assessment

The modified JADAD scale was used to assess study quality and reporting [15].

2.8. Strategy for data synthesis

Odds ratios were calculated for dichotomous data. Mean differences were calculated for continuous data. Meta-analyses were completed for continuous data by calculating the mean difference between intervention and control groups from post-intervention data only. It is an accepted practice to only use post-intervention data for meta-analysis, but this method assumes that random allocation of participants always creates intervention groups matched at baseline for age, disease severity. All analyses were conducted using Revman 5.0 (Nordic Cochrane Centre, Denmark). A fixed effects inverse variance model was used unless heterogeneity was >75%, then a random effects model was used. Heterogeneity was quantified using the I^2 test [16]. We used a 5% level of significance and 95% confidence intervals; figures were produced using Revman 5.3.

3. Results

The 8 studies (9 intervention groups) [5,8–14] included in the analyses had an aggregate of 596 participants, 298 of which had minimally invasive cardiac surgery and 298 had conventional cardiac surgery via a median sternotomy. Table 1 summarizes the characteristics of the included studies. Supplementary Table S1 lists the excluded trials and reasons for exclusion.

3.1. Cross-clamp time

Five studies reported the cross-clamp time in minutes. The mean difference (MD) for the pooled analysis was MD 6.7 min (95% confidence interval (CI) 1.24 to 12.17, $I^2 = 91\%$, $p = 0.02$), see Fig. 1. Cross-clamp times were significantly longer in the minimally invasive group.

3.2. Cardiopulmonary bypass time

Five studies reported the cardiopulmonary bypass (CPB) time in minutes. The mean difference for the pooled analysis was MD 26.68 min (95% CI 10.31 to 43.05, $I^2 = 96\%$, $p = 0.001$), see Fig. 2. CPB times were significantly longer in the minimally invasive group.

3.3. Operation time

Four studies (5 intervention groups) reported the operation time in minutes. The mean difference for the pooled analysis was MD 55.03 min (95% CI 22.76 to 87.31, $I^2 = 95\%$, $p = 0.0008$), see Fig. 3. Minimally invasive cardiac surgery operations took a significantly longer time to complete compared to conventional cardiac surgery.

3.4. Ventilation time

Seven studies (8 intervention groups) reported the ventilation time in hours. The mean difference for the pooled analysis was −4.68 h (95% CI −9.27 to −0.1, $I^2 = 98\%$, $p = 0.05$), see Fig. 4. There was a strong trend towards a shorter ventilation time in patients operated on by minimally invasive cardiac surgery; however, this failed to reach significance.

3.5. Length of ICU stay

Six studies reported the length of ICU stay in days. The mean difference for the pooled analysis was MD −0.7 days (95% CI −1.23 to −0.18, $I^2 = 92\%$, $p = 0.009$), see Fig. 5. Patients operated on by