Mode of blood pressure monitoring and morbidity after non-cardiac surgery: prospective multi-centre observational cohort study.

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Running title: Haemodynamic monitoring and perioperative myocardial injury.

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MESH Keywords: blood pressure; Troponin; organ dysfunction; Perioperative Period; surgery

Study registration: The study was not registered with a registry.

Manuscript word count: 2673 Abstract word count: 250

Abstract

Background: Control of blood pressure remains a key goal of perioperative care, since hypotension is associated with adverse outcomes after surgery.

Objectives: We explored whether increased vigilance afforded by intra-arterial blood pressure monitoring may be associated with less morbidity after surgery.

Design: Prospective observational cohort study.

Setting: Four UK secondary care hospitals.

Participants: 4342 patients ≥45 years undergoing non-cardiac surgery.

Exposure of interest: Perioperative intra-arterial blood pressure monitoring compared to non-invasive blood pressure monitoring.

Outcomes: The primary outcome was perioperative myocardial injury (high-sensitivity troponin-T ≥15ng.L^{-1} within 72hr after surgery), compared between patients who received intra-arterial versus non-invasive blood pressure monitoring. Secondary outcomes were morbidity within 72h of surgery (Postoperative Morbidity Survey), vasopressor and fluid therapy. Multivariable logistic regression analysis explored associations between morbidity and age, gender, location of postoperative care, mode of blood pressure/haemodynamic monitoring and Revised Cardiac Risk Index (RCRI). Data are presented as n (%) or odds ratios (OR) with 95% confidence intervals.

Results: Intra-arterial monitoring was used in 1137/4342 (26.2%) patients. Myocardial injury occurred in 440/1137 (38.7%) patients with intra-arterial monitoring compared to 824/3205 (25.7%) with non-invasive monitoring (OR: 1.82 [1.58-2.11]; p<0.001). Intra-arterial monitoring remained associated with myocardial injury when adjusted for potentially confounding variables (adjusted OR: 1.56 [1.29-1.89]; p<0.001). The results were similar for planned ICU versus ward postoperative care.

Conclusions: Intra-arterial monitoring is associated with greater risk of morbidity after noncardiac surgery, after controlling for surgical and patient factors. These data provide useful insights into the design of a definitive monitoring trial.

Introduction

Invasive arterial blood pressure monitoring is a central tenet of intensive care for higher-risk surgical patients.[1] Beyond patients in cardiovascular shock requiring vasopressor or inotropic support,[2] the impact of intra-arterial blood pressure monitoring in surgical intensive care patients remains uncertain.[3] Reducing the duration and magnitude of perioperative hypotension appears to be important[1,4] but whether direct intra-arterial monitoring mitigates this risk remains unclear.[5] Vasopressors are commonly administered to surgical intensive care unit patients to raise blood pressure. Among patients 65 years or older receiving vasopressors for vasodilatory hypotension, permissive hypotension compared with usual care appears to reduce mortality (odds ratio: 0.82 (95%CI:0.68-0.98) when pre-specified baseline variables were accounted for.[6] Thus, balancing the risks and benefits of vasopressors is a challenge, particularly in older patients.[7]

Non-cardiac surgery offers a unique opportunity to address whether the mode of blood pressure monitoring impacts on clinical management and/or outcomes. Surgery is very common; over 7 million surgical procedures are carried out in the United Kingdom every year.[8,9] Relative hypotension is associated with several serious complications after non-cardiac surgery, including acute kidney injury,[10,11] neurologic dysfunction[12,13] and myocardial injury/infarction. [14,15] [16-19] [20] [21] However, the impact of interventions to lower blood pressure on postoperative morbidity has been inconsistent.[22-25] The duration of relative hypotension is also associated with perioperative myocardial injury,[21] suggesting that more intensive beat-to-beat, intra-arterial blood pressure monitoring may mitigate the potentially deleterious consequences of lower perioperative blood pressure and haemodynamic disturbance. But, arterial catheterisation may promote perioperative interventions that could exacerbate organ injury, including more frequent use of vasopressor infusions and more blood transfusions compared with the use of non-invasive blood pressure measurements.[3] Thus far, multicentre,

prospective observational studies examining the possible impact of intra-arterial monitoring on objective biomarkers of organ injury are limited - yet are necessary to inform the optimal design of future trials examining the impact of tight arterial blood pressure control.

Hypothesis

We hypothesized that the development of perioperative myocardial injury and postoperative morbidity may be reduced when closer haemodynamic monitoring is undertaken using intra-arterial blood pressure monitoring.

Methods

Study design and setting

This was a planned secondary analysis of data from a prospective multicentre observational cohort study of perioperative outcomes at four UK centres between October 2010 and November 2013.[26] This report is consistent with STROBE reporting guidelines for observational studies.

Ethics

The study was approved by North Wales Research Ethics Committee (Central and East), chaired by Professor Alex Carson, on 30th September 2010 (Reference: 10/WNo03/25). It was conducted in accordance with the principles of the declaration of Helsinki and institutional guidelines. Participants undergoing elective non-cardiac surgery gave written informed consent before surgery.

Participants

Participants were aged 45 years or older and underwent elective non-cardiac surgery under general or regional anaesthesia and required at least one night in hospital after surgery. Participants were excluded if they refused consent or if they had previously enrolled in the VISION study.[14]

Data Collection

Researchers collected a detailed and standardised dataset from patients and their medical records, before and during the 30 days after surgery, including postoperative morbidity (defined by PostOperative Morbidity Survey and Clavien-Dindo grading). Intraoperative data were collected from anaesthetic charts and the medical record, but not using electronic data

capture. Maximum and minimum blood pressures, the use of vasopressor drugs to treat clinically significant hypotension and the volume of intravenous fluid administered were recorded on the case report form for the intraoperative and postoperative periods. Continuous measures of haemodynamic variables were not recorded. Blood samples were taken before, between 6-12 hours after the end of surgery, and on postoperative days one, two and three. At two centres, investigators, patients and healthcare providers were blinded to troponin results throughout the study period.

Variables

The exposure of interest was the use of intraoperative intra-arterial blood pressure monitoring, recorded as a binary categorical variable. The interpretation of haemodynamic monitoring data was left to the discretion of the attending clinician.

The primary outcome measure was myocardial injury defined as serum high sensitivity troponin T concentration ([hs TnT]) $\geq$15ng.L^{-1}, measured by high sensitivity troponin T assay (Elecsys, Roche, Basel, Switzerland) daily for three days after surgery. This hsTnT assay enables the detection of cTnT at the 99th percentile of an apparently healthy reference population with <10% variability, with a 5ng/L limit of detection.[27] We did not seek to define ischaemic versus non-ischaemic causes of hsTnT elevation, since elevated troponin is linked to poorer clinical outcomes regardless of its aetiology.[28] We also assessed the association between intra-arterial blood pressure measurement and morbidity defined by the Post Operative Morbidity Survey (POMS) within 48h after surgery.

Statistical analysis

The statistical analysis was prospectively planned and published online prior to analysis (https://www.ucl.ac.uk/anaesthesia/trials). We used NCSS 11 (Utah, USA) and STATA version 14 (StataCorp LP, Texas, USA) to analyse the data. We stratified the baseline characteristics of the cohort according to whether patients had intraoperative intra-arterial blood pressure monitoring or non-invasive blood pressure monitoring. Categorical data were expressed as numbers with percentages and continuous data were expressed as mean with standard deviation (SD) or median with interquartile range (IQR). We used multivariable logistic regression analysis to test for association between intra-arterial blood pressure and perioperative myocardial injury, compared to non-invasive blood pressure monitoring, adjusted for potential confounding factors.[29-33] Covariates in the multivariable model were pre-specified and selected on the basis of prior evidence of association with the dependent variable or similar clinical outcomes, rather than univariable analysis or p-value based approaches. Covariates included: age, gender, Revised Cardiac Risk Index (RCRI) score greater than or equal to two, metastatic cancer, type of surgery, blood products and duration of surgery.[18,20] The components of the RCRI are: high-risk surgery, ischaemic heart disease, congestive cardiac failure, cerebrovascular disease, diabetes mellitus requiring insulin therapy and preoperative creatinine > 176.8 micromol per litre.[32] Results are represented as odds ratios (OR) with 95% confidence intervals. Missing data were handled by list-wise deletion.

Sensitivity analysis

A potential indication for invasive blood pressure monitoring is for patients with significant preoperative comorbidity and/or operations of greater complexity and duration. Therefore we assessed whether elective admission to intensive care, or ward care, after surgery altered the relationship between intra-arterial monitoring and the primary outcome. Intensive care was defined according to the VISION study criteria.[29] We also assessed whether additional

haemodynamic (cardiac output) monitoring or the insertion of a central venous catheter altered the association between intra-arterial monitoring and outcomes. Another potential indication for invasive blood pressure monitoring is to identify and treat hypotension. We tested for association between invasive arterial blood pressure monitoring and the incidence of intraoperative hypotension, defined as systolic blood pressure less than 90mmHg.[29] To reduce confounding by clinical management, we restricted this analysis to a single centre comprising 45% of the cohort, where clinicians and patients were blinded to troponin results.

Power calculation

We performed a post-hoc power calculation using STATA version 14 (StataCorp LP, Texas, USA). We estimated that a total sample of 4342 patients with an allocation ratio of 0.35 (intra-arterial monitoring compared to non-invasive monitoring), a type one error rate of 0.05 and respective incidences of myocardial injury of 38.7% and 25.7% (intra-arterial versus non-invasive) would give a power of 100% to detect a difference between groups.

Results

Patient characteristics

Perioperative intra-arterial monitoring was used in 1137/4342 (26.2%) patients during surgery, of whom 391/1137 (34.4%) returned to routine ward care after their operation. Intra-arterial monitoring was more frequent in patients undergoing major abdominal or vascular surgery (Table 1).

Primary outcome: myocardial injury and intra-arterial monitoring

Myocardial injury occurred in 1264/4342 (29.1%) patients. The median troponin rise was 19 (IQR: 14-30) $ng.L^{-1}$ in patients with troponin $\geq 15 ng.L^{-1}$ within 72h after surgery. Myocardial injury was more frequent in 440/1137 (38.7%) patients who received intra-arterial monitoring, compared to 824/3205 patients (25.7%) who were monitored by non-invasive blood pressure measurements alone (OR: 1.82 [1.58-2.11]; p<0.001). Intra-arterial monitoring remained associated with myocardial injury when we adjusted for age, sex, RCRI, metastatic cancer, type of surgery, duration of surgery, use of blood products, the use of vasopressors to treat hypotension (OR: 1.56 [1.29-1.89]; p<0.001) (table 2).

Secondary outcome: postoperative morbidity

Morbidity within 72h of surgery was more frequent in 715/1137 (62.9%) patients who received intra-arterial monitoring, compared to 909/3205 patients (28.4%) who were monitored by non-invasive blood pressure measurements (OR: 4.27 [3.71-4.94]; p<0.001). Acute kidney injury within 72h of surgery was more common in patients who received intra-arterial monitoring (OR: 2.04 [1.43-2.9]; p<0.001). The frequency of most postoperative complications was similar among patients who received ICU compared with patients who received ward-based care after surgery (Table 3).

Location of care

When we stratified the analysis by location of postoperative care, the incidence of myocardial injury was similar in patients with intra-arterial monitoring during surgery (319/746; (42.8%)) compared to non-invasive monitoring during surgery (91/227 (40.1%)) (OR:1.12 (95%CI:0.83-1.51); p=0.49) who were initially cared for in an intensive care unit. Patients cared for in a non-intensive care area, who received intra-arterial monitoring during surgery were more likely to sustain myocardial injury (121/391 (31.0%)), compared to patients who had non-invasive blood pressure monitoring during surgery (733/2978 (24.6%)) (OR: 1.37 (95%CI:1.09-1.73); p=0.007).

Myocardial injury and cardiac output monitoring

Cardiac output monitoring was used in 450/4342 (10.4%) patients. The incidence of myocardial injury was similar among patients who received both intra-arterial and cardiac output monitoring modalities (116/294; 39.5%; OR 1.91 [1.49-2.44]), compared to intra-arterial monitoring alone (324/843; 38.4%; OR 1.83 [1.55-2.14]). When we repeated the primary analysis including cardiac output monitoring and central venous catheterization as covariates, intra-arterial monitoring remained associated with myocardial injury (OR: 1.30 [1.07-1.59]; p=0.008) (supplementary table 1).

Intraoperative hypotension

We investigated the relationship between intra-arterial monitoring and hypotension in a single-centre representing 1680/4342 patients. Intra-arterial monitoring was associated with more frequent episodes of intraoperative hypotension (OR: 1.70 (1.39-2.07); p<0.001), as well as further hypotensive episodes occurring up to 3 days after surgery (Figure 2). For patients who developed intraoperative hypotension, the nadir, duration and percentage change from

preoperative systolic blood pressure were similar between NIBP and intra-arterial monitoring (Figure 3). This relationship was observed in patients who received intensive care or ward care. Compared with standard monitoring, intraoperative hypotension detected by intra-arterial monitoring was more likely to be treated with vasopressors (OR: 2.88 [2.37-3.51]; $p<0.001$) rather than fluid administration (OR: 0.52 [0.41-0.65]; $p<0.001$).

Discussion

The principal finding of this prospective observational cohort study is that more intensive arterial blood pressure monitoring using intra-arterial catheters both during surgery was associated with increased incidence of perioperative myocardial injury and postoperative morbidity, compared to non-invasive blood pressure monitoring. The association between intra-arterial monitoring and postoperative myocardial injury was independent of risk factors for cardiovascular disease and postoperative morbidity. The location of postoperative care (ward versus ICU) did not appear to alter this association, in that similar findings were found in patients cared for on the ward and ICU after surgery. These data suggest that more intensive perioperative measurement of haemodynamics may not reduce the likelihood of postoperative organ dysfunction.

The question of whether or not avoiding hypotension reduces perioperative myocardial injury, non-cardiac organ injury and/or mortality has been the focus of several previous studies.[6] Our data provide further insight into this question, since this is the largest multicentre prospective study of the relationship between haemodynamic monitoring and the development of morbidity after surgery. There are several possibilities that may explain this association. First, the use of intra-arterial monitoring may merely reflect higher risk patients and/or procedures. While these data certainly confirm the higher risk surgery involving intra-arterial monitoring, multivariable analyses do not support the hypothesis that our findings are solely attributable to operative type. Indeed, patients who received intraoperative invasive monitoring but not intensive care after surgery had a similarly high risk of myocardial injury and non-cardiac morbidity within 72h after surgery.

Second, the huge range of relative hypotensive values in the perioperative literature that are associated with postoperative morbidity may merely reflect blood pressure as a biomarker

for underlying pathophysiology that predisposes patients to haemodynamic compromise during surgery, including cardiac failure and autonomic dysfunction. In that case, mode of blood pressure monitoring would be unlikely to impact on postoperative outcomes. Randomised controlled trials targeting pre-specified intraoperative BP thresholds have failed to reduce 30 day[24,25] or 90-day[23] mortality. Similarly, in critically ill patients 65 years or older receiving vasopressors for vasodilatory hypotension, permissive hypotension compared with usual care did not result in lower mortality at 90 days.[6] When adjusted for pre-specified baseline variables, the odds ratio for 90-day mortality was lower in patients randomised to less exposure to vasopressors (0.82 (95% CI, 0.68 to 0.98).[6] Although maintaining blood pressure within 10% of preoperative values has been reported to reduce postoperative morbidity, cardiorenal complications were similar (albeit in the absence of troponin being reported).[23] Given the robust association between morbidity and intermediate to longer term outcomes (including mortality),[34] the lack of impact on morbidity is striking. In part, this is very likely to reflect the uncertainty over the threshold at which blood pressure should be treated, which remains controversial. Large numbers of disparate studies have examined the association between intraoperative hypotension and adverse postoperative outcomes, with huge variation in study populations, definitions of hypotension, surgical procedures, outcome measurements and analytic methodology.[35] Thus, it remains unclear whether intraoperative hypotension – or, at least at non-catastrophic low blood pressure levels - is a mediator, or marker, of morbidity after surgery.

Third, we found that intra-arterial monitoring was associated with higher use of vasopressors, in marked preference to administering intravenous fluid. Experimental data clearly show that transient exposure to high concentrations of agonists selective for either beta-1[36] or alpha-1[37] adrenoreceptors results in myocardial injury. From mechanistic studies

examining microRNA release after non-cardiac surgery, adrenergic stress is a prominent feature of the perioperative period.[38] Given the association between early troponin elevation and subsequent organ dysfunction,[34] additional exogenous adrenergic stimulation may be injurious in patients in whom higher blood pressure targets are more aggressively sought, as suggested by the 65 trial.[6] The ESC/ESA guidelines on perioperative care of patients undergoing non-cardiac surgery advocate a strategy of preventing hypotension.[39] While this is the aspiration of many clinicians, in the majority of situations the only course of action is to prevent further hypotension by the administration of vasopressors, which may, in fact, be more harmful. As has been observed previously, the presence of an arterial line does appear to promote more frequent perioperative interventions including use of vasopressor infusions and blood transfusions compared with the use of non-invasive blood pressure measurements.[3] Vasopressors may also reduce blood pressure lability, preservation of which is associated with lower mortality.[40]

Strengths and limitations

The results of this large prospective study, involving more than 4300 elective patients undergoing a wide variety of non-cardiac surgical procedure, are generalizable to the majority of patients having non-cardiac surgery. The scheduled capture of morbidity data reduces the chance of under-reporting of complications after surgery, which were also graded by severity. The enrolment of patients in two centres masked to troponin results removes any unforeseen influence of clinicians changing their management on the basis of abnormal troponin values. The centres involved reflect international contemporary practice in perioperative medicine. However, there are several limitations. The decision to insert an arterial line is often based on a complex combination of clinical and non-clinical factors, which may not have been accounted

for in our analysis. It is possible that placement of arterial catheters represents a perception of increased perioperative risk, which in turn drives further intervention and clinical monitoring during and after surgery. We collected data according to a detailed and standardised case record form, which was prospectively designed and included a large number of variables. While we adjusted our analysis for known measures of perioperative cardiovascular risk, there is likely to be substantial unmeasured confounding. We did not collect electronic outputs from either arterial monitors or cardiac output monitors, so we are unable to analyse the beat-by-beat numerical data or waveform analysis derived from these. The absence of these data preclude further mechanistic insight into the relevance of intra-arterial monitoring, particularly in terms of baroreflex control during the perioperative period.[41] We were unable to differentiate between different vasopressors administered as a bolus but did capture the use of norepinephrine. Nevertheless, our data contrast with several other studies where the use of vasopressors has not been reported. We observed a strong relationship between intra-arterial monitoring and myocardial injury. However, whether or not this represents a causal relationship is unclear. It is plausible that management initiated by a clinician in response to intra-arterial monitoring may lead to harm. This warrants further investigation with a randomised trial.

In summary, these data suggest that the there was an approximately 30% higher risk of myocardial injury among patients who had intra-arterial blood pressure monitoring, compared to patients who had non-invasive blood pressure monitoring. Further research is needed to understand the clinical implications of this finding.

Author contributions

GLA designed the analysis plan. GLA, TEFA performed the data analysis independently. The manuscript was drafted by GLA, TEFA and revised following critical review by all authors.

Acknowledgements relating to this article

Assistance with the study: None.

Financial support and sponsorship: TEFA was supported by a Medical Research Council and British Journal of Anaesthesia clinical research training fellowship (grant reference MR/M017974/1); RP is supported by a UK National Institute for Health Research Professorship; GLA is supported by an NIHR Advanced Fellowship (NIHR300097), British Journal of Anaesthesia/Royal College of Anaesthetists basic science Career Development award, British Oxygen Company research chair grant in anaesthesia from the Royal College of Anaesthetists and British Heart Foundation Programme Grants (RG/14/4/30736; RG/19/5/34463).

Conflicts of interest: TEFA is a member of the associate editorial board of the British Journal of Anaesthesia; RP holds research grants, and has given lectures and/or performed consultancy work for Nestle Health Sciences, BBraun, Medtronic, GlaxoSmithKline, Intersurgical and Edwards Lifesciences, and is a member of the Associate editorial board of the British Journal of Anaesthesia; GLA is a member of the editorial advisory board for Intensive Care Medicine Experimental, Editor for British Journal of Anaesthesia and has undertaken consultancy work for GlaxoSmithKline and Kynos Therapeutics Ltd; there are no other relationships or activities that could appear to have influenced the submitted work.

Presentation: None.

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Figures

Figure 1. Patient flow diagram showing cases included in the primary analysis.

Figure 2. Hospital length of stay for patients with and without intra-arterial monitoring. Kaplan-Meier plot showing time to hospital discharge, stratified by intraoperative mode of monitoring. Numbers at risk for each category are matched to coloured lines shown in graph panel.

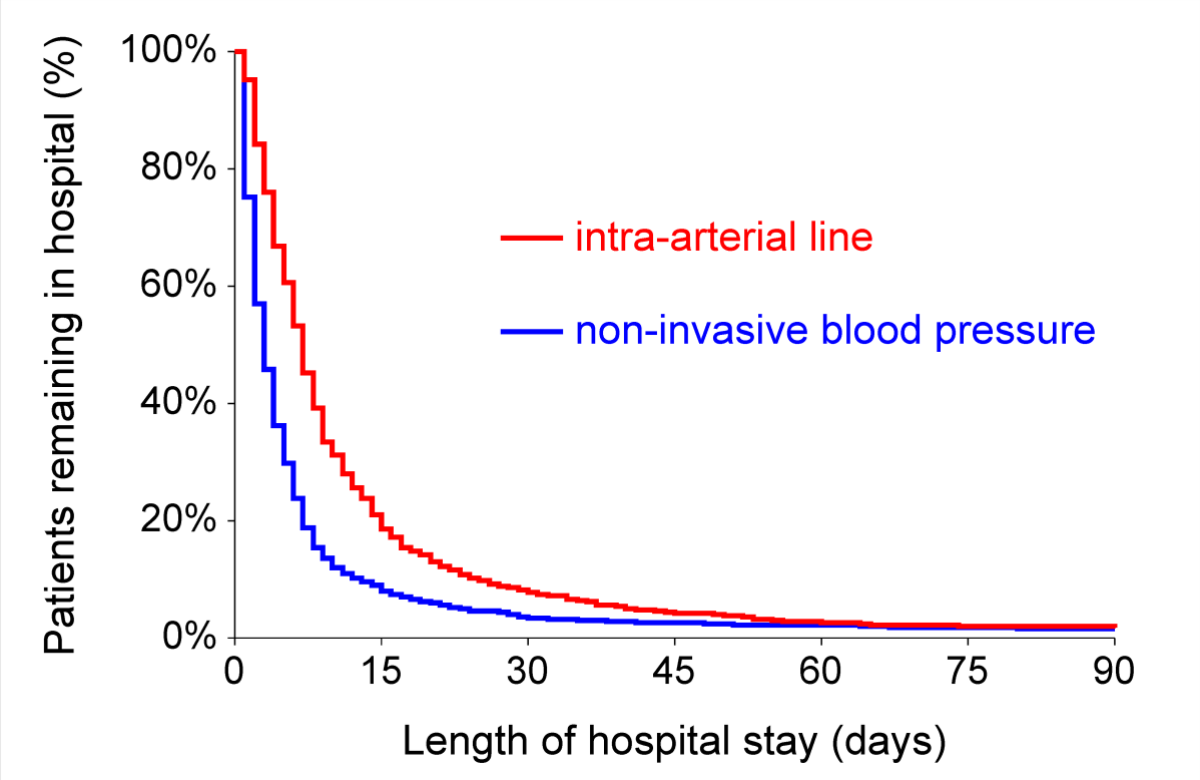

Figure 3. Proportion of patients with hypotension at each time point throughout the hospital stay, stratified by mode of blood pressure monitoring.

Time-to-event plots showing phases of the surgical from preoperative assessment to the third day after surgery. Hypotension was defined as systolic blood pressure (SBP) <90 mmHg. The lines show the proportion of the cohort with systolic blood pressure (SBP) less than 90mmHg stratified at any given time point, stratified by mode of arterial pressure monitoring (A) and further by intraoperative blood pressure (B).

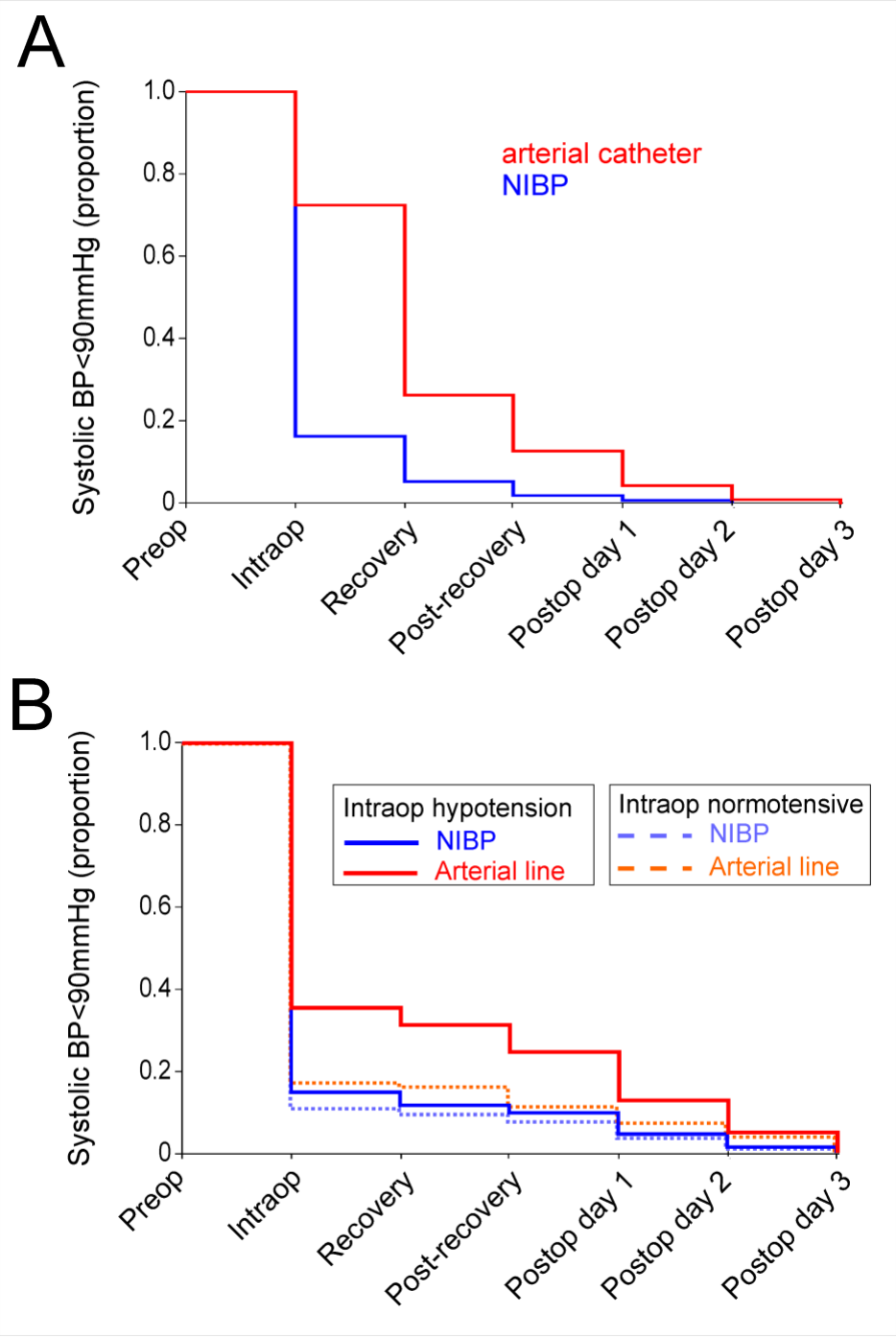

Table 1. Patient characteristics.

Preoperative characteristics were collected at study entry, surgical type at the time of surgery, perioperative characteristics during surgery and in the period immediately after surgery and level of care in the postoperative period. Continuous data are presented shown as mean with standard deviation (SD) or median with interquartile range (IQR). Categorical data are presented as number (n) with percentage (%).

Characteristic	**NIBP**	**Intra-arterial**
Preoperative		
Number of patients	3205	1137
Age in years (IQR)	64 (55-73)	66 (57-74)
Female gender (n;%)	1560 (48.7%)	397 (34.9%)
Body-mass index (IQR)	28.0 (24.6-32.0)	27.1 (24.1-30.7)
Systolic blood pressure in mmHg (IQR)	136 (122-150)	139 (124-153)
Diastolic blood pressure in mmHg (IQR)	75 (67-83)	76 (68-83)
Heart rate in beats.min^{-1} (IQR)	75 (67-85)	76 (66-85)
ASA≥3	882 (27.5%)	488 (42.9%)
RCRI ≥2 (n; %)	336 (10.5%)	265 (23.3%)
Creatinine in micromol.L^{-1} (IQR)	76 (64-91)	79 (66-95)
Haemoglobin in g.L^{-1} (IQR)	134 (123-144)	132 (119-145)
No comorbidity	1910 (60.1%)	507 (45.1%)
Coronary artery disease (n;%)	338 (10.6%)	191 (17.0%)
Cardiac failure (n;%)	36 (1.1%)	22 (2.0%)
Atrial fibrillation (n;%)	55 (4.8%)	109 (3.4%)
Diabetes mellitus, insulin treated (n:%)	114 (3.6%)	62 (5.5%)
Diabetes mellitus, non-insulin treated (n:%)	345 (10.9%)	138 (12.3%)

Metastases (n;%)	64 (2%)	96 (8.5%)
Cirrhosis (n;%)	18 (0.6%)	8 (0.7%)
Stroke (n;%)	93 (2.9%)	45 (4.0%)
COPD (n;%)	203 (6.4%)	99 (8.8%)
CKD (n;%)	111 (3.5%)	64 (5.7%)
Surgical type		
Intra-abdominal	749 (23.4%)	469 (41.3%)
Orthopaedic	1009 (31.5%)	98 (8.6%)
Urology	569 (17.8%)	127 (11.2%)
Vascular	165 (5.2%)	227 (20.0%)
Other	713 (22.3%)	216 (19.0%)
Perioperative		
Major surgery	1350 (42.1%)	915 (80.4%)
Duration of surgery (minutes)	120 (75-170)	225 (155-315)
Intraoperative fluid (ml/kg/h)	10.3 (6.9-15.0)	9.2 (6.5-12.9)
Estimated blood loss >500ml	164 (5.1%)	231 (20.3%)
Allogenic blood products (ml/h)	53 (2%)	153 (14%)
Cardiac output monitoring (n;%)	156 (4.9%)	294 (25.9%)
Central venous catheter (n;%)	78 (2.5%)	439 (38.7%)
Postoperative care		
Postoperative care		
Level 2 (n;%)	199 (6.2%)	565 (49.7%)
Level 3 (n;%)	28 (0.1%)	181 (15.9%)
Hospital length of stay, days (IQR)	3 (1-6)	7 (4-13)

Table 2. Multivariable logistic regression model of intra-arterial monitoring and myocardial injury after non-cardiac surgery.

Dependent variable is myocardial injury within first three days of surgery. Results presented as odds ratios with 95% confidence intervals.

Factor	Odds ratio	Lower 95%CI	Upper 95%CI	P value
Intra-arterial catheter	1.56	1.29	1.89	<0.001
Age				
<50 years (reference)	-	-	-	-
50-59 years	1.02	0.75	1.40	0.881
60-69 years	1.30	0.96	1.76	0.084
70-79 years	1.69	1.25	2.30	0.001
80-89 years	2.64	1.90	3.68	<0.001
>89 years	2.56	1.41	4.67	0.002
Male gender	1.63	1.40	1.90	<0.001
RCRI ≥2	2.85	2.34	3.47	<0.001
Metastatic cancer	1.15	0.79	1.66	0.463
Surgery Type				
Intra-abdominal (reference)	-	-	-	-
Orthopaedic	1.36	1.11	1.67	0.003
Urological	1.06	0.84	1.33	0.619
Vascular	1.58	1.22	2.04	0.001
Blood products used	1.53	1.11	2.11	0.010
Duration of surgery				
<90 minutes (reference)	-	-	-	-
90-210 mintues	0.67	0.56	0.80	<0.001
>210 minutes	0.66	0.53	0.83	<0.001
Hypotension requiring vasopressor	4.85	2.55	9.22	<0.001

Table 3. Morbidity at 72h after surgery and mode of intraoperative blood pressure monitoring. Data are shown as absolute median (IQR) values or n;%, as indicated. Odds ratio (OR) with 95% confidence intervals shown, where applicable. Only patients residing in hospital after surgery enabling POMS assessment were analysed.

	WARD					**ICU**				
	NIBP		**Arterial**		**OR [95%CI]**	**NIBP**		**Arterial**		**OR [95%CI]**
	2963	%	385	%		227		746		
Infection										
Antibiotics	328	11.0	69	17.7	1.7 (1.3-2.3)	32	14.1	196	26.3	2.2 (1.4-3.3)
Fever	58	2.0	8	2.1	1.1 (0.5-2.2)	10	4.4	38	5.1	1.2 (0.6-2.4)
Pulmonary										
Oxygen	134	4.5	35	9.0	2.1 (1.4-3.1)	26	11.5	185	24.8	2.5 (1.6-4.0)
Ventilation	7	0.2	1	0.3	1.1 (0.1-8.9)	2	0.9	20	2.7	3.1 (0.7-13.4)
Cardiac										
Ischaemia	6	0.2	1	0.3	1.3 (0.2-10.6)	3	1.3	9	1.2	0.9 (0.2-3.4)
Hypotension needing therapy	15	0.5	2	0.5	1.0 (0.2-4.5)	5	2.2	31	4.2	1.9 (0.7-5.0)
Arrythmia	19	0.6	1	0.3	0.4 (0.1-3)	7	3.1	36	4.8	1.6 (0.7-3.6)
Pulmonary oedema	1	0.0	0	0.0	-	1	0.4	1	0.1	-
Renal										
Oliguria	10	0.3	3	0.8	2.3 (0.6-8.4)	3	1.3	9	1.2	0.9 (0.2-3.4)
Creatinine rise	2749	92.3	339	86.7	0.5 (0.4-0.7)	185	81.5	523	70.1	0.5 (0.4-0.8)
Gastrointestinal										
Nausea/ vomiting	179	6.0	39	10.1	1.8 (1.2-2.5)	16	7.1	124	16.6	2.6 (1.5-4.5)
Lack of feed	73	2.5	25	6.4	2.7 (1.7-4.3)	16	7.1	129	17.3	2.8 (1.6-4.7)
Neurologic										
Focal signs	5	0.2	1	0.3	1.5 (0.2-13.1)	0	0.0	6	0.8	
Delirium	17	0.6	3	0.8	1.3 (0.4-4. 6)	3	1.3	22	3.0	2.3 (0.7-7.7)
Coma	1	0.0	0	0.0	-	1	0.4	9	1.2	2.8 (0.3-21.9)
Wound										
Pus	32	1.1	11	2.8	2.7 (1.3-5.3)	4	1.8	29	3.9	2.3 (0. 8-6.5)
Wound	5	0.2	0	0.0	-	1	0.4	4	0.5	1.2 (0.1-11.0)
Haematologic										
Packed red cells	54	1.8	9	2.3	1.3 (0.6-2.6)	12	5.3	34	4.6	0.9 (0.4-1.7)
Products	4	0.1	0	0.0	-	2	0.9	6	0.8	0.9 (0.2-4.6)
Pain										
Parenteral opioids	144	4.8	40	10.2	2.3 (1.6-3.3)	23	10.1	168	22.5	2.6 (1.6-4.1)
Regional analgesia	28	0.9	11	2.8	3.0 (1.5-6.2)	3	1.3	117	15.7	13.9 (4.4-44.1)