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Cardiovascular

Myocardial infarction after noncardiac surgery in Sweden: a national, retrospective observational cohort study

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Abstract

Background: The precise incidence of perioperative myocardial infarction (MI) after noncardiac surgery remains unclear. We determined the incidence and risk factors for perioperative MI after noncardiac surgery and the risk of MI and mortality compared with matched non-surgical patients.

Methods: Patients >18 yr undergoing noncardiac surgery in 23 Swedish hospitals from 2007 to 2014 were included in this national observational retrospective cohort study. We combined national surgical and outcome databases with Swedeheart, a national quality registry capturing data from patients with acute MI. The primary outcome was incidence of MI within 30 days of surgery. Multivariable logistic regression identified preoperative risk factors associated with MI, including ASA grade, diabetes mellitus, and cardiovascular pathology including previous MI. Standardised incidence rate ratios were calculated. Mortality rates were estimated using Cox proportional hazards.

Results: A total of 1605/400 742 (0.41%) patients (median age: 64 [49–75] yr) had an MI after surgery, which was independently associated with increasing age, comorbidities and higher risk (vascular, thoracic), emergency surgery, or all. The incidence of perioperative MI (per 1000 surgeries) varied from 0.064 (95% confidence interval [CI], 0.02–012) in low-risk patients (ASA physical status 1) to 15.8 (95% CI, 14.9–16.8) among higher risk patients (ASA physical status ≥3, age ≥80 yr, high-risk surgery). Perioperative MI was associated with higher 30-day mortality (adjusted odds ratio: 5.49 [95% 4.76–6.32]). Compared with the non-surgical Swedish population, the perioperative standardised incidence rate ratio was five-fold higher (odds ratio: 5.35 [95% CI: 5.09–5.61]).

Conclusions: In a large Swedish surgical cohort, the incidence of MI within 30 days of noncardiac surgery was 0.41%, chiefly occurring in a small subset of higher risk patients.

Keywords: myocardial infarction; noncardiac surgery; perioperative mortality; postoperative outcome; preoperative risk factors

Editor's key points

- Large, representative population-based studies on perioperative myocardial infarction are sparse.
- Using data captured by large national databases in >400 000 Swedish patients, the authors found that 0.41% patients were diagnosed with myocardial infarction after noncardiac surgery.
- Compared with the non-surgical Swedish population, the standardised risk-increase for myocardial infarction in the noncardiac surgical population was five-fold higher.
- As has been reported for myocardial injury, perioperative myocardial infarction was associated with substantially increased short- and long-term mortality after surgery.
- The study is limited by the lack of high-sensitivity troponin monitoring.

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More than 300 million patients undergo noncardiac surgery each year.[1] Older surgical patients with multimorbidity[2] sustain more complications more frequently.[3] Perioperative complications increase the risk of death five-fold.[4] In the US surgical population, death within 30 days after surgery was the 3rd leading cause of death, exceeded only by heart disease and cancer.[5]

Acute myocardial infarction (MI)[6] after noncardiac surgery may occur in up to 1% of US patients.[7] Risk prediction models to predict perioperative MI were constructed more than 40 yr ago.[8] Although numerous other risk models have been proposed,[9–11] the prevention of MI after surgery remains challenging.[12–14] In the perioperative setting, diagnosing MI is often difficult,[15–17] since ischaemic symptoms often are absent. MI is classified as either Type 1, because of occlusive coronary artery disease, plaque rupture, and thrombosis, or Type 2 characterised by supply-demand imbalance.[6] Isolated elevations in circulating cardiac troponin without ECG or clinical symptoms of infarction is termed myocardial injury. *Secondary myocardial injury*, followed by a description of the underlying cause, (ischemic or non-ischemic) has been suggested as a useful term.[18] For example, haemodynamic instability may contribute to perioperative MI.[16,19–21] Perioperative myocardial injury and MI are associated with increased mortality.[17,22–24]

In this study, our primary objective was to determine the incidence, characteristics, and predictors of acute perioperative MI, defined by the Universal Definition,[6] in a large noncardiac surgical cohort sampled in Swedish hospitals across university, county, and district levels. We combined data from the Swedeheart Swedish National Quality register, the Orbit national surgical database (Orbit) plus the National Patient Register, the Swedish Prescribed Drug Register, and the Cause of Death Registry (all supplied by the National Board of Health and Welfare) to obtain highly detailed perioperative information on the incidence of perioperative MI, allowing us to report reliable risk estimates. Our secondary objectives were to explore whether major noncardiac surgery increases the risk of short- and long-term mortality after MI, as compared with matched non-hospitalised controls.

Methods

Study design

This was a prospectively registered observational multicentre cohort study using data collected from 23 Swedish hospitals (NCT03837535). The study protocol (2014/1306–31/3) was approved by the Regional Ethics Committee of Stockholm, Sweden.

Study participants

Patients aged >18 yr undergoing surgery from January 1, 2007 to December 31, 2014, were included. Exclusion criteria were: ambulatory care surgery, cardiac, obstetric, and minor surgery, performed before 2007 or after 2014, and if a valid surgery code in Orbit—or a corresponding surgery code in NPR—was lacking. The cohort was further refined by excluding patients from hospitals with a high percentage of missing American Society of Anesthesiologists (ASA) physical status classification.

Data sources and study population

Orbit—surgical planning system

The study population was identified from hospitals of all levels (university, county, and district) in Sweden between 1999 and 2015. The Orbit system includes Swedish identity number,[25] patient characteristics, ASA physical status classification, date, type, and duration of anaesthesia and surgery.

The National Board of Health and Welfare

Data were linked to the *National Patient Register* (NPR) using the unique Swedish personal identification number which is assigned at birth or immigration.[26] The *Swedish Prescribed Drug Register* contains data on all dispensed drug prescriptions in Sweden since July 2005.[27] In the *Swedish Cause of Death Registry*, since 1952, >99% of all deaths are reported.[28] The National Board of Health and Welfare records MI through the Hospital Discharge Register or the Cause of Death Register. Statistics are presented by year, sex, age, and geographical area, incidence per 100 000 inhabitants provided. This was used to calculate standardised incidence ratios (SIRs).

Swedeheart

The surgical cohort was linked to Swedeheart, a National Quality Registry containing data on patients with acute MI.[29] Swedeheart was developed in 1995 and has a coverage of 95% among incident cases of MI treated at cardiology departments.

Data collection

Data were obtained from the above described registries. Data collection included individual-level information of patient characteristics and medical history; including age, sex, geographic region of residence, ASA physical status classification, hospital diagnoses, and dispensed drug prescriptions within 5 yr before surgery. This made it possible to identify comorbidities in patients treated in outpatient care, to validate preoperative hospital diagnoses and calculation of Charlson comorbidity index.[30] Perioperative characteristics included date, type, and duration of surgery. Based on surgical codes used in the Nordic countries (NOMESCO), procedures were clustered into 13 subtypes: gastrointestinal; endocrine; ophthalmic; ear, nose, and throat; dental; thoracic; neuro; breast; urologic; gynaecologic; orthopaedic; vascular; and dermatologic surgery. Both Swedeheart and NPR were used to identify all cases of MI <30 days after surgery.

Primary outcome

The primary endpoint was perioperative MI, diagnosed <30 days after noncardiac surgery. MI was defined according to the Universal Definition by the joint European Society of Cardiology and American College of Cardiology consensus.[6] MI was identified using ICD-10-SE diagnosis codes (I21.0-I21.4), for acute transmural, subendocardial, and unspecified MI (thus including Type I and Type II MI).

Secondary outcome

The secondary outcome was mortality after MI, comparing between major noncardiac surgery and non-hospitalised (non-surgical) controls.

Multivariable logistic regression analyses

The association between perioperative MI and mortality <30 days after surgery was evaluated using multivariable logistic regression. A Cox proportional hazards model was undertaken to analyse mortality Days 31–90 and 91–365. Covariates previously associated with a risk of MI and mortality were included in the adjusted analyses; the lowest value for each variable was used as reference. Preoperative risk was defined using the following criteria:

1. Very low risk: age <65 yr, ASA physical status 1, low-risk surgery, no cardiovascular comorbidity or diabetes mellitus.
2. Low risk: same as Group 1, but with two or three factors described in risk Group 3 below.
3. Medium risk: age 65–79, ASA physical status 2, medium-risk surgery, cardiovascular comorbidity without previous MI, diabetes mellitus.
4. High risk: same as Group 3 but with two or three factors described in Group 5 below.
5. Very high risk: age ≥80 yr, ASA physical status >2, high-risk surgery, cardiovascular comorbidity with previous MI.

The relative risks of MI after different surgeries were calculated with logistic regression, using GI surgery as a reference, adjusting for age and sex (Supplementary Table S1). The surgeries were divided into three risk groups; *low* (endocrine; ear, nose, and throat; ophthalmic; dental; breast; and gynaecological surgery), *medium* (GI, neuro, urologic, orthopaedic, and dermatologic surgery), and *high* (vascular and thoracic surgery) risk surgery, according to odds ratios (OR). To evaluate the association between risk factors and MI, multivariable logistic regression models were generated. A selection of covariates was based on clinical consideration and *P*-values in the bivariate analyses. The following were entered into the model: age (six categories); sex; ASA physical status classification; cardiovascular, renal, cerebrovascular, and pulmonary comorbidity; diabetes mellitus; Charlson comorbidity score; surgical risk group; and year.

Statistical analysis

The statistical analysis followed a predefined statistical plan. Continuous data are presented as medians with 25–75th percentiles and categorical variables as percentages. Crude and adjusted hazard ratios (HR) with 95% confidence intervals (CIs) are presented. For comparison of linear and categorical variables, the Mann–Whitney *U*-test or the χ^2 test were used.

SIRs were calculated as the ratio of the observed and expected number of cases using the direct standardisation method. The expected number of cases was calculated according to the yearly incidence rate for all individuals in the statistical database provided by the National Board of Health and Welfare. The SIRs were standardised by 5-yr age groups, sex, 1-yr time periods, and geographic region. The 95% CIs were produced. Statistical tests are two-sided and $P<0.05$ was considered to be significant. Data were analysed by STATA version 14.2 (Stata Corp., College Station, TX, USA).

Sensitivity analyses

Several sensitivity analyses and tests for interaction were performed, most importantly to evaluate potential confounding in patients with missing ASA physical status information. There were no significant differences when this group was analysed separately, or in the remaining cohort when hospitals with a high percentage of missing ASA physical status information were excluded. Further sensitivity analyses were conducted, adjusting for time trends and potential clustering by centre, and restriction of the cohort by age. Furthermore, the timing of MI in the postoperative period was analysed in 326 MI cases.

Results

Patient characteristics

We identified 400 742 eligible patients identified from 23 Swedish hospitals between 2007 and 2014 (Fig 1), comprising 220 434 (55%) female patients with a median (IQR) age 64 (49–75) yr (Table 1). Elective surgical procedures accounted for 281 507/400 742 (70%) cases (Supplementary Tables S1–3). The percentage of patients with missing ASA classification was below 10%, so no imputation of data was deemed necessary.

Primary outcome

A total of 1605/400 742 (0.41%) patients suffered MI within 30 days after surgery. MI was associated with older age, more comorbidities, and higher ASA classification (Table 1). MI occurred more frequently after emergency surgery and higher risk procedures, including vascular and thoracic surgery. The duration of surgery was similar between patients who developed perioperative MI, compared with patients who did not.

Multivariable analysis of risk factors associated with perioperative MI

Estimated crude and adjusted ORs are presented in Table 2. After adjusting for covariates significantly associated with MI, emergency surgery, perioperative MI was independently associated with increasing age, pre-existing cardiovascular disease, higher surgical risk group (Table 3), and ASA classification. Perioperative MI was most likely to occur in the predefined highest surgical risk group (15.8 MI per 1000 surgeries [95% CI: 14.9–16.8]), compared with 0.064 per 1000 surgeries (0.02–012) in the lowest risk group (Table 3 and Fig 2).

Secondary outcome: mortality associated with perioperative MI

Mortality increased progressively over the year after surgery, with 7152 (1.8%), 13 818 (3.5%), and 29 571 (7.4%) deaths within 30, 90, and 365 days of surgery, respectively. At 30, 90, and 365 days after operation, 420/1605 (26%), 562/1605 (35%), and 728/1605 (45%) patients with perioperative MI had died, compared with 6732/399 137 (1.7%), 13 256/399 137 (3.3%), and 29 571/399 137 (7.4%) deaths in patients who did not have a diagnosis of perioperative MI, respectively. Compared with matched non-hospitalised controls in the wider Swedish population, surgical patients had a standardised incidence rate ratio for MI 5.35 (95% CI: 5.09–5.61; Table 4).

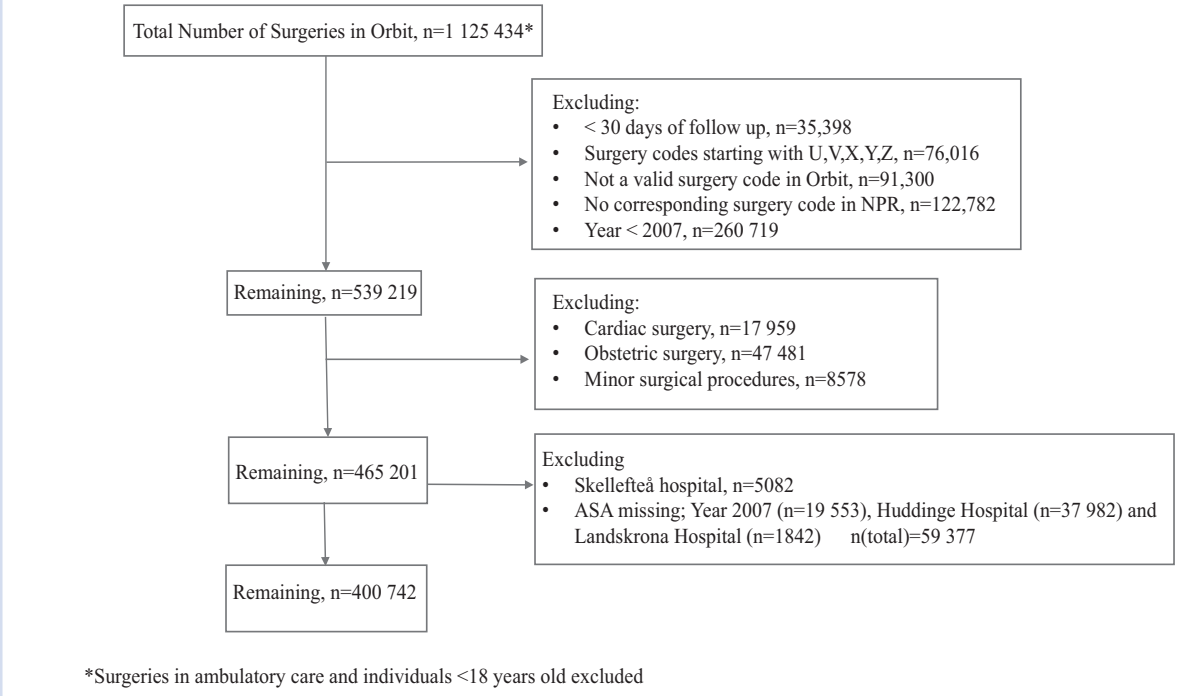

Fig 1. Participant flowchart.

Multivariable analysis of risk factors associated with death after perioperative MI

The unadjusted OR for 30-day mortality was 22.2 (95% CI 19.7–25.1) in patients developing MI<30 days. The adjusted OR for 30-day mortality was lower (5.49 [4.76–6.32]), controlling for covariates we identified as being independently associated with a higher risk of perioperative MI. The crude HRs of mortality Days 31–90 and 91–365 in patients who developed MI within 30 days of surgery were 8.03 (95% CI: 6.72–9.58) and 4.29 (95% CI: 3.63–5.06), respectively. In multivariable Cox regression analyses, perioperative MI was independently associated with higher mortality (Table 5).

Sensitivity analysis

The results remained similar when patients with missing ASA information were analysed separately. Subanalysis of patients ≥45 yr revealed 0.5% incidence for perioperative MI. Some 75% of MI occurred within a week after surgery. Hospital variability in MI rates had no effect on multivariable risk estimates (Supplementary Table S3).

Discussion

In this large noncardiac surgical cohort, MI within 30 days of noncardiac surgery occurred in 0.4% of adult patients. A higher risk of perioperative MI was associated with increasing age, surgical procedure, and preoperative cardiovascular comorbidity. A small subset of high-risk patients sustained the majority of perioperative cardiac morbidity. Compared with the Swedish population, surgical patients had at least a five-fold higher risk for MI, standardised by age, sex, geographical region, and year. Perioperative MI was associated with accelerated short- and long-term mortality, which persisted for at least 1 yr after surgery. ASA classification was as an independent risk predictor, suggesting that measures that reflected combinations of risk factors may assist the prediction of perioperative MI and mortality.

Perioperative MI incidence in our cohort was half of the incidence (0.9%) reported in a large study of MI in noncardiac surgical patients.[7] Although the age inclusion criteria differed, median age, patient risk factors, and surgical procedures carrying the highest risk were similar in our study. However, there was a major difference in how MI patients were identified. In the study by Smilowitz and colleagues,[7] MI diagnosis was reported during the surgical inpatient hospitalisation without specifying when MI occurred, which could erroneously lead to a higher incidence being reported. Using the unique Swedish Quality Registry (Swedeheart) and the National Patient Register, MI could be identified within a prespecified 30 day period after surgery including those diagnosed with Type 2 MI, not referred to cardiology clinics or referred for cardiac intervention. However, these incidents are often clinically silent,22 suggesting that the lack of routine cardiac biomarker surveillance (cardiac troponins) in our patient cohort underestimates the incidence of perioperative MI.

Reports on long-term mortality after perioperative MI are lacking. In a smaller study of patients with perioperative myocardial injury in noncardiac surgery, 8.9% died <30 days and 22.5% <1 yr after surgery, with adjusted HR for 30-day and 1-yr mortality of 2.73 and 1.58, respectively.[23] This cohort comprised high-risk patients, as defined by age and

Table 1 Participant baseline characteristics and proportion of myocardial infarction <30 days after surgery.

Patient characteristics		Total N=400 742 (%)	MI<30 days N=1605 (0.4%*)	P-value
Type of surgery	Elective	281 507 (70)	687 (0.24)	<0.001
	Acute	119 235 (30)	918 (0.77)	
Gender	Female	220 434 (55)	763 (0.35)	<0.001
	Male	180 308 (45)	842 (0.47)	
ASA physical status	1	96 583 (24)	22 (0.02)	<0.001
	2	159 092 (40)	298 (0.19)	
	3	96 977 (24)	810 (0.84)	
	4	8038 (2)	280 (3.5)	
	Missing	40 052 (9.9)	195 (0.49)	
Age (yr)		64 (49–75)	81 (72–86)	<0.001
Age (yr)	<65	201 500 (50)	181 (0.09)	<0.001
	65–69	49 810 (12)	131 (0.26)	
	70–74	44 992 (11)	185 (0.41)	
	75–79	39 194 (10)	247 (0.63)	
	80–84	32 246 (8)	304 (0.94)	
	≥85	33 090 (8)	557 (1.7)	
Preoperative data	Cardiovascular† disease; yes, excl MI	189 980 (47)	983 (0.52)	<0.001
	yes, incl MI	19 453 (5)	456 (2.3)	
	no	191 309 (48	166 (0.09	
	Renal‡ disease; yes	21 038 (5)	211 (1.0)	<0.001
	no		1394 (0.37)	
	Cerebrovascular¶ disease; yes	22 787 (6)	241 (1.1)	<0.001
	no		1364 (0.36)	
	Pulmonary§ disease; yes	30 545 (8)	297 (0.97)	<0.001
	no		1308 (0.35)	
	Diabetes mellitus; yes	45 613 (11)	420 (0.91)	<0.001
	no		1185 (0.33)	
Perioperative duration	Charlson score 0	198 082 (49)	372 (0.19)	<0.001
	1	38 617 (10)	188 (0.49)	
	≥2	164 043 (41)	1045 (0.64)	
	≥2 h	110 914 (28)	1193 (0.41)	
	<2 h	0.072	412 (0.37)	
Surgery	Low risk‖	87 141 (22)	69 (0.08)	<0.001
	Medium risk#	291 505 (73)	1284 (0.44)	
	High risk**	22 096 (6)	252 (1.14)	
Year of surgery	2007–2008	71 377 (18)	361 (0.51)	<0.001
	2009–2010	90 635 (23)	366 (0.40)	
	2011–2012	111 929 (28)	440 (0.39)	
	2013–1014	126 801 (32)	438 (0.35)	
Mortality	30-day; dead	7152 (1.8)	420 (5.9)	<0.001
	alive		1185 (0.3)	
	90-day; dead	13 818 (3.5)	562 (4.1)	<0.001
	alive		1043 (0.27)	
	1-yr; dead	29 571 (7.4)	728 (2.5)	<0.001
	alive		877 (0.24)	

MI, myocardial infarction.
* Percentage of MI<30 days within the horizontal subpopulation of the cohort.
† Chronic ischemic heart disease, angina pectoris, hypertensive disease, cardiac arrest, heart failure, valve disease, pulmonary heart disease, cardiomyopathy, conduction disorders/cardiac arrhythmias, cardiac arrest, diseases of arteries, arterioles and capillaries.
‡ Acute renal failure/unspecified renal failure, chronic renal failure, other renal disease.
¶ Cerebrovascular disease.
§ Pneumonia, chronic obstructive pulmonary disease.
‖ Endocrine; ear, nose, and throat; ophthalmic; dental; breast; gynaecologic surgery.
Gastrointestinal, neuro, urologic, orthopaedic, dermatologic surgery.
** Vascular, noncardiac, thoracic surgery

comorbidities, and is likely to explain the higher overall mortality compared with ours. In a large observational study, an overall mortality of 1.2–1.8% in major noncardiac surgical patients was reported (similar to our cohort mortality) with a three-fold higher 30-day mortality in patients with perioperative myocardial injury (adjusted HR, 3.69).[17,31] In another recent study evaluating MI incidence in a US surgical cohort, in-hospital mortality was 18% in patients corresponding to an adjusted OR 5.76 for in-hospital MI.[7]

In our study, a higher absolute risk for death after perioperative MI was associated with preoperative comorbidity and older age. After adjustment for comorbidity, patients with perioperative MI had a five-fold increased risk of dying <30 days after surgery. Our data are consistent with the in-hospital mortality after perioperative MI reported by Smilowitz and colleagues[7] but higher compared with VISION-defined myocardial injury.[17,23] A plausible explanation would be that only patients fulfilling the universal criteria for MI[6] were

Table 2 Predictors of myocardial infarction <30 days after surgery.

Risk factor	OR (Unadjusted)	OR (adjusted*)
Non-elective	3.15 (2.84–3.51)	1.75 (1.55–1.97)
Male	1.35 (1.22–1.50)	1.13 (1.02–1.27)
Age (yr) <65	Ref	ref
65–69	3.03 (2.38–3.87)	1.64 (1.28–2.10)
70–74	4.78 (3.83–5.97)	2.22 (1.76–2.79)
75–79	7.57 (6.15–9.31)	2.97 (2.39–3.69)
80–84	11.4 (9.37–14.0)	3.82 (3.09–4.72)
≥85	20.4 (17.0–24.5)	5.47 (4.48–6.69)
ASA physical status 1	ref	ref
2	8.24 (5.34–12.7)	3.38 (2.15–5.32)
3	37.0 (24.2–56.5)	7.65 (4.86–12.1)
4	158 (102–245)	23.2 (14.5–37.1)
Cardiovascular† disease, no	ref	ref
yes, excluding MI	5.91 (4.97–7.03)	1.75 (1.45–2.12)
yes, including MI	4.41 (3.54–5.50)	
Renal‡ disease	2.67 (2.29–3.13)	1.05 (0.89–1.24)
Cerebrovascular¶ disease	2.86 (2.46–3.32)	0.97 (0.83–1.13)
Pulmonary§ disease	2.88 (2.52–3.29)	1.00 (0.87–1.16)
Diabetes mellitus	2.68 (2.38–3.02)	1.28 (1.13–1.46)
Charlson score: 0	ref	ref
1	2.60 (2.16–3.13)	0.93 (0.76–1.13)
≥2	3.31 (2.92–3.75)	0.86 (0.74–1.01)
Surgery: low risk	ref	ref
Medium risk	6.66 (5.04–8.79)	2.22 (1.66–2.96)
High risk	16.8 (12.4–22.7)	4.40 (3.21–6.02)
Year: 2013–2014	ref	
2011–2012	1.14 (0.99–1.31)	1.19 (1.04–1.37)
2009–2010	1.13 (0.97–1.31)	1.29 (1.11–1.50)
2007–2008	1.44 (1.24–1.67)	1.88 (1.62–2.19)

MI, myocardial infarction; ref, reference.
* Adjusted for all variables in the table.
† Chronic ischemic heart disease, angina pectoris, hypertensive disease, cardiac arrest, heart failure, valve disease, pulmonary heart disease, cardiomyopathy, conduction disorders/cardiac arrhythmias, cardiac arrest, diseases of arteries, arterioles and capillaries.
‡ Acute renal failure/unspecified renal failure, chronic renal failure, other renal disease.
¶ Cerebrovascular disease.
§ Pneumonia, COPD.

included in our study, but asymptomatic myocardial injuries were not. However, several studies suggest that both symptomatic and asymptomatic MI are associated with an equally poor prognosis.[22]

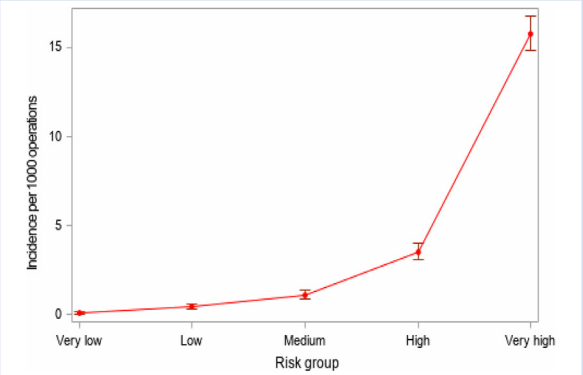

Fig 2. Myocardial infarction incidence per 1000 operations. Cohort divided into five equally sized risk groups. Very low risk: age<65 yr, ASA 1, low risk surgery, no cardiovascular comorbidity or diabetes. Low risk: same as risk Group 1, but with two or three factors described in risk Group 3 below. Medium risk: age 65–79 yr, ASA 2, medium risk surgery, cardiovascular comorbidity without previous myocardial infarction, diabetes. High risk: same as risk Group 3 but with two or three factors described in risk Group 5 below. Very high risk: age ≥80 yr, ASA>2, high risk surgery, cardiovascular comorbidity with previous myocardial infarction.

A strength of this study was the combined use of the Swedeheart quality register and the NPR, which comprise a large, representative patient population with detailed data on comorbidity. Uniquely, we used the National Board of Health and Welfare statistical database, making standardised incidence ratios quantifiable. The overall low incidence for perioperative MI reflects the broad inclusion of low-risk patients and procedures. To our knowledge, there are no previous reports of comparing the risk of perioperative MI with that of the general population. This is the first time the overall impact of perioperative care on increasing risk of MI has been reported. Lastly, the Swedish identity number makes it possible to report short- and long-term mortality.

Since our data were collected from large registries and databases, reporting bias is likely, as errors in coding may increase the risk of misclassification bias. As this was not a prospective study, physicians who diagnosed MI will have also

Table 3 Risk of myocardial infarction <30 days after surgery. Cohort divided into five equally sized risk groups.*

Risk group	Total N (%)	MI<30 days N (%)	OR (95% CI)	Inc/1000 (95% CI)
Very low	77 628 (22)	5 (0.0064)	Ref	0.064 (0.02–0.12)
Low	75 348 (21)	31 (0.041)	6.39 (2.48–16.4)	0.41 (0.27–0.56)
Medium	77 132 (21)	85 (0.11)	17.1 (6.95–42.2)	1.10 (0.87–1.34)
High	63 178 (18)	223 (0.35)	55.0 (22.7–133)	3.53 (3.07–3.99)
Very high	67 404 (19)	1066 (1.58)	249 (104–601)	15.8 (14.9–16.8)

CI, confidence interval; MI, myocardial infarction; OR, odds ratio; Ref, reference.
* Very low risk: age<65 yr, ASA 1, low risk surgery, no cardiovascular comorbidity or diabetes. Low risk: same as risk Group 1, but with two or three factors described in risk Group 3 below. Medium risk: age 65–79 yr, ASA 2, medium risk surgery, cardiovascular comorbidity without previous MI, diabetes. High risk: same as risk Group 3 but with two or three factors described in risk Group 5 below. Very high risk: age ≥80 yr ASA>2, high risk surgery, cardiovascular comorbidity with previous MI.

Table 4 Myocardial infarction risk in surgical patients, with the Swedish population as reference.

	Observed cases	SIR* (95% CI)	Observed cases /100 000	Expected cases /100 000
Total	1605	5.35 (5.09–5.61)	401	75
Female	763	6.06 (5.63–6.49)	190	31
Male	842	4.83 (4.51–5.17)	210	43

CI, confidence interval; SIR, standardised incidence ratio.
* Standardised by 5-yr age group, gender, 1-yr time period, and geographic region

Table 5 Mortality rates in patients developing myocardial infarction within 30 days after surgery; odds ratios presented for 30-day mortality, hazard ratios presented for mortality Day 31–90 and 91–365 after surgery.

		OR (unadjusted)	OR (adjusted*)	HR (unadjusted)	HR (adjusted*)
Mortality	<30 days	22.2 (19.7–25.1)	5.49 (4.76–6.32)		
	Day 31–90			8.03 (6.72–9.58)	2.05 (1.72–2.46)
	Day 91–365			4.29 (3.63–5.06)	1.37 (1.16–1.62)

HR, hazard ratio; OR, odds ratio.
* Adjusted for 5-yr age group, gender, ASA-class, cardiovascular disease, previous myocardial infacrtion, renal, cerebrovascular, and pulmonary disease, diabetes, Charlson comorbidity index, surgical risk group, acute *vs* elective status and year of surgery.

used the 3rd Universal definition which may influence our estimated MI incidence. Another major limitation is the lack of cardiac biomarker information in all patients, which would capture clinically silent events. There is also an inherent risk that troponins were obtained more frequently in older/high-risk patients, leading to a risk of confounding by indication. The question of whether MI after noncardiac surgery can be reduced cannot be addressed by our study, which may be influenced by intraoperative hypotension.[21]

In summary, the overall incidence of MI within 30 days of noncardiac surgery was 0.41% in a large Swedish multicentre cohort of surgical patients. A small subset of patients appear most likely to develop MI after noncardiac surgery. Compared with the general Swedish population, the standardised risk for MI was five-fold higher, which in turn was strongly associated with higher mortality rates.

Authors' contributions

Study design: all authors
Acquisition of data: LH, MB
Statistical analysis: LH, FG
Interpretation of data: all authors
Manuscript writing: LH
Supervising the scientific process: FG, MB
Critically revising the manuscript; final approval of the version to be published: MB

Declarations of interest

The authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2020.03.015.

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