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Predictive risk factors for intra-abdominal hypertension after cardiac surgery

Nathan Tyson * and Christopher Efthymiou

Department of Cardiac Surgery, Glenfield Hospital, Leicester, UK

* Corresponding author. Department of Cardiothoracic Surgery, Glenfield Hospital, Leicester, UK. Tel: +44-7595-947102; e-mail: nathan.tyson@nhs.net (N. Tyson).

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Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was is it possible to identify predictive risk factors for the development of intra-abdominal hypertension (IAH) or abdominal compartment syndrome after cardiac surgery. Altogether 131 papers were found using the reported search, of which **7** represented the best evidence to answer the clinical question. The authors, journal, date and country of publication, patient group studied, study type, relevant outcomes and results of these papers are tabulated. A total of 755 patients were included, with the incidence of IAH between 26.9% and 83.3%. The limited evidence on IAH after cardiac surgery should be interpreted with caution. Obesity is a strong predictor of postoperative IAH, although not confined to a central pattern and body mass index is correlated with intra-abdominal pressure (IAP). Prolonged cardiopulmonary bypass and aortic cross-clamp time predisposed to IAH in 4 cohorts. IAH in cardiac surgery patients is associated with hepatic and renal impairment, and corresponding biochemical markers may be helpful in screening, although lacking specificity. In contrast to the development of IAH in other settings, the evidence for the role of fluid balance is poor. Accurate prediction of IAH remains elusive. Based on the available evidence, routine IAP measurement should be considered postoperatively in patients with obesity, particularly those with renal or hepatic impairment, prolonged cardiopulmonary bypass or operative time, requiring vasopressor support, to prevent the deleterious effects of IAH.

Keywords: Abdominal compartment syndrome • Intra-abdominal hypertension • Abdominal pressure • Cardiac surgery

INTRODUCTION

A best evidence topic was constructed according to a structured protocol. This is fully described in the *ICVTS* [1].

THREE-PART QUESTION

In [adult patients undergoing cardiac surgery], what are the [predictive risk factors] for the development of [postoperative intra-abdominal hypertension (IAH) or abdominal compartment syndrome]?

CLINICAL SCENARIO

A 69-year-old male patient undergoes urgent on-pump coronary artery bypass grafting without initial complications and has an intra-aortic balloon pump in situ. He subsequently develops abdominal distension, lactic acidosis and renal impairment; and computed tomography suggests bowel ischaemia. Emergency laparotomy is performed with no intraoperative evidence of intestinal ischaemia, and the patient subsequently improves following decompression. A clinical diagnosis of IAH is made and you are aware that conservative medical therapies can be used to manage this entity without the need for laparotomy. You consider if there are any factors which may be been suggestive of IAH in your patient, and therefore avoided laparotomy.

SEARCH STRATEGY

A search was performed of the MEDLINE and Embase databases from 1946 to September 2020 using the Ovid interface. Search strategy included:

[exp cardiac surgery/OR exp cardiopulmonary bypass/OR exp heart surgery/OR exp thoracic surgery/] AND [exp abdominal compartment syndrome/OR exp abdominal pressure/OR exp intraabdominal hypertension/OR intraabdominal pressure.mp OR abdominal compartment.mp OR exp intra-abdominal hypertension/or intra-abdominal pressure.mp] AND [risk*.mp OR predict*.mp]

SEARCH OUTCOME

A total of 131 papers were found using the reported search. From these, 7 papers were identified that provided the best evidence to answer the question. All papers reviewed were of level IV evidence. These are presented in Table 1.

Table 1: Best evidence papers

Author, date, journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Kilic *et al.* (2020), Turk gogus kalp damar cerrahisi dergisi, Turkey [2] Observational study (level IV)	July 2016–January 2017 100 cardiac surgery patients on CPB 49 IAH (≥12 mmHg) 51 non-IAH Length of ITU stay, fluid balance, CVP and RIFLE score WSACS Intravesicular IAP method at induction, 0, 12 and 24 h	Central venous pressure Hypertension Age Intraoperative lactate CPB time Inotrope usage Transfusion requirements	IAP $r = 0.499$; $P = 0.0001$ OR 6.87; $P = 0.023$ OR 0.93; $P = 0.032$ OR 0.57; $P = 0.035$ 93 ± 47 vs. 60 ± 25 min; $P = 0.0001$ $P < 0.002$ 2.3 ± 1 vs 0.5 ± 0.7 units; $P = 0.0001$	Significant increase at 12 and 24 h found only in IAH group Patients developing IAH were also found to have higher rates of AF ($P = 0.002$) and aortic atheroma (0.003)
Nazer *et al.* (2019), Surgery, Saudi Arabia [3] Observational study (level IV)	January–August 2018 50 CABG patients 25 obese (≥30 kg/m^2) 25 non-obese (<30 kg/m^2) Haemodynamic parameters, liver function and Schindl score WSACS Intravesicular IAP method 4 hourly for 24 h	IAH incidence Baseline IAP Change in IAP Peak IAP Mean APP Renal injury Peak ALT	84 vs 20%; $P < 0.001$ 10.3 ± 2.4 vs 8.4 ± 2.4 mmHg; $P = 0.001$ 5.1 ± 3.3 vs 2.2 ± 2.4 mmHg; $P = 0.001$ 15.4 ± 1.6 vs 10.6 ± 1.6 mmHg; $P = 0.011$ 63.0 ± 8.0 vs 70.1 ± 11 mmHg; $P = 0.017$ 32% vs 8%; $P = 0.034$ 59.0 ± 15 vs 46.5 ± 9 U/l; $P = 0.045$	1:1 matching of groups based on BMI (≥30 kg/m^2) No difference in transfusion requirement, postoperative dialysis or mortality
Mazeffi *et al.* (2016), J Cardiothorac Vasc Anesth, USA [4] Observational study (level IV)	Duration not specified 42 cardiac surgery patients on CPB 35 IAH (≥12 mmHg) 7 non-IAH Pre- and postoperative renal function WSACS intravesicular IAP method at 0, 3, 6, 12 and 24 h	Postoperative fluid balance Total perioperative fluid balance Renal injury Urinary NGAL at 24 h	1,731 vs 1,812 ml; $P = 0.88$ 4,841 vs 3,118 ml; $P = 0.79$ RR -31.4, 95% CI -48.0 to 6.3; $P = 0.09$ 156.0 ± 228.2 vs 25.3 ± 25.5 ng/ml; $P = 0.002$	Small number of patients ($n = 7$) without IAH No significant association with CPB time, or ventricular function with IAH Peak IAP after 3–6 h postoperatively
Smit *et al.* (2016), Ann Intensive Care, The Netherlands [5] Observational study (level IV)	October 2014–March 2015 186 elective patients 38 obese (≥30 kg/m^2) 148 non-obese (<30 kg/m^2) Pre- and postoperative renal function WSACS intravesicular IAP method at ICU admission	Mean IAP (mmHg) IAH Postoperative creatinine WC WHR CPB time BMI	10.4 ± 4.7 vs 8.7 ± 4.2 mmHg; $P = 0.031$ 39.5% vs 23.6%; $P = 0.667$ IAP $r^2 = 0.003$; $P = 0.491$ IAP 9.2 ± 4.3 vs 8.9 ± 4.4 mmHg; $P = 0.687$ IAP 9.3 ± 4.3 vs 8.9 ± 4.4 mmHg; $P = 0.171$ 177.6 ± 95.4 vs 143.7 ± 64.5 min; $P = 0.049$ IAP $r^2 = 0.05$; $P = 0.003$	IAP >20 mmHg measured in 4 patients IAH has 26.9% prevalence BMI and WHR responsible for 5% of IAP variance in IAP No significant correlation between IAP and perfusion or cross-clamp time

Continued

Table 1: Continued

Author, date, journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments
Iyer *et al.* (2014), Crit Care Resusc, Australia [6] Observational study (level IV)	February–May 2013 108 adult patients; elective and emergency 50 IAH (≥12 mmHg) 58 non-IAH Haemodynamics, SOFA, APACHE II scores, liver and renal function WSACS intravesicular IAP method twice daily	SOFA score CPB time Cross-clamp time ITU stay CVP (mmHg) Serum AST Serum albumin Admission pH	>6, AUC 0.65; $P = 0.01$ 120 vs 93 min; $P = 0.01$ 80 vs 70 min; $P = 0.02$ 3 vs 2 days; $P = 0.005$ 18 ± 4.0 vs 15 ± 3.1 mmHg; $P < 0.001$ ≥46 U/l AUC 0.65; $P = 0.04$ ≤32 g/l AUC 0.63; $P = 0.04$ 7.27 ± 0.06 vs 7.30 ± 0.05; $P = 0.01$	No reported incidence of ACS Data analysed only for 5 post-operative days (>90% of study cohort) Peak in IAP at postoperative day 5
Dalfino *et al.* (2013), Interact CardioVasc Thorac Surg, Italy [7] Observational study (level IV)	3 months (date not specified) 69 on- and off-pump elective patients 22 IAH (≥12 mmHg) 47 non-IAH Haemodynamic data, fluid balance, urine output, SOFA and RIFLE scores WSACS intravesicular IAP method at induction, 2, 4 6, 12 and 24 h	Fluid balance CVP (mmHg) Baseline IAP Vasopressor usage SOFA score On-pump surgery Acute kidney injury	IAP $r^2 = 0.4548$, $P < 0.0001$ IAP ($r = 0.3881$, $P < 0.0001$) IAH OR 3.35, 95% CI 1.68 to 5.37; $P = 0.012$ OR 4.58, 95% CI 2.76 to 5.72; $P = 0.002$ OR 4.81, 95% CI 1.57 to 6.9; $P = 0.029$ OR 2.68, 95% CI 1.85 to 3.93; $P = 0.049$ OR 2.73, 95% CI 1.92 to 5.12; $P = 0.037$ OR 2.27, 95% CI 1.12 to 4.71; $P = 0.035$	No association between IAH and hypertension, peripheral arterial disease or CPB time
Dabrowski and Rzecki (2009), Acta Clin Belg, Poland [8] Observational study (level IV)	January 2006–December 2007 50 adult cardiac surgery patients 27 group A (<75 kg) 23 group B (>75 kg) WSACS intravesicular IAP method at 11 perioperative time points	BMI CVP CPB time Actual body weight APP	Baseline IAP $r = 0.8$; $P < 0.0001$ Postoperative IAP $r = 0.79$; $P < 0.001$ IAP $r = 0.55$; $P < 0.001$ IAP group A $r = 0.34$; $P < 0.05$ IAH prevalence $\chi^2 = 1.08$; $P = 0.28$ MAP $r = 0.96$; $P \leq 0.001$ SVR $r = 0.38$; $P < 0.001$	Peak IAP noted to occur 6 h after surgery, with decreasing trend after 18 h Drop in APP associated with drop in MAP, no association with body weight Significant correlations between IAP and cardiac output, MAP, stroke volume and pulmonary wedge pressure

ACS: abdominal compartment syndrome; APP: abdominal perfusion pressure; AST: aspartate aminotransferase; BMI: body mass index; CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; CVP: central venous pressure; IAH: intra-abdominal hypertension; IAP: intra-abdominal pressure; MAP: mean arterial pressure; NGAL: neutrophil gelatinase-associated lipocalin; SOFA: Sequential Organ Failure Assessment score; SVR: systemic vascular resistance; WSACS: World Society of the Abdominal Compartment Syndrome; OR: odds ratio; RIFLE: risk, injury failure, loss of kidney function and end-stage renal disease; ALT: alanine aminotransferase; RR: risk ratio; CI: condifence interval; WHR: waist to hip ratio; WC: waist circumferencel; ITU: intensive therapy unit.

RESULTS

Kilic *et al.* [2] enrolled 100 on-pump cardiac surgery patients at the Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Hospital, Turkey, between July 2016 and January 2017. All patients underwent serial IAP measurement, and were grouped into IAH (49%) or non-IAH groups. The mean age (55.9 ± 14.3 years) was considerably younger that other included studies. Several parameters were analysed, and multiple regression showed age, hypertension, blood transfusion and prolonged cardiopulmonary bypass (CPB) time were all independent risk factors. Interestingly, the authors included the presence of aortic atheroma as an outcome measure, although patients with peripheral arterial disease were excluded. In addition, IAH was associated with higher central venous pressure (CVP), vasoactive drug use and higher incidence of atrial fibrillation.

Nazer *et al.* [3] performed a cohort study of 50 patients at the King Fahad Cardiac Centre, Saudi Arabia, between January and August 2018, primarily to investigate the impact of obesity on intra-abdominal pressure (IAP). Patients were prospectively identified based on body mass index (BMI), with 1:1 matching between obese (BMI $\geq$30 kg/m^2) and non-obese groups. IAP was measured at baseline and 4-hourly intervals for 24 h. The authors performed logistic regression analysis showing obesity to be an independent risk factor for the development of postoperative IAH, associated with higher baseline IAP, CVP, renal injury and hepatic dysfunction in this group. CPB time, fluid balance and urine output were not associated with the increased risk of IAH. It should be noted that the prevalence of IAH was higher than in several cohorts (52%), despite the utilization of lower instillation volumes (20 ml intravesicular saline) when measuring IAP, and the diagnosis of IAH over 3 measurements.

Mazzeffi *et al.* [4] prospectively enrolled 42 patients undergoing on-pump cardiac surgery at the University of Maryland Cardiac Centre, USA. The study was primarily aimed at investigating the link between IAP and renal dysfunction in cardiac surgical patients. Baseline and postoperative IAP was measured, alongside pre- and postoperative urinary neutrophil gelatinase-associated lipocalin (NGAL). The prevalence of IAH (83.3% at any postoperative timepoint) was considerably higher than other groups. Development of IAH was not associated with CPB time, fluid balance or urine output. Urinary NGAL >100 ng/ml was shown to have high sensitivity (100%) but poor specificity (24.1%) for detecting IAH. This suggests that, although urinary NGAL measurement may be a useful clinical screening tool after cardiac surgery, it should be interpreted with caution and in the context of other risk factors.

Smit *et al.* [5] conducted a cohort study of 186 patients at the University Medical Centre Groningen, the Netherlands, between October 2014 and March 2015. The authors hypothesized that central obesity, rather than BMI alone, was a better predictor of IAH following cardiac surgery. IAP was measured pre- and postoperatively, and 26.9% of patients developed IAH at any time point. Although the mean IAP was higher in obese patients based on BMI, this was not true of central obesity, based on several definitions. Multivariate analysis revealed BMI to be a unique contributor to IAP; this was independent of CPB, cross-clamp or total operative time. Interestingly, the authors also demonstrated the association of C-reactive protein to BMI and central obesity; however, the data suggest that this has no role in predicting IAP. The outcomes in this group are limited to a single time point in the immediate postoperative period and may not be representative of IAH during intensive care unit (ICU) therapy.

Iyer *et al.* [6] report a cohort study of 108 cardiac surgery patients at Liverpool Hospital, Sydney, Australia. IAP was measured at baseline and twice daily in the postoperative period, alongside objective measures of organ dysfunction. The follow-up period in this cohort (up to 5 days in the ICU) was the longest of all studies, and perhaps more representative of patients who subsequently develop IAH. A total of 46% of patients developed IAH, but there was no overt abdominal compartment syndrome. Stepwise logistic analysis showed that serum aspartate aminotransferase (>46 u/l), serum albumin (<32 u/l), higher peak away pressure, prolonged CPB time and cross-clamp time were predictive of IAH. This group also had higher Sequential Organ Failure Assessment (SOFA) scores.

The cohort reported by Dalfino *et al.* [7] at the University of Bari, Italy, included 69 elective and emergency cardiac surgery patients over a 3-month period. IAP was measured at baseline and several postoperative time points, alongside objective measures of renal impairment (RIFLE criteria), organ dysfunction (SOFA score) and haemodynamic parameters. Interestingly, the authors attempted to examine the relationship between IAH and hepatic dysfunction. Although the elevation in serum bilirubin is significant from baseline only after 12 h, and the relationship with surgical factors is therefore unclear. A total of 31.8% of patients developed IAH; this was significantly higher in the on-pump group (OR 2.73; $P = 0.037$). Baseline IAP (with a cut off of 8 mmHg), CVP, vasopressor usage, duration of CPB and ventilation were predictive. IAH was associated with higher SOFA score and acute kidney injury.

Dabrowski and Rzecki [8] report outcomes in 200 patients undergoing cardiac surgery at the University of Lublin, Poland, between January 2006 and December 2007. The incidence of IAH was 44% postoperatively. Interestingly, there was no association between IAH and actual body weight, although there was a significant correlation with BMI. IAP is correlated with CVP and CPB time, although a decrease in MAP was responsible for reduced abdominal perfusion pressure. The authors report that all patients underwent normovolaemic haemodilution, although the haematrocit was not defined in this study. It should be noted that association between fluid balance and IAP in this group was only significant up to 1 h postoperatively, suggesting that other factors predominate in the development of IAH in the ICU.

CLINICAL BOTTOM LINE

A total of 755 patients were included, with the incidence of IAH between 26.9% and 83.3%. The limited evidence on IAH after cardiac surgery should be interpreted with caution. Obesity is a strong predictor of postoperative IAH, although not confined to a central pattern and BMI is correlated with IAP. Prolonged CPB and aortic cross-clamp time predisposed to IAH in 4 cohorts. In addition, IAH in cardiac surgery patients is associated with hepatic and renal impairment, and corresponding biochemical markers may be helpful in screening, although lacking specificity. In contrast to the development of IAH in other settings, the evidence for the role of fluid balance is poor.

Accurate prediction of IAH remains elusive. Based on the available evidence, routine IAP measurement should be considered postoperatively in patients with obesity, particularly those with renal or hepatic impairment, prolonged CPB or operative time, requiring vasopressor support, to prevent the deleterious effects of IAH.

Conflict of interest: none declared.

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