



ORIGINAL ARTICLE

Perioperative myocardial necrosis in patients at high cardiovascular risk undergoing elective non-cardiac surgery

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ABSTRACT

Objective Cardiovascular complications are important causes of morbidity and mortality in elective non-cardiac surgery. Although difficult to diagnose, perioperative myocardial infarction (MI) remains prognostically important. High-sensitivity troponin T (hs-TnT) assays allow detection of very minor damage to cardiac muscle. These assays are yet to be fully evaluated in the perioperative setting. Our aim was to determine the incidence and predictors of myocardial necrosis in patients at high cardiovascular risk undergoing elective non-cardiac surgery using hs-TnT.

Design Prospective observational cohort study.

Patients 352 consecutive patients undergoing elective major non-cardiac surgery prescribed antiplatelet therapy for primary or secondary cardiovascular event prevention.

Main outcome measure The incidence of elevated preoperative hs-TnT (≥ 14 ng/litre), hs-TnT-defined perioperative myocardial necrosis (≥ 14 ng/litre and 50% increase from preoperative level), and perioperative MI were determined in relation to patient and surgical factors.

Results Preoperative hs-TnT was elevated in 31% and postoperative myocardial necrosis occurred in 22% of patients. Predictors of elevated baseline hs-TnT included age (OR 1.10, $p < 0.001$), male gender (OR 2.91, $p < 0.001$), diabetes requiring insulin therapy (OR 4.85, $p = 0.004$) and chronic kidney disease (OR 3.60, $p < 0.001$). Independent predictors of perioperative myocardial necrosis were age (OR 1.07, $p < 0.001$), intraoperative hypotension (OR 3.67, $p = 0.001$) and orthopaedic surgery (OR 2.46, $p = 0.005$). Only 2% of patients suffered clinically apparent MI. Elevated preoperative hs-TnT did not predict perioperative myocardial necrosis or MI.

Conclusions Perioperative myocardial damage occurs frequently in patients undergoing elective non-cardiac surgery, although the majority of events are clinically undetected. Age and intraoperative hypotension are independent predictors of myocardial necrosis in this setting.

INTRODUCTION

The incidence and prevalence of cardiovascular disease increases with age and it is expected that both will continue to rise with the ageing population. Similarly, the majority of surgical procedures are undertaken in older patients, with an estimated 200 million major operations performed annually

worldwide.¹ Although such surgery has obvious benefits there are associated risks. In particular, cardiovascular complications are important causes of morbidity and mortality in patients undergoing elective non-cardiac surgery, with adverse cardiac outcomes estimated to occur in approximately 4% of all patients.^{2–4} The risk among those with established ischaemic heart disease or at increased cardiovascular risk is even higher, with the incidence of perioperative myocardial infarction (MI) ranging from 4% to 16%,^{5,6} depending on the precise characteristics of the population and the definitions used.

Although MI may complicate elective non-cardiac surgery, early detection remains a challenge in the perioperative setting. Myocardial ischaemia and MI frequently occur without symptoms or ECG changes.⁷ Even in the absence of clinically apparent symptoms, perioperative MI remains prognostically important.⁸

Cardiac troponins are highly sensitive and specific biochemical markers for myocardial necrosis and are fundamental to the diagnosis of acute MI,⁹ in addition to predicting longer-term morbidity and mortality.¹⁰ Similarly, cardiac troponin elevation in the postoperative setting has been shown to predict adverse short-term and longer-term outcomes.^{11,12} The development of high-sensitivity assays has greatly improved the analytical performance of cardiac troponin, allowing detection of very minor damage to cardiac muscle.¹³ In particular, elevated levels of high-sensitivity troponin T (hs-TnT) are detectable in stable populations, with prognostic significance.¹⁴

The aims of our study were to identify the incidence of elevated preoperative hs-TnT in higher-risk patients undergoing non-cardiac surgery, to determine the incidence and predictors of perioperative myocardial necrosis, and to investigate the association between elevated preoperative hs-TnT and perioperative myocardial necrosis and infarction.

METHODS**Patient selection**

Consecutive patients presenting to a tertiary referral centre for preoperative anaesthetic evaluation between January and November 2011 were recruited. Patients aged 45 years or older, undergoing major elective non-cardiac surgery (defined by procedures requiring a hospital admission of 24 h or

longer), and receiving antiplatelet therapy for primary or secondary cardiovascular event prevention were eligible for inclusion in the study. Detailed clinical evaluation by an experienced anaesthetist and laboratory testing were performed preoperatively in all patients. The institutional Human Research and Ethics Committee approved the study protocol and written informed consent was obtained from all participants.

Perioperative cardiac risk was estimated using the Revised Cardiac Risk Index.² This includes six equally weighted clinical variables: history of ischaemic heart disease; history of congestive cardiac failure; cerebrovascular disease; diabetes requiring insulin therapy; impaired renal function (serum creatinine >176 µmol/litre); and high-risk surgery (intraperitoneal, intrathoracic or suprainguinal vascular procedures). Moderate risk is defined as two risk factors and high risk as three or more risk factors, corresponding to a perioperative risk for an adverse cardiac event of 7% and 11% respectively.²

Perioperative antiplatelet therapy management

Management of antiplatelet therapy in the perioperative period was left to the discretion of the anaesthetist performing the preoperative evaluation and the treating surgeon. Cardiology involvement in decision-making was also at the discretion of the assessing anaesthetist. Continuation or discontinuation of antiplatelet therapy, as well as the time interval between therapy cessation and surgical procedure were recorded. Patients on dual antiplatelet therapy (ie, aspirin and clopidogrel) were categorised as having antiplatelet therapy ceased only if both agents were discontinued.

Cardiac troponin T and myocardial events

Baseline preoperative hs-TnT (Roche Diagnostics, Mannheim, Germany; 99th percentile 13 ng/litre, lower limit of detection 5 ng/litre, assay linearity to 10 000 ng/litre)¹⁵ were collected from patients at preoperative assessment in the week preceding scheduled surgery, with postoperative samples collected at 24 and 48 h following surgery. Fourth-generation cardiac troponin T (Roche Diagnostics; 99th percentile 10 ng/litre) was also determined in the initial 86 patients recruited. A baseline elevation of hs-TnT was defined as a concentration above the 99th percentile reference range for the assay (≥ 14 ng/litre). Perioperative myocardial necrosis was defined as an hs-TnT concentration above the 99th percentile (≥ 14 ng/litre) and a delta value of 50%.¹⁶ Further analysis was also performed using a comparison delta value of 30%. Clinically apparent perioperative MI was defined using the current Universal Definition for MI,¹⁷ which outside the setting of myocardial revascularisation requires the presence of typical ischaemic symptoms, ECG changes indicative of ischaemia or new pathological Q-waves, or subsequent imaging evidence of MI, in conjunction with myocardial necrosis.

Intraoperative variables

The method of anaesthesia, intraoperative haemodynamics and length of surgery were collected. There were no protocol-based restrictions of anaesthetic or surgical technique, and the primary anaesthesia providers made all clinical decisions as per their routine practice. Haemodynamic variables (blood pressure and heart rate) were electronically recorded at 5-min intervals throughout the procedure. Abnormal intraoperative haemodynamics were defined as hypotension (systolic BP <100 mm Hg), hypertension (systolic BP >160 mm Hg), bradycardia (heart rate <55 beats per minute) and tachycardia (heart rate >100

beats per minute), with two or more sequential readings at least 5 min apart defining occurrence.

Adverse perioperative cardiovascular outcomes

Patients and medical records were reviewed daily until hospital discharge. Study events comprised adverse cardiovascular outcomes during the index hospitalization, including major cardiac events (death and clinically apparent MI), myocardial necrosis (hs-TnT concentration ≥ 14 ng/litre and a delta value of 50%), cerebrovascular events (defined as a new focal neurological deficit thought to be vascular in origin with signs and symptoms lasting more than 24 h), atrial fibrillation (defined as new atrial fibrillation resulting in angina, congestive heart failure, symptomatic hypotension or requiring pharmacological treatment, or electrical cardioversion) and venous thromboembolic disease (deep venous thrombosis or pulmonary embolism). Perioperative bleeding complications were classified according to the Thrombolysis in Myocardial Infarction definition: major bleed as intracranial haemorrhage or a > 5g/dl decrease in haemoglobin concentration, minor bleed as a 3 g/dl to ≤ 5 g/dl decrease in haemoglobin concentration. In addition the requirement of blood transfusion, as determined by the treating surgical team, was recorded.

Statistical analysis

Continuous data are expressed as mean (SD) and median (IQR) and categorical data as total number of patients (percentages). Predictors of both baseline elevated hs-TnT and perioperative myocardial necrosis were identified using binary logistic regression and the relationship expressed as an OR (95% CI). Multivariable analysis was performed using stepwise binary logistic regression. All variables predictive of perioperative myocardial necrosis with a p value < 0.10 on univariable analysis were included in the multivariable analysis. A two-tailed p value < 0.05 was considered significant. All the analyses were performed using SPSS V.15.0 (SPSS Inc).

RESULTS

The study cohort consisted of 352 consecutive patients undergoing major elective non-cardiac surgery, prescribed antiplatelet therapy for primary or secondary cardiovascular prevention. The mean (SD) patient age was 72 (10) years and 64% were men (table 1). The relatively high prevalence of cardiovascular risk factors, comorbidities and medications reflect our patient selection criteria. The listed baseline medications reflect chronic prescription at the time of preoperative assessment. Although all patients either had established cardiovascular disease or were at high risk of the disease, the Revised Cardiac Risk Index suggested that the majority of our cohort were at low risk for a major adverse perioperative cardiovascular outcome (table 1).

Baseline cardiac hs-TnT

Preoperative baseline hs-TnT was elevated above the reference 99th percentile in 31% of patients, with the majority of elevated levels falling just above the 14 ng/litre threshold (figure 1). The independent predictors of an elevated baseline hs-TnT included age (HR 1.10; 95% CI 1.06 to 1.14, p < 0.001), male gender (HR 2.91; 95% CI 1.61 to 5.26, p < 0.001), diabetes requiring insulin therapy (HR 4.85; 95% CI 1.85 to 12.72, p = 0.004) and chronic kidney disease (HR 3.60; 95% CI 2.09 to 6.19, p < 0.001) defined as an estimated glomerular filtration rate < 60 ml/min per 1.73 m².

Table 1 Baseline characteristics

Variable	Study population
Age, years ± SD	72.2±9.6
Median (25–75th percentile)	73 (65–79)
Male gender, n (%)	226 (64)
Comorbid conditions, n (%)	
Ischaemic heart disease	152 (43)
Congestive cardiac failure	10 (3)
Atrial fibrillation (permanent or paroxysmal)	34 (10)
Previous coronary stent	53 (15)
Previous coronary bypass surgery	70 (20)
Cerebrovascular disease	53 (15)
Peripheral vascular disease	60 (17)
Hypertension	274 (78)
Diabetes mellitus	121 (34)
Diabetes mellitus requiring insulin	27 (7)
Current smoker	28 (8)
Ex smoker	139 (39)
Obstructive sleep apnoea	21 (6)
Renal impairment (eGFR <60 ml/min per 1.73 m ²)	106 (30)
Medications, n (%)	
Aspirin	300 (85)
Clopidogrel	77 (22)
Dipyridamole and aspirin combination	10 (3)
Prasugrel	1 (<1)
Dual antiplatelet therapy	36 (10)
ACE-I/ARB	243 (68)
Statin	239 (68)
β blocker	114 (32)
Calcium channel blocker	97 (28)
Digoxin	8 (2)
Nitrate	36 (10)
Revised cardiac risk index, n (%)	
0	133 (38)
1	146 (41)
2	57 (16)
≥3	16 (5)
Baseline hs-TnT (ng/litre)	
Mean±SD	15.7±27.4
Median (25–75th percentile)	9.0 (4.0–16.9)
Elevated ≥14 ng/litre, n (%)	109 (31)

Values are expressed as mean±SD, n (%) or median (IQR). ACE-I, ACE inhibitor; ARB, angiotensin II receptor blocker; eGFR, estimated glomerular filtration rate; hs-TnT, high-sensitivity troponin T.

Surgical and procedural variables

All major non-cardiac surgical procedures were represented in our study with the exception of major thoracic surgery, which is not routinely performed at our institution. General anaesthesia was the preferred anaesthetic technique in the majority of cases, either alone or in combination with other methods. Intraoperative hypotension was the predominant haemodynamic disturbance, occurring in 70% of patients, with mean hypotensive duration of 33 min. The wide SD in duration of surgery and postoperative length of stay reflects the heterogeneity of surgical procedures included (table 2). Compared with other methods of anaesthesia, only general anaesthesia was significantly associated with intraoperative hypotension (OR 4.58; 95% CI 2.53 to 8.30, p<0.001).

Perioperative antiplatelet therapy management

Antiplatelet therapy was prescribed for secondary cardiovascular prevention in 235 (67%) of patients, including 152 (43%) for ischaemic heart disease, with 53 (15%) having previous coronary artery stenting and 70 (20%) having previously undergone

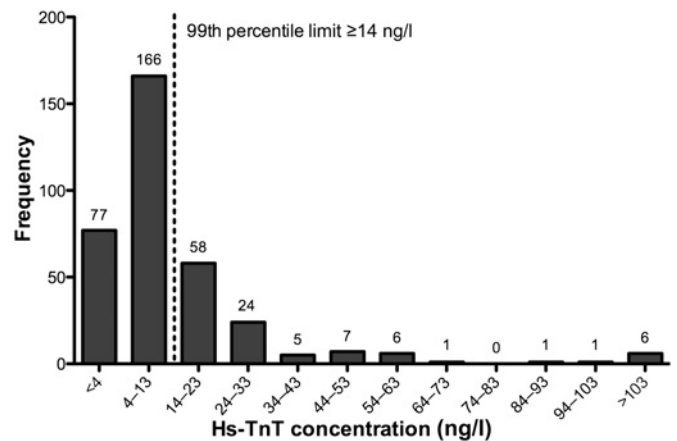


Figure 1 Distribution of baseline high-sensitivity troponin T (TnT) concentration. The dashed line represents the 99th percentile (≥14 ng/litre) reference concentration from a healthy population.

coronary artery bypass grafting. All antiplatelet therapy was ceased in 280 (80%) of all patients in the perioperative period, including 70% of patients with ischaemic heart disease and 50% with previous coronary stenting. With the exception of major vascular procedures, antiplatelet therapy was ceased in the majority of patients (table 3). The management of antiplatelet therapy had no impact on the occurrence of perioperative minor or major bleeding complications, or the need for blood transfusion.

Adverse perioperative cardiovascular events

Myocardial necrosis occurred in 22% of patients undergoing an elective major non-cardiac surgical procedure (table 4). Myocardial necrosis, utilising the alternative 30% delta

Table 2 Surgical and procedural variables

Variable	Study population
Surgical procedure, n (%)	
Major vascular	52 (15)
Major orthopaedic	80 (23)
General	48 (13)
Major urological	66 (19)
Major neurosurgery	18 (5)
Lower risk	88 (25)
Anaesthesia, n (%)	
General	294 (84)
Spinal	64 (18)
Epidural	5 (1)
Nerve block	53 (15)
Intraoperative haemodynamics, n (%)	
Hypotension (SBP <100 mm Hg)	245 (70)
Duration of hypotension (mean±SD, min)	33±24
Hypertension (SBP >160 mm Hg)	123 (35)
Bradycardia (HR <55 bpm)	67 (19)
Tachycardia (HR >100 bpm)	15 (4)
Duration of surgery	
Mean±SD, min	117±73
Median, min (25–75th percentile)	105 (67–147)
Length of stay, days	
Mean±SD	5.6±6.7
Median (25–75th percentile)	4 (2–7)

Values are expressed as mean±SD, n (%) or median (IQR). bpm, beats per minute; HR, heart rate; SBP, systolic blood pressure.

Table 3 Perioperative management of antiplatelet therapy

Variable	Number of patients	Antiplatelet therapy continued	Antiplatelet therapy ceased
All patients, n (%)	352	72 (20)	280 (80)
Primary indication, n (%)			
Ischaemic heart disease	152	47 (31)	105 (69)
Coronary stent	53	26 (49)	27 (51)
Coronary bypass surgery	70	18 (26)	52 (74)
Cerebrovascular disease	31	7 (23)	24 (77)
Atrial fibrillation	19	2 (11)	17 (89)
Peripheral vascular disease	23	15 (65)	8 (35)
Venous thromboembolic	10	0 (0)	10 (100)
Primary prevention	117	1 (1)	116 (99)
Surgery, n (%)			
Major vascular	52	36 (69)	16 (31)
Major orthopaedic	80	7 (9)	73 (91)
General	48	3 (6)	45 (94)
Major urological	66	4 (6)	62 (94)
Major neurosurgery	18	3 (17)	15 (83)
Lower risk	88	19 (22)	69 (78)
Revised cardiac risk index, n (%)			
0	133	11 (8)	122 (92)
1	146	38 (26)	108 (74)
2	57	15 (26)	42 (74)
≥3	16	8 (50)	8 (50)
Duration of antiplatelet cessation (days)			
Mean±SD			9.5±4.7
Median (25–75th percentile)			7 (7–10)

Values are expressed as mean±SD, median (IQR) or n (%).

definition, in addition to an elevation above the 99th reference percentile, occurred in 26% of patients. Only seven patients (2%) suffered clinically apparent MI as defined by the current universal definition.¹⁷ In the initial 86 patients who had both fourth generation TnT and hs-TnT measured, myocardial necrosis occurred in 6% and 26% of patients respectively, resulting in near a fivefold increase in diagnosis using the more sensitive assay. There were no deaths prior to discharge in our cohort. Other major adverse perioperative cardiovascular outcomes occurred infrequently (table 4). Major and minor Thrombolysis in Myocardial Infarction defined bleeding occurred in 7% and 21% of patients respectively, with 7% requiring blood transfusion in the postoperative period.

For patients with Revised Cardiac Risk Index scores of 0, 1, 2 and ≥3, myocardial necrosis occurred in 22%, 19%, 28% and

38% respectively (figure 2A). Those undergoing major orthopaedic or neurosurgical procedures had significantly higher rates of myocardial necrosis than the other surgical procedures (figure 2B). The majority of major orthopaedic surgery undertaken consisted of large joint replacement, with major neurosurgery predominantly lumbar laminectomy or decompressive procedures.

Predictors of perioperative myocardial necrosis

Table 5 summarises the univariable and multivariable Cox analysis for predictors of perioperative myocardial necrosis. By multivariable Cox regression analysis, age (OR per year 1.07; 95% CI 1.03 to 1.10, $p<0.001$), orthopaedic surgery (OR 2.46; 95% CI 1.32 to 4.59, $p=0.005$) and intraoperative hypotension (OR 3.67; 95% CI 1.69 to 7.94, $p=0.001$) were the only independent predictors of perioperative myocardial necrosis. When the categorical variable intraoperative hypotension was replaced in the multivariable analysis by duration of hypotension, it also predicted perioperative myocardial necrosis (OR 1.10 per 5-min interval; 95% CI 1.03 to 1.17, $p=0.004$). Elevated baseline preoperative hs-TnT and pre-operative cessation of antiplatelet therapy were not predictive of myocardial necrosis.

DISCUSSION

In our prospective cohort of patients at high cardiovascular risk undergoing elective non-cardiac surgery we found that perioperative myocardial necrosis occurred in 22% of patients and was clinically undetected in the majority of cases. However, hs-TnT defined myocardial necrosis did not result in any hospital mortality. Independent predictors of myocardial necrosis included increasing age, intraoperative hypotension and orthopaedic surgical procedures.

There are several potential mechanisms that contribute to the pathophysiology of perioperative MI, the first being an acute

Table 4 Adverse perioperative outcomes

Variable	Study population
Major cardiac event, n (%)	
Death	0 (0)
Myocardial infarction (Universal Definition)	7 (2)
Myocardial necrosis, n (%)	
50% delta	79 (22)
30% delta	93 (26)
Cerebrovascular event, n (%)	1 (<1)
Venous thromboembolic, n (%)	9 (3)
Atrial fibrillation, n (%)	9 (3)
Bleeding events, n (%)	
Major TIMI	23 (7)
Minor TIMI	74 (21)
Blood transfusion	26 (7)

Values are expressed as n (%).
TIMI, Thrombolysis in Myocardial Infarction.

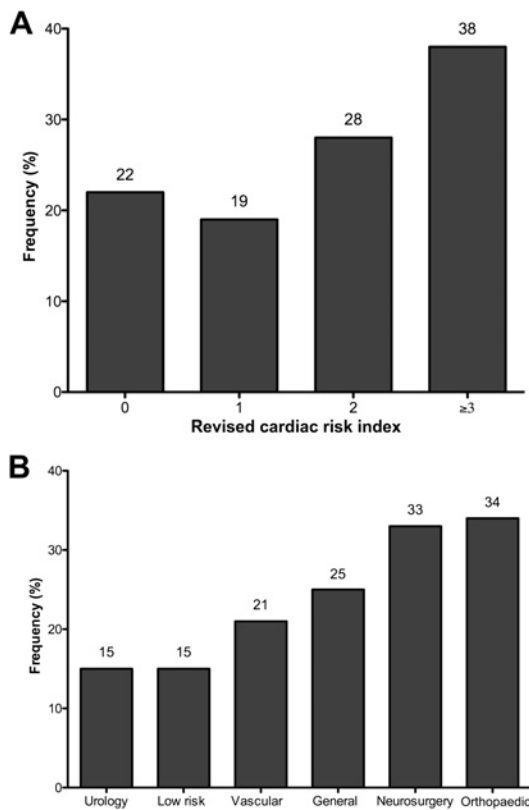


Figure 2 Myocardial necrosis by Revised Cardiac Risk Index (rCRI) and surgery type. (A) Myocardial necrosis by rCRI demonstrating a graded occurrence with increased rCRI score. (B) Myocardial necrosis by surgical type.

coronary syndrome with plaque disruption and resultant thrombus (type 1), the second an imbalance between oxygen supply and demand (type 2),^{17 18} and the third being stent thrombosis, particularly associated with complete interruption of oral antiplatelet therapy.¹⁹ Reduced oxygen supply for required demand in the perioperative period can be due to multiple factors, including hypotension, hypoxia, anaemia, pre-existing coronary stenosis or tachycardia,^{17 20 21} and several of these may occur in combination. Intraoperative hypotension was the predominant haemodynamic abnormality in our cohort and increasing duration of hypotension strongly predicted myocardial necrosis. This has previously been identified as an independent predictor of 1-year mortality after non-cardiac

surgery.²² The relationship of increasing age and myocardial necrosis may reflect an increasing burden of disease, including underlying coronary artery and structural heart disease, in addition to reduced cardiopulmonary reserve. These factors suggest that a ‘type 2’ mechanism may predominantly underlie perioperative myocardial necrosis and infarction.

Despite the high incidence of hs-TnT-defined myocardial necrosis in our cohort, only 2% met diagnostic criteria for clinically apparent MI, and there were no deaths in the immediate postoperative period. This suggests in the non-cardiac surgical setting the criteria for MI may need to be broadened to include these adverse events, which are likely to be prognostically significant. Although we included only patients receiving antiplatelet therapy for the primary or secondary prevention of cardiovascular events, the Revised Cardiac Risk Index suggests that our patients were predominantly a lower risk group. The incidence of myocardial necrosis did however occur in a graded manner, rising in line with increasing estimated perioperative risk. This suggests that perioperative hs-TnT elevation may be clinically relevant and that larger studies with longer follow-up might confirm that even minor elevations of hs-TnT are prognostically significant, as has been recently confirmed for less sensitive troponin assays.^{8 11 12} Our findings are similar to those reported recently in a similar cohort, where 38% of patients had postoperative hs-TnT elevations exceeding an 85% delta value from baseline.²³

A high incidence of perioperative cardiac events among patients undergoing orthopaedic surgery has been reported previously. Using less sensitive cardiac troponin assays, myocardial necrosis occurs in approximately 6% of patients undergoing major joint arthroplasty,²⁴ and predicts worse long-term outcomes.²⁵ Patients undergoing joint replacement surgery tend to be older. However, orthopaedic surgery, predominantly knee and hip replacement surgery in our cohort, remained an independent predictor of perioperative myocardial necrosis even after correction for age and other univariable predictors. Although not investigated in this study, other potential reasons for the high prevalence of hs-TnT elevation after orthopaedic surgery include subclinical fat embolism. This has been reported to occur in up to 67% of patients following lower-limb joint surgery.²⁶ It is plausible that the more significant embolic events may impose haemodynamic cardiac stress through increased pulmonary arterial pressure resulting in the release of troponin.

Preoperative troponin elevation

Several biomarkers have been shown to strongly predict major cardiovascular events following non-cardiac surgery, including

Table 5 Univariate and multivariate predictors of perioperative myocardial necrosis

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age (per year)	1.06 (1.02 to 1.09)	<0.001	1.07 (1.03 to 1.10)	<0.001
Diabetes (oral therapy)	1.80 (1.00 to 3.21)	0.049		
Prior CABG	1.66 (0.92 to 2.98)	0.093		
ACE-I/ARB therapy	2.03 (1.11 to 3.72)	0.021		
Renal impairment	1.83 (1.09 to 3.09)	0.023		
Haemoglobin concentration	0.98 (0.97 to 0.99)	0.026		
Orthopaedic surgery	2.16 (1.24 to 3.75)	0.007	2.46 (1.32 to 4.59)	0.005
Intraoperative hypotension	3.57 (1.75 to 7.26)	<0.001	3.67 (1.69 to 7.94)	0.001
Duration of surgery	1.01 (1.00 to 1.01)	0.047		
Elevated baseline hs-TnT	1.50 (0.89 to 2.54)	0.127		

ACE-I, ACE inhibitor; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass graft; hs-TnT, high-sensitivity troponin T.

N-terminal pro-B-type natriuretic peptide and C-reactive protein.²⁷ However, there are limited data on the prognostic role of elevated preoperative hs-TnT in this setting. In our apparent healthy cohort undergoing elective non-cardiac surgery, we found that 31% of patients had an hs-TnT level above the 99th percentile for a healthy population, prior to the planned procedure. This finding is consistent with a recent report in a similar cohort.²³ It has been demonstrated that circulating levels of hs-TnT incrementally predict cardiovascular death and heart failure in both the general population²⁸ and those with stable coronary disease,¹⁴ however this association is not apparent with incident MI. Similarly we demonstrated no relationship between preoperative hs-TnT and subsequent perioperative myocardial necrosis. Independent predictors of an elevated preoperative hs-TnT in our cohort included age, male gender, diabetes requiring insulin therapy and chronic kidney disease. This is consistent with previous data²⁸ and in our study the high proportion of patients with an elevated baseline hs-TnT may reflect the prevalence of these risk factors. Although only a single baseline measurement of hs-TnT was recorded preoperatively, the high prevalence of elevated hs-TnT in an apparent healthy population has important implications for the use of sensitive troponin assays in this setting, and reinforces the need to include a delta value in the definition of perioperative MI.¹⁶

Cessation of antiplatelet therapy

Current guidelines recommend against the routine cessation of antiplatelet therapy in patients undergoing elective non-cardiac surgery.²⁹ Despite this we found 80% of all patients had therapy ceased during the perioperative period, occurring a mean of 9 days prior to planned surgery. This occurred despite a high prevalence of established cardiovascular disease, and in half of all patients with previous coronary stents. Although the available data are largely retrospective, they suggest that aspirin withdrawal may precipitate a number of acute cardiovascular events.^{30–32} In addition, approximately 5% of patients admitted with an acute coronary syndrome have had aspirin therapy ceased in the prior 3 weeks, largely due to scheduled surgery.³³ Furthermore, antiplatelet therapy interruption more than 5 days preoperatively is independently associated with major adverse cardiac events in patients with coronary stents.¹⁹ Thus, the routine practice of antiplatelet cessation prior to planned surgery may be detrimental.

Interestingly, we found that antiplatelet cessation was not a predictor of perioperative myocardial necrosis in our cohort. Rather, the independent association of age and intraoperative hypotension with myocardial necrosis suggests that the most common mechanism is likely to be a mismatch between myocardial oxygen supply and demand, rather than thrombus formation on vulnerable plaque, when antiplatelet therapy would be expected to benefit. It might be expected that 'type 1' aetiology of MI is associated with higher mortality, but our data suggest that these occur less commonly than anticipated.

Although antiplatelet management had no impact on bleeding complications or transfusion requirements, this may be confounded. Patients considered higher risk for bleeding complications may have been more likely to have therapy interrupted compared with those assessed to be at lower risk of bleeding.

LIMITATIONS

Our observational study describes perioperative practice and outcomes from a single institution including only elective

surgery, limiting generalisability. Although hs-TnT-defined myocardial necrosis occurred commonly in our perioperative cohort, it has yet to be correlated with short-term and longer-term adverse events. Routine hs-TnT measurements in our cohort were performed only on the first two postoperative days; it is possible that myocardial necrosis developing after this may have been missed. However, previous studies have demonstrated the majority of events occur in this timeframe.^{5 8 34} Although we used a 50% delta value in our cohort, the optimal approach in defining myocardial necrosis, whether a percentage or absolute change, still remains to be fully defined. Finally the study is not adequately powered to assess the impact of antiplatelet management on adverse perioperative cardiac and bleeding events.

CONCLUSION

In patients with established cardiovascular disease or at risk of the disease who are undergoing major elective non-cardiac surgery, hs-TnT-defined perioperative myocardial injury occurs frequently and is usually clinically undetected. This represents approximately a fivefold increase in diagnosis compared with the previous generation troponin T assay. Independent predictors of myocardial necrosis include increasing age and intraoperative hypotension, suggesting that supply and demand mismatch may play an important role in cardiac troponin release in this setting. Our findings reinforce the need for thorough preoperative specialist assessment, and highlight the importance of careful intraoperative haemodynamic monitoring.

Contributors All authors contributed equally to the conception, design, data collection and analysis and reporting of data. RFA drafted the manuscript which was reviewed and edited by all other authors. All authors approved the final manuscript.

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Competing interests None.

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