A meta-analysis of intraoperative factors associated with postoperative cardiac complications

**Abstract**

**Background:** Preoperative cardiac risk is commonly determined with the help of risk scores and risk stratification tools. This predetermined cardiac risk may be profoundly changed by intraoperative surgical events. This meta-analysis aimed to identify intraoperative factors that independently predict postoperative cardiac complications in the presence of preoperative cardiac risk factors.

**Method:** A PubMed Central search was conducted from January 1966 to June 2010, to identify independent intraoperative predictors of postoperative cardiac complications in observational perioperative studies and randomised controlled trials which controlled for preoperative cardiac risk factors.

**Results:** Eleven studies were identified for inclusion in this meta-analysis. Intraoperative blood transfusion (odds ratio (OR) 2.6, 95% confidence interval (CI) 1.8-3.4) was the only independent intraoperative risk predictor identified in more than one study. Other identified independent intraoperative factors included a > 20 mmHg fall in mean arterial blood pressure for > 60 minutes (OR 3.0, 95% CI 1.8-4.9), > 30% increase in baseline systolic pressure (OR 8.0, 95% CI 1.3-50), tachycardia in the recovery room (> 30 beats per minute from baseline for > 5 minutes) (OR 7, 95% CI 1.9-26), new onset atrial fibrillation (OR 6.6, 95% CI 2.5-20), hypothermia (OR 2.2, 95% CI 1.1-5) and remote ischaemic preconditioning (OR 0.22, 95% CI 0.07-0.67). None of these studies controlled for blood transfusion.

**Conclusion:** Both surgical and haemodynamic intraoperative events significantly increased the risk of postoperative cardiac complications. Intraoperative blood transfusion has the strongest evidence that supports this finding. It is possible that modification of these intraoperative risk factors by anaesthetists and surgeons might reduce postoperative cardiac events.

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**Introduction**

A recent study has shown that 5% of patients who undergo noncardiac surgery will suffer a perioperative myocardial infarction. More than 11% of these patients will die within 30 days of the surgery. Preoperative cardiac risk is commonly determined with the help of risk scores and risk stratification tools, such as the Revised Cardiac Risk Index (RCRI). These scores are of limited utility as intraoperative events that relate to the surgery itself profoundly alter this calculated cardiac risk. If these events could be identified and their impact quantified, then surgeons and anaesthetists might be able to intervene to improve perioperative cardiac outcomes.

The aim of this meta-analysis was to identify intraoperative factors that changed a patient’s preoperative cardiac risk of postoperative cardiac complications.

**Method**

A meta-analysis was conducted to identify modifiable independent intraoperative predictors of postoperative cardiac complications in studies that controlled for preoperative cardiac risk factors. The Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines were adhered to in conducting and reporting this meta-analysis.
Study end-points
The intention was to extract data on postoperative cardiac complications from each study.

Study identification and selection
On 22 June 2011, a search of PubMed Central was conducted from January 1966 to June 2010. The terms that were used in the search strategy were “intraoperative risk stratification”, “intraoperative risk prediction”, “perioperative risk stratification” and “perioperative risk assessment”. The limits that were activated on the search included “humans”, “English” and “all adults 19+ years”.

Observational perioperative studies and randomised controlled trials of noncardiac surgery were included. Studies published only in abstract form, non-human, cardiac surgical, and paediatric studies, those that considered preoperative risk factors only, those that did not report a postoperative cardiac complication, and studies of endovascular surgery only were excluded. Citations were independently screened, data abstracted and methodological quality assessed using a standardised data extraction sheet. Any disagreements were resolved by the reviewers who were not involved in the aforementioned processes. Full papers for all relevant citations were retrieved for detailed evaluation. Where potential intraoperative predictors of postoperative adverse outcomes were identified, but not reported, the authors of studies were contacted for the data.

Data analysis
The quality of each study was assessed for completeness of follow-up, method of patient follow-up, blinding of outcome adjudicators and factors entered into the multivariable analysis. Concordance of article extraction was determined using a kappa statistic. Comparability of the prevalence of preoperative cardiac risk factors between the cohorts from the included studies were analysed using a Kruskal-Wallis test [non-parametric analysis of variance (ANOVA) test] (GraphPad InStat version 3.06®, GraphPad Software, 2003).

The data from all the studies were converted to adjusted odds ratios (OR) for the meta-analysis. Additional data from two studies were received to enable this conversion to be performed. The relative risk (RR) was calculated using the following formula:

\[ \text{RR} = \frac{1 - e^{HR \times (1 - P_0)}}{P_0} \]

where \( P_0 \) is the proportion of patients without the intraoperative independent predictor who sustained an adverse cardiac outcome.

From the RR, the OR could be calculated as follows:

\[ \text{OR} = \frac{\text{RR} \times (1 - P_0)}{1 - \text{RR} \times P_0} \]

The meta-analysis was conducted using RevMan version 4.3® software (The Nordic Cochrane Centre, Kobenhavn, Denmark). Heterogeneity between studies was assessed using univariate chi-square analysis. Random or fixed-effects models were used, based on the presence or absence of significant heterogeneity between studies, respectively. Pooled dichotomous outcomes were reported as the OR and the 95% CI.

Results
In the literature search from 1966-2010, 2 013 studies were identified. Forty-two studies were identified for full-paper analysis. The kappa statistic was 0.87 (95% CI 0.78-
A further 10 studies were identified from the authors’ records and by reviewing the references of papers identified for further analysis. From these 52 studies, 11 fulfilled the inclusion criteria (Figure 1).1,6,7,9,12-18

The characteristics of the included studies are shown in Table I. From the 11 included studies, five were prospective.1,12,13,15,17 These studies recruited patients from a variety of surgical disciplines, and included both elective and emergency patients.

The study quality characteristics are shown in Table II.

The variation between the prevalence of the preoperative cardiac risk factors identified in the RCRI6 did not differ significantly between the study cohorts (Table III).

### Control for preoperative cardiac risk factors

Based on the five RCRI factors,5 10 studies (91%) controlled for a history of ischaemic heart disease,1,7,9,12-18 eight studies (73%) controlled for congestive heart failure,1,6,7,12,14,16-18 seven (64%) for renal dysfunction,1,6,7,9,16-18 and three (27%) for diabetes,6,7,12,13,16,18 and three (27%) for stroke.6,7,18

One study controlled for the number of RCRI risk factors.17 Two studies controlled for all five of the RCRI variables included in the European guidelines for cardiovascular assessment for noncardiac surgery,7,18 two studies for four risk factors,6,16 three studies for three of the risk factors,1,9,12 two studies for two of the risk factors,13,14 and one study for ischaemic heart disease only.15

### Primary adverse cardiac outcome

The definition of a postoperative cardiac complication varied between the studies as shown in Table I. However, all the studies included myocardial infarction in the outcome definition.

### Independent intraoperative factors predicting postoperative cardiac complications

Seven independent intraoperative factors were identified when controlling for preoperative cardiac risk factors. These included risk factors associated with surgical complexity (operative duration and blood transfusion), physiological for diabetes,6,7,12,13,16,18 and for stroke.6,7,18

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Table II: Study quality characteristics

| Authors            | Patients with completed follow-up (n/N) | Blinded outcome assessment | Method of patient follow-up | Preoperative cardiac risk factors adjusted for in the analysis |
|--------------------|-----------------------------------------|----------------------------|-----------------------------|---------------------------------------------------------------|
| Charlson et al12   | 254/278 (91.4%)                         | Yes                        | Daily patient review        | Coronary artery disease, cardiomegaly (only patients with hypertension and diabetes enrolled) |
| Frank et al13      | 270/300 (90%)                           | Yes                        | Holter monitoring           | Age, ASA class, coronary artery disease, beta-blockade, diabetes, hypertension |
| Sprung et al14     | 6 946/6 948 (100%)                      | No                         | Patient charts              | Coronary artery disease, cardiac failure, beta-blockade, valvular heart disease |
| Ali et al15        | 82/82 (100%)                            | Yes                        | Patient charts              | Age, coronary artery disease, cholesterol, hypertension, NYHA functional capacity, POSSUM score |
| Davenport et al8   | 182 900/183 069 (99.9%)                 | No                         | Chart review, morbidity and mortality meetings, letter or telephonic patient communication | Age, ASA class, cardiac failure, CVA, gender, renal dysfunction |
| Bursi et al16      | 359/359 (100%)                         | Yes                        | Chart review, telephonic interviews, death certificates, autopsy reports | Age, coronary artery disease, diabetes, gender, hypertension, renal dysfunction, smoking history |
| Winkel et al18     | 317/317 (100%)                         | No                         | Outpatient visits           | Cardiac risk classification, gender, hypertension |
| D’Ayala et al9     | 300/300 (100%)                         | No                         | Chart review                | Coronary artery disease, diabetes, hypertension, renal dysfunction |
| Devereaux et al1   | 8 331/8 351 (99.7%)                    | No                         | Telephonic interviews       | Age, cardiac failure, heart rate, renal dysfunction, statin therapy |

ASA: American Society of Anesthesiologists, CVA: cerebrovascular accident, NYHA: New York Heart Association, POSSUM: Physiologic and Operative Severity Score for the enUmeration of Mortality and Morbidity

Table III: Comparability of the preoperative Revised Cardiac Risk Index cardiac risk factors in included studies

| Authors            | Ischaemic heart disease | Cardiac failure | Diabetes | Renal dysfunction | Stroke |
|--------------------|-------------------------|-----------------|----------|-------------------|--------|
| Charlson et al12   | 17%                     | 12%             | 36%      | 8%                | 11%    |
| Frank et al13      | 49%                     | Not reported    | 16%      | 2%                | Not reported |
| Sprung et al14     | 2%                      | 1%              | 1%       | Not reported      | 1%     |
| Ali et al15        | 26%                     | 4%              | 5%       | 4%                | Not reported |
| Davenport et al8   | Not reported            | 23%             | 19%      | 22%               | 8%     |
| Bursi et al16      | 27%                     | 22%             | 38%      | 22%               | Not reported |
| Kheterpal et al17  | 10%                     | 1%              | 13%      | 2%                | 5%     |
| Oscarsson et al17  | 53%                     | 40%             | 20%      | Not reported      | 28%    |
| Winkel et al18     | 24%                     | 6%              | 15%      | 8%                | 12%    |
| D’Ayala et al9     | 47%                     | Not reported    | 70%      | 30%               | Not reported |
| Devereaux et al1   | 43%                     | 6%              | 29%      | 5%                | 15%    |
| p-value            | 0.19                    | 0.45            | 0.10     | 0.45              | 0.35   |

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Predictors (tachycardia, hypotension, hypertension and hypothermia), and an interventional predictor (remote ischaemic preconditioning).

In our study, a meta-analysis was conducted on the need for intraoperative blood transfusion only, as it was the only intraoperative risk predictor that was presented in more than one publication. Six studies reported on the association between blood transfusion and postoperative adverse cardiac events. A single study was excluded from the blood transfusion meta-analysis, as data from the same centre was included in a larger dataset.6,19 The need for intraoperative blood transfusion was associated with significantly increased adverse cardiac events (OR 2.6, 95% CI 1.8-3.4) (Figure 2). However, there is significant heterogeneity in the estimate of risk for blood transfusion, probably due to different definitions of a postoperative cardiac complication between the studies (Table I) and different definitions for blood transfusion. These definitions
Original Research: A meta-analysis of intraoperative factors associated with postoperative cardiac complications

190
2012;18(4) South Afr J Anaesth Analg

include bleeding disorder, blood given, units of blood given, and serious bleeding (defined as disabling bleeding or two or more units given). Only one of these studies controlled for hypotension and tachycardia, neither of which were independently predictive of adverse cardiac events in the presence of red blood cell transfusion and surgery exceeding 3.8 hours in duration (OR 2.2, 95% CI 1.3-3.7).7

Other identified independent intraoperative factors included > 20 mmHg fall in mean arterial blood pressure for > 60 minutes (OR 3.0, 95% CI 1.8-4.9),3 > 30% increase in baseline systolic pressure (OR 8.0, 95% CI 1.3-50),11 tachycardia in the recovery room (> 30 beats per minute from baseline for > 5 minutes) (OR 7, 95% CI 1.9-26),17 new onset atrial fibrillation (OR 6.6, 95% CI 2.5-20),13 hypothermia (OR 2.2, 95% CI 1.1-5),13 and remote ischaemic preconditioning (OR 0.22, 95% CI 0.07-0.67).15 None of these studies controlled for blood transfusion.

Discussion

Intraoperative events significantly increased the risk for postoperative cardiac complications. This meta-analysis has identified a number of intraoperative predictors, the majority of which fall into two broad groups, namely surgery-related predictors (e.g. intraoperative bleeding or operative time) and haemodynamic predictors (e.g. intraoperative tachycardia or hypotension). It is difficult to determine the relative importance of these two groups, as the majority of studies did not control for each other. Some controlled for surgical predictors only,6,9,14,16 while others controlled only for physiological haemodynamic predictors.12,17,18 Only two studies controlled for both groups.17 However, the data from Devereaux et al do not inform this discussion, as only haemodynamics are considered.

The data from Kheterpal et al suggest that intraoperative surgical predictors may be stronger predictors of cardiac complications than perioperative haemodynamic changes. In this study, a number of haemodynamic variables for hypotension and tachycardia were examined in 10-minute epochs. None of these were shown to be independent predictors of adverse cardiac events after adjusting for operative duration and the number of packed red blood cell units given.7 Although the heterogeneity associated with blood transfusion as a risk factor is large within this meta-analysis, the signal that perioperative blood transfusion is strongly associated with adverse perioperative cardiac outcomes is consistent. This is in keeping with other studies that suggest that surgery complexity6,17 and the extent of the surgical insult12,17,18 are strong modifiers of perioperative cardiac risk.

Adding independent intraoperative risk factors to preoperative risk prediction models reduces the significance of “traditional” preoperative risk factors. Arguably, the RCRI is the most commonly used preoperative risk scoring system. Of the five risk factors in this model (a history of coronary artery disease, heart failure, stroke, diabetes and the presence of renal dysfunction), only a history of stroke6,7 and renal dysfunction1,6,9 were shown to remain as independent predictors once the intraoperative predictors were added to the models.

Not surprisingly, the strongest preoperative predictors of perioperative cardiac complications, known as “active cardiac conditions” (unstable coronary syndromes, decompensated cardiac failure, severe valvular disease and significant arrhythmias), also remain in the intraoperative models. These included active or recent congestive cardiac failure,6,7,14 or recent coronary interventions.7 Elective surgery should be postponed until these conditions are successfully managed.2

From these data, it would appear that anaesthetists and surgeons have the capacity to alter cardiac risk by management decisions taken prior to and during surgery. Preoperatively, this could include the decision to undertake a lesser procedure.6 Intraoperatively, temporising measures could be undertaken in unexpectedly difficult or complicated cases. These management decisions might have a significant impact on patient cardiac morbidity.

This meta-analysis suggests that further work is necessary to accurately determine the relative importance of

| Study or sub-category | Odds ratio (SE) | Weight |
|-----------------------|----------------|--------|
| Sprung                | 1.2400 (0.0734)| 21.90  |
| Davenport             | 1.4700 (0.1038)| 23.81  |
| Burnt                | 4.4500 (0.4134)| 17.57  |
| D’Aylia              | 2.6000 (0.2919)| 18.22  |
| Devereaux           | 3.6200 (0.2862)| 19.93  |
| Total (95% CI)       |                | 1.00   |

Test for heterogeneity: DM² = 125.63, df = 4 (P < 0.00001), I² = 96.8%

Test for overall effect: Z = 3.55 (P < 0.00001)

Figure 2: Meta-analysis of perioperative blood transfusion and associated adverse cardiac events
intraoperative risk factors on perioperative adverse cardiac events. Once these factors have been defined, interventional trials should be designed to test different intraoperative management plans.

Limitations

This meta-analysis is limited by a paucity of data specifically addressing intraoperative risk factors that modify preoperative cardiac risk prediction. Only a single risk factor, blood transfusion, provided enough data to conduct a meta-analysis. This analysis confirms that perioperative blood transfusion significantly and independently increases the risk of perioperative cardiovascular complications. Differences in baseline cardiac risk, type of surgery performed (major noncardiac, vascular surgery), study quality (retrospective vs. prospective) and definitions used for blood transfusion and cardiac outcomes between the studies mean that this risk could not be accurately determined. Despite these limitations, perioperative physicians should keep in mind that perioperative blood transfusion significantly increases the risk of an adverse cardiac outcome in patients undergoing major noncardiac surgery. Other potential intraoperative predictors were identified in this review, although it is difficult to determine their impact on cardiac risk.

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References

1. Devereaux PJ, Xavier D, Pogue J, et al. Characteristics and short-term prognosis of perioperative myocardial infarction in patients undergoing noncardiac surgery: A cohort study. Ann Intern Med. 2011;154(8):523-528.
2. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery; executive summary; a report of the American College of Cardiology/American Heart Association task force on practice guidelines (writing committee to revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery); developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. Circulation. 2007;116(17):1971-1996.
3. Poldermans D, Bax JJ, Borsma E, et al. Guidelines for preoperative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery: the Task Force for Preoperative Cardiac Risk Assessment and Perioperative Cardiac Management in Non-cardiac Surgery of the European Society of Cardiology (ESC) and European Society of Anaesthesiology (ESA). Eur Heart J. 2009;30(22):2769-2812.
4. Gupta PK, Gupta H, Sundaram A, et al. Development and validation of a risk calculator for prediction of cardiac risk after surgery. Circulation. 2011;124(4):381-387.
5. Lee TH, Marcontonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation. 1999;100(10):1043-1049.
6. Davenport DL, Ferraris VA, Hosokawa P, et al. Multivariable predictors of postoperative cardiac adverse events after general and vascular surgery; results from the patient safety in surgery study. J Am Coll Surg. 2007;204(6):1199-1210.
7. Kheterpal S, O’Reilly M, Englesbe MJ, et al. Preoperative and intraoperative predictors of cardiac adverse events after general, vascular, and urological surgery. Anesthesiology. 2009;110(1):58-66.
8. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA. 2000;283(15):2008-2012.
9. D’Ayala M, Huzar T, Briggs W, et al. Blood transfusion and its effect on the clinical outcomes of patients undergoing major lower extremity amputation. Ann Vasc Surg. 2010;24(4):486-473.
10. Zhang J, Yu KF. What’s the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. JAMA. 1998;280(19):1690-1691.
11. Levy M, Heels-Ansdell D, Hirala R, et al. Prognostic value of troponin and creatine kinase muscle and brain isoenzyme measurement after noncardiac surgery: a systematic review and meta-analysis. Anesthesiology. 2011;114(4):796-806.
12. Charlson ME, MacKenzie CR, Gold JP, et al. The preoperative and intraoperative hemodynamic predictors of postoperative myocardial infarction or ischemia in patients undergoing noncardiac surgery. Ann Surg. 1989;210(5):637-648.
13. Frank SM, Fleisher LA, Breslow MJ, et al. Perioperative maintenance of normothermia reduces the incidence of morbidity cardiac events. A randomized clinical trial. JAMA. 1997;277(14):1127-1134.
14. Sprung J, Abdelmalek B, Gottlieb A, et al. Analysis of risk factors for myocardial infarction and cardiac mortality after major vascular surgery. Anesthesiology. 2000;93(1):129-140.
15. Ali ZA, Callaghan CJ, Lim E, et al. Remote ischemic preconditioning reduces myocardial and renal injury after elective abdominal aortic aneurysm repair: a randomized controlled trial. Circulation. 2007;116(11 Suppl):I98-I105.
16. Bursi F, Barbieri A, Politi L, et al. Perioperative red blood cell transfusion and outcome in stable patients after elective major vascular surgery. Eur J Vasc Endovasc Surg. 2009;37(3):311-318.
17. Oscarsson A, Fredrikson M, Sorliien M, et al. Predictors of cardiac events in high-risk patients undergoing emergency surgery. Acta Anaesthesiol Scand. 2009;53(8):986-994.
18. Winkel TA, Schouten O, Hoeks SE, et al. Prognosis of transient new-onset atrial fibrillation during vascular surgery. Eur J Vasc Endovasc Surg. 2009;38(6):683-688.
19. Khuri SF, Henderson WG, Daley J, et al. The patient safety in surgery study: background, study design, and patient populations. J Am Coll Surg. 2007;204(6):1089-1102.
20. Cuypers PW, Gardien M, Buth J, et al. Cardiac response and complications during endovascular repair of abdominal aortic aneurysms: a concurrent comparison with open surgery. J Vasc Surg. 2001;33(2):353-360.