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Original Article

Troponin Testing After Noncardiac Surgery in Ontario: An Observational Study

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ABSTRACT

Background: In 2017, the Canadian Cardiovascular Society (CCS) published guidelines recommending postoperative troponin surveillance in higher-risk patients having major noncardiac surgery. The objective of this study was to evaluate the proportion of major noncardiac surgery patients that would meet recommendations for troponin testing and to assess the rates of troponin testing before guideline adoption.

Methods: We conducted a retrospective observational study of patients age 40 to 105 undergoing a subset of major noncardiac surgeries that included orthopedics, gynecology, general, urology, vascular, and thoracic surgeries in Ontario, Canada from January 1, 2010 to December 31, 2017. The primary outcomes were the proportion of patients recommended for testing based on the guidelines and rates of troponin testing within 2 days of surgery.

Results: We identified 257,704 patients who underwent noncardiac surgery. Mean age was 66.4 ± 11.9 years, and 12.4% underwent urgent surgery. Applying the CCS guidelines, 71.2% of elective surgery patients and 81.0% of urgent surgery patients

RÉSUMÉ

Introduction : En 2017, la Société canadienne de cardiologie (SCC) a publié des lignes directrices dont les recommandations portaient sur la surveillance de la troponine en phase postopératoire chez les patients exposés à un risque accru de subir une intervention chirurgicale non cardiaque importante. L'objectif de la présente étude était d'évaluer le nombre de patients subissant une intervention chirurgicale non cardiaque importante qui répondraient aux recommandations sur le dosage de la troponine et de déterminer la fréquence des dosages de la troponine avant l'adoption des lignes directrices.

Méthodes : Nous avons mené une étude observationnelle rétrospective auprès de patients âgés de 40 à 105 ans subissant des interventions chirurgicales non cardiaques importantes, à savoir des interventions de chirurgie orthopédique, de chirurgie gynécologique, de chirurgie générale, de chirurgie urologique, de chirurgie vasculaire et de chirurgie thoracique en Ontario, au Canada, du 1er janvier 2010 au 31 décembre 2017. Les principaux critères d'évaluation étaient le nombre de patients pour qui le dosage était recommandé selon les lignes directrices, et la fréquence des dosages de la troponine dans les deux jours après l'intervention chirurgicale.

More than 300 million surgeries are performed worldwide each year.[1] Despite clinical advancements, postoperative complications after surgery are common and can affect up to 40% of patients.[2] Moreover, the 30-day mortality rate is approximately 2% for patients undergoing major noncardiac surgery, most of which is cardiac related.[3,4] Some have suggested that postoperative cardiovascular events are grossly underestimated because myocardial injury after noncardiac surgery (MINS) and perioperative myocardial infarction are often silent after surgery.[5-7] Studies that test all noncardiac surgery patients postoperatively with troponin show that MINS and perioperative myocardial infarction occur at a much higher rate of 8.0% to 17.9%.[3,5,6] Early identification of cardiac complications has the potential to change patient management and may improve outcomes.[8-10] Routine troponin monitoring for higher-risk patients has been suggested for identification of patients with silent ischemic events; yet, practice guidelines currently diverge substantially across countries. European guidelines recommend that noncardiac surgery patients with a revised cardiac risk index (RCRI)[11] score of 3 or more receive testing, whereas vascular surgery patients with a score of 2 or more should receive testing.[12] American guidelines, conversely, only recommend troponin testing in patients with symptoms of myocardial ischemia.[13]

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Ethics Statement: The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act without the requirement for research ethics board approval.

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would have met recommendations for postoperative troponin screening, whereas 10.8% and 27.1% received postoperative troponin testing, respectively. Most elective surgery patients met recommendations for testing based on the age criterion (54.9%), followed by diabetes (24.6%) and high-risk surgery (22.7%) criteria. Troponin testing varied substantially by types of surgery: highest for open abdominal aortic aneurisms and lowest for hysterectomies.

Conclusions: Based on the CCS guidelines, most patients undergoing the subset of surgeries assessed would have met recommendations for routine troponin testing. In contrast, routine troponin testing before guideline adoption was done infrequently in Ontario, with substantial variations based on the surgery type.

Résultats : Nous avons relevé 257 704 patients qui avaient subi une intervention chirurgicale non cardiaque. L'âge moyen était de 66,4 ± 11,9 ans, et 12,4 % avaient subi une intervention chirurgicale urgente. En appliquant les lignes directrices de la SCC, 71,2 % des patients avaient subi une intervention chirurgicale élective et 81,0 % des patients qui avaient subi une intervention chirurgicale urgente répondaient aux recommandations de dépistage de la troponine en phase postopératoire, alors que respectivement 10,8 % et 27,1 % avaient reçu le dosage de la troponine en phase postopératoire. La plupart des patients qui avaient subi une intervention chirurgicale élective répondaient aux recommandations sur le dosage selon le critère d'âge (54,9 %), puis selon le critère de diabète (24,6 %) et le critère d'intervention chirurgicale à risque élevé (22,7 %). Le dosage de la troponine variait de façon substantielle selon le type d'intervention chirurgicale : le dosage le plus élevé lors des traitements chirurgicaux ouverts des anévrismes de l'artère abdominale et le dosage le plus faible lors d'hystérectomies.

Conclusions : Selon les lignes directrices de la SCC, la plupart des patients qui subissaient les interventions chirurgicales évaluées avaient répondu aux recommandations de dosage systématique de la troponine. En revanche, le dosage systématique de la troponine avant l'adoption des lignes directrices était rarement réalisé en Ontario, et des variations substantielles selon le type d'intervention chirurgicale étaient observées.

The Canadian Cardiovascular Society (CCS) recently published perioperative guidelines to also recommend routine troponin screening for noncardiac surgeries requiring at least one overnight stay.[14] For patients undergoing elective noncardiac surgeries, B-type natriuretic peptide (BNP) or N-terminal pro b-type ntriuretic peptide (NT-proBNP) preoperative testing is recommended in patients who are 65 years of age or older, 45-64 years who have significant cardiovascular disease, or who have a RCRI score of 1 or greater. If BNP/NT-proBNP levels are elevated or not available, postoperative troponin testing is recommended. Patients undergoing urgent procedures are recommended to receive testing if they are 65 years or older or have significant cardiovascular disease. The proportion of patients that would be recommended for routine testing under these guidelines is uncertain. Accordingly, we evaluated the proportion of major noncardiac surgery patients who would be eligible for routine troponin testing based on the latest recommendations and the troponin testing rate during that period. We hypothesize that use of postoperative troponin testing before the adoption of the guidelines will be relatively low compared with what the guidelines currently recommend.

Methods

Design and data sources

We conducted a retrospective observational study using administrative and laboratory data housed at ICES (formerly known as the Institute for Clinical Evaluative Sciences) in Toronto, Canada. The primary database used for this study was the Ontario Laboratory Information System (OLIS). OLIS is a repository of all hospital and community laboratory information with the purpose of sharing laboratory records between hospitals, community laboratories, public health laboratories, and health care providers. Additional data sources for this study included the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD), a database containing administrative and clinical data on patients admitted to hospital, which was used to identify hospitalizations and comorbidities; the Ontario Health Insurance Plan, a registry containing all provincial physician billing; and Statistics Canada, census data used to identify neighborhood income data. All the data were linked and analyzed at ICES. The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board.

Study population

This study included patients 40-105 years of age undergoing select major inpatient noncardiac surgeries from January 1, 2010-December 31, 2017. We used a convenience sampling strategy of 12 commonly performed major noncardiac surgeries: orthopedics (hip, knee, and shoulder replacement), gynecologic (hysterectomy), general surgery (large bowel, rectum, and upper gastrointestinal surgeries), urology (nephrectomy and prostatectomy), vascular (amputation, carotid endarterectomy, open and endovascular abdominal aortic aneurysm repair), and thoracic (lobectomy). Surgeries were ascertained using Canadian Classification of Health Interventions codes described in Supplementary Table S1. Urgent admission status describes the initial status of the patient at the time of admission and was assessed by CIHI-DAD. For months in which hospitals were not reporting laboratory data to OLIS, all patients at that institution were excluded. Nine percent of hospitals reported data to OLIS in 2010, whereas 75% and 78% of hospitals reported data in 2016 and 2017, respectively. We included data after the publication of the

guidelines after confirming that troponin use did not change in 2017 compared with previous years. Additional indications for exclusions were for non-Ontario residents, operative deaths, or missing location information.

Outcome

This study assessed 2 outcomes in the entire study cohort: (1) eligibility for guideline recommended testing and (2) actual receipt of troponin testing within 2 days after surgery. Eligibility for guideline-recommended testing was modelled using the 2017 CCS Guidelines.[14] NT-proBNP/BNP records were not available and thus were not used to determine eligibility. Eligibility for guideline-recommended testing was also modelled using the European Society of Cardiology and the European Society of Anaesthesiology guidelines.[12] The receipt of postoperative troponin testing was assessed using OLIS. We included all troponin assays captured in OLIS, including plasma and serum troponin as well as conventional and high-sensitivity assays.

Analyses

The CCS guidelines recommend testing for all patients with a baseline risk greater than a threshold of 5% for cardiovascular death or myocardial infarction. This threshold is defined differently based on elective and urgent surgery status, and, as such, we created cohorts for each. Baseline characteristics were stratified either by the urgency (ie, elective vs urgent) of surgery and the type of surgery. We assessed the proportion of patients meeting recommendations for testing based on the guidelines for those undergoing elective and urgent surgery separately. Elective surgery patients met recommendations for testing if they were (1) 65 years or older, (2) 45-64 years with significant cardiovascular disease, or (3) RCRI $\geq$ 1. Urgent surgery patients met recommendations for testing if they were (1) aged 65 years or older or (2) had significant cardiovascular disease. Significant cardiovascular disease was defined as history of coronary artery disease, cerebral vascular disease, peripheral artery disease, and congestive heart failure. Severe pulmonary hypertension, severe obstructive intracardiac abnormality, and hypertrophic obstructive cardiomyopathies were not included in this definition, as the data were not available. The RCRI is an externally validated tool used to predict major perioperative cardiovascular complications for patients undergoing elective noncardiac procedures.[15,16] The RCRI consists of 6 components with 1 point given for each component: (1) high-risk surgery, (2) history of ischemic heart disease, (3) history of congestive heart failure, (4) history of cerebrovascular disease, (5) history of diabetes requiring preoperative insulin use, and (6) chronic kidney disease (creatinine > 176.8 μmol/L). High-risk surgery was defined as any intraperitoneal surgery, intrathoracic surgery, or suprainguinal vascular surgery as described by CCS guidelines. These surgeries included large bowel and rectum surgery, nephrectomy, lobectomy, upper gastrointestinal surgery, and endovascular and open AAA repair surgeries. We did not have data regarding preoperative creatinine and insulin use and thus used chronic kidney disease[17] and diabetes as surrogates, consistent with previous studies.[18] The codes used to define the RCRI components are described in Supplemental Table S2. We reported the proportion of patients that met recommendations for testing by each CCS criteria stratified by surgery type. These analyses were done in the entire cohort and in patients that only met one CCS criteria for recommendations. The proportion of guideline-recommended patients receiving troponin tests were calculated in both elective and urgent surgery cohorts using data from OLIS. In the elective surgery cohort, we also assessed the proportion of patients receiving postoperative troponin stratified by RCRI score. Chi-squared tests were used to assess if there were differences in testing rates across types of surgeries within both cohorts. We assessed temporal changes in rates of eligibility for troponin recommendations and for troponin testing rates by stratifying by year. A linear regression was modelled adjusting for only year of surgery to assess the temporal trend. We also assessed the proportion of patients in our cohort who would have met European Society of Cardiology/European Society of Anaesthesiology recommendations for testing, and the proportion of recommended patients that received testing.[12] According to these guidelines, patients meet recommendations for testing if they are undergoing noncardiac surgery with an RCRI $\geq$ 3, or in the case of vascular surgery, if they have an RCRI of $\geq$ 2. All analyses were performed using SAS statistical software, version 9.4 (SAS Institute, Cary, NC).

Results

Cohort creation

After excluding noneligible patients, our final cohort consisted of 257,704 patients. We excluded 4.50% of patients who were < 40 or > 105 years. We also excluded patients with missing neighborhood location data, amounting to 0.21% of the cohort. Additional exclusions were for non-Ontario residents (0.03%), and operative deaths (0.02%).

Baseline characteristics

Baseline characteristics stratified by urgency of surgery are summarized in Table 1. More than half (52.5%) of our sample had hip or knee replacements (Table 1). Hysterectomies and large bowel and rectal surgeries accounted for 13.7% and 10.4% of our surgeries, respectively. The remaining surgical groups individually each account for less than 10% of the sample. Among the 87.6% of patients who underwent elective surgery, the mean age was 65.3 $\pm$ 11.2 years, and 60.2% were women. A total of 55.9% of patients had an RCRI score of 0, 32.6% had a score of 1, 8.8% had a score of 2, 2.0% had a score of 3, and 0.6% had a score of 3 or more. A total of 44.1% of patients had an RCRI of 1 or more. Burden of comorbidities was low as indicated by a median Charlson comorbidity index of 0 (interquartile range, 0-0). For the 12.4% of patients undergoing urgent surgery, mean age was 74.2 $\pm$ 13.1 years, and 56.7% were women. Comorbidity burden was higher than those having elective procedures, indicated by a median Charlson index of 1 (interquartile range, 0-2). Baseline characteristics also varied by type of surgery (Supplementary Table S3). Across the different types of surgeries, mean age ranged from 55.4 to 75.4 years. For most surgeries, most patients were 65 or older.

Table 1. Baseline characteristics

	Elective n = 225,871	Urgent n = 31,833	Total N = 257,704
Demographics			
Age (Mean ± SD)	65.3 ± 11.2	74.2 ± 13.1	66.4 ± 11.9
Age ≥ 65	54.9%	76.0%	57.5%
Female	60.2%	56.7%	59.8%
Rural	14.6%	12.8%	14.3%
Income quintile			
1	17.6%	24.1%	18.4%
2	19.8%	21.4%	20.0%
3	20.1%	19.0%	20.0%
4	20.3%	17.2%	19.9%
5	22.2%	18.3%	21.7%
RCRI			
0	55.9%	29.9%	52.7%
1	32.6%	40.5%	33.6%
2	8.8%	18.4%	10.0%
3	2.0%	7.6%	2.7%
4+	0.6%	3.6%	1.0%
Charlson Index* (Median [IQR])	0 (0-0)	1 (0-2)	0 (0-1)
Cardiovascular comorbidities			
Atrial fibrillation	3.4%	12.6%	4.5%
Coronary artery disease	4.8%	12.5%	5.8%
Dyslipidemia	3.5%	7.8%	4.0%
Heart failure	5.4%	20.2%	7.2%
Hypertension	63.8%	75.8%	65.2%
Stroke/transient ischemic attack	1.1%	5.1%	1.6%
Peripheral vascular disease	1.7%	8.4%	2.5%
Prior myocardial infarction	2.0%	6.3%	2.6%
Medical comorbidities			
Anemia/blood disease	4.5%	17.3%	6.0%
Cancer	9.0%	12.8%	9.4%
Chronic kidney disease	1.1%	6.4%	1.7%
Chronic obstructive pulmonary disease	19.3%	30.2%	20.7%
Diabetes	24.6%	34.3%	25.8%
Hospital factors			
Teaching hospital	34.7%	32.3%	34.4%
Hospital beds (Median [IQR])	343 (236-507)	325 (227-499)	342 (235-505)
Surgeries			
Below-/above-knee amputation	0.6%	9.1%	1.6%
Carotid endarterectomy	1.1%	2.8%	1.3%
Endovascular AAA repair	1.1%	1.2%	1.1%
Hip/knee replacement	55.3%	50.3%	54.7%
Hysterectomy	16.0%	1.4%	14.2%
Large bowel and rectum surgery	8.8%	25.2%	10.8%
Lobectomy	4.4%	2.0%	4.1%
Nephrectomy	2.8%	0.7%	2.6%
Open AAA Repair	1.1%	2.2%	1.2%
Prostatectomy	3.5%	0.1%	3.1%
Shoulder replacement	2.3%	2.5%	2.4%
Upper GI surgery	2.9%	2.7%	2.8%

AAA, abdominal aortic aneurysm; GI, gastrointestinal; IQR, interquartile range; RCRI, revised cardiac risk index; SD, standard deviation.

*Modified Charlson index included acute myocardial infarction, heart failure, peripheral vascular disease, dementia, chronic obstructive pulmonary disease, rheumatologic disorders, digestive ulcer, mild/moderate/severe liver disease, diabetes with and without chronic complications, hemiplegia or paraplegia, renal disease, primary cancer, metastatic cancer, and HIV as variables.

Guideline recommendations for testing and observed testing rates

If the CCS guidelines were applied to our cohort, 186,699 patients (72.4%) would meet the recommendations for troponin screening following surgery (Table 2). However, only 24,408 (13.1%) of these patients received a troponin test.

Elective procedures. For patients undergoing elective procedures, 71.2% would have met recommendations for testing given the CCS guidelines. This varied by surgery such that 34.0%-100% of patients met recommendations depending on the procedure (Fig. 1). A total of 54.9% patients met indications for testing via age criteria, 44.1% via the RCRI criteria, and 10.6% via the significant cardiovascular disease criteria (Table 3). The proportion of patients that met recommendations for testing varied substantially by surgery. For 6 of the 12 surgeries assessed, all patients met recommendations for testing via the high-risk criteria. Most patients for 9 of the 12 procedures assessed also met recommendations for testing via the age criterion. In patients who only met one of the CCS criteria for testing, 27.0% only met recommendations via age criteria, 6.5% via the RCRI high-risk criteria, and 5.9% via the RCRI diabetes criteria (Supplemental Table S4). Although most patients would have met CCS recommendations for testing, only 10.8% received a troponin test within 2 days of surgery. Testing rates varied significantly by surgery (5.1%-61.4%; χ^2; $P < 0.001$; Supplementary Table S5).

Urgent procedures. There were 31,833 patients in our cohort undergoing urgent surgery, 25,800 (81.0%) of whom would have met indications for troponin testing under CCS criteria (Table 2). The proportion of patients that met the recommendations for testing varied substantially by the type of surgery (27.2%-94.7%). Most (76.0%) patients met indications for testing based on the age criteria alone. For all but one surgery (hysterectomies), most patients met recommendations via the age criteria. When assessing patients who met recommendations for testing based on only one component of the CCS criteria, 49.0% met recommendations via the age criteria and 5.0% met recommendations via significant cardiovascular disease criteria (Supplement Table S4). In patients that met recommendations for testing, 7004 (27.2%) received a troponin test within 2 days of surgery. Testing rates for guideline-recommended patients varied significantly by surgery (0.0%-74.5%; χ^2; $P < 0.001$; Supplementary Table 5).

European guidelines. When applying the European guidelines to our cohort, 5.1% of all patients met recommendations for testing (Supplemental Table S6). When stratified by surgery type, only 0.2% of patients undergoing prostatectomies met criteria for testing, whereas 53.2% of patients undergoing endovascular AAA repair would be recommended for testing.

Testing rate by RCRI

We also assessed the testing rates across RCRI scores for elective surgeries. Testing rates remained low across most RCRI scores; however, increasing RCRI scores were generally associated with higher rates of testing (Fig. 2). This trend was weaker for the vascular surgeries. Also, despite increasing testing rates with higher RCRI scores, for most surgeries, most patients with an RCRI of 4 or more did not receive testing.

Table 2. Indications for CCS testing recommendations and testing rates

	Number recommended for testing	Proportion recommended for testing	Number received troponin testing	Proportion of recommended tested
Total Cohort (N = 257,704)	186,699	72.4%	24,408	13.1%
Elective surgery cohort (n = 225,871)				
Age ≥ 65	123,904	54.9%	13,407	10.8%
Cardiovascular disease	23,876	10.6%	5313	22.3%
RCRI ≥ 1	99,515	44.1%	14,182	14.3%
Total	160,899	71.2%	17,404	10.8%
Urgent Surgery Cohort (n = 31,833)				
Age ≥ 65	24,196	76.0%	6471	26.7%
Cardiovascular disease	10,195	32.0%	3547	34.8%
Total	25,800	81.0%	7004	27.1%

CCS, Canadian Cardiovascular Society; RCRI, revised cardiac risk index.

Rates of eligibility for CCS guideline recommendations and troponin testing rate by year

Applying the CCS guidelines to our cohort by year, a similar proportion of patients would have met recommendations for testing throughout the study period, ranging from 71.3% in 2010 to 72.8% in 2017 (Fig. 3). This finding corresponded to a minor but statistically significant average annual increase of 0.2% ($P = 0.032$). The proportion of patients receiving testing was 13.9% in 2010 and 10.3% in 2017. This finding corresponded to a minor, but statistically significant average annual decrease of −0.7% ($P = 0.040$). Although these temporal trends are statistically significant, they are likely not of practical importance.

Discussion

In this large population-based study of Ontarians undergoing major orthopedic, gynecologic, general, urologic, vascular, and thoracic surgeries we estimate that 71.2% of elective surgery patients and 81.0% of urgent surgery patients would have met recommendations for postoperative troponin testing if the guidelines were retroactively applied. Among recommended patients, we found that overall troponin testing rates

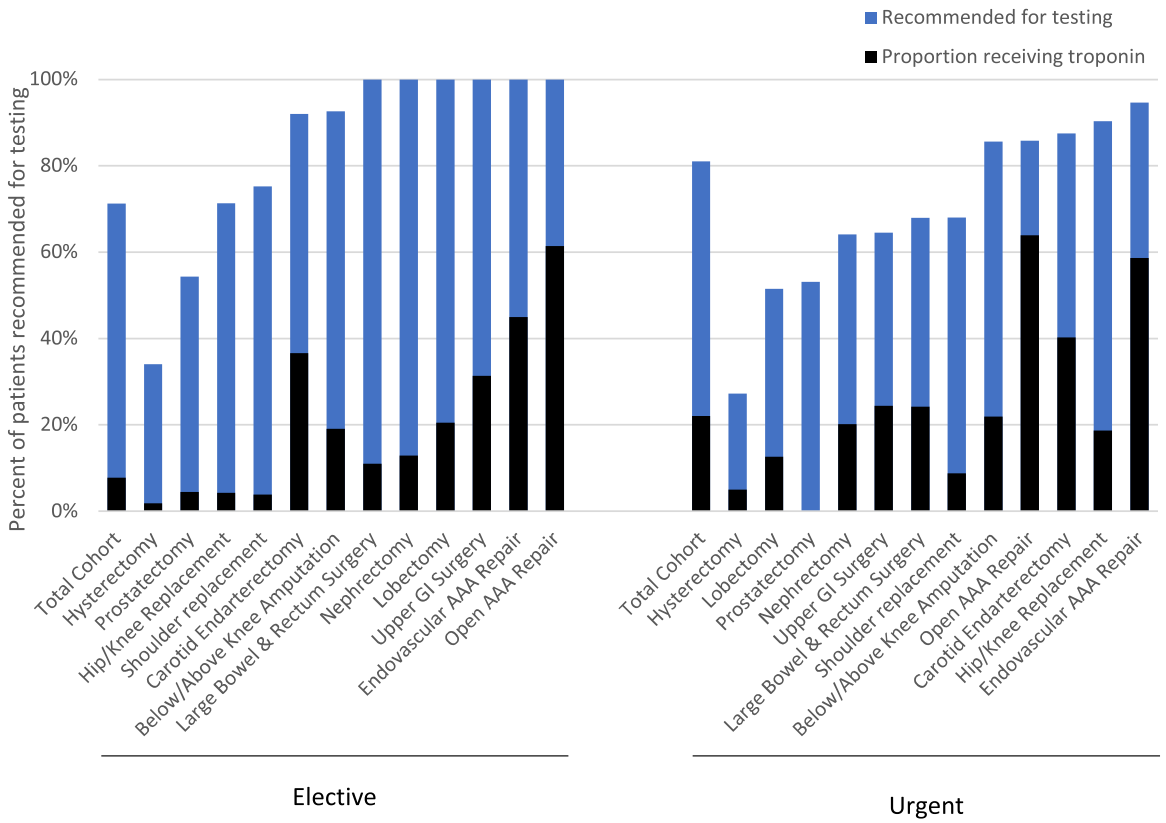

Figure 1. Rates of recommendations and testing by surgery. Left and right panels correspond to elective and urgent surgeries, respectively. Blue bars represent the percent of patients that meet Canadian Cardiovascular Society (CCS) recommendations for testing. Black bars represent the proportion of CCS recommended patients that received a troponin test within 2 days.

Table 3. Indications for CCS testing recommendations

	Below-/above-knee amputation	Carotid endarterectomy	Endovascular AAA Repair	Hip/knee replacement	Hysterectomy	Large bowel and rectum surgery	Lobectomy	Nephrectomy	Open AAA repair	Prostatectomy	Shoulder replacement	Upper GI surgery	Total
Elective procedures	n = 1322	n= 2549	n = 2547	n = 124,939	n = 36,213	n = 19,789	n = 9993	n = 6349	n = 2447	n = 7949	n = 5291	n = 6483	N = 225,871
Age ≥ 65	59.1%	76.6%	90.2%	62.3%	23.6%	57.0%	61.2%	47.2%	69.2%	44.3%	66.5%	52.1%	54.9%
Significant CVD	72.2%	45.2%	44.4%	9.7%	2.8%	12.4%	14.2%	12.5%	43.0%	5.2%	12.4%	11.5%	10.6%
RCRI Components													
Ischemic heart disease	29.0%	18.0%	20.0%	4.5%	1.1%	5.7%	7.3%	5.7%	15.5%	3.2%	6.0%	6.2%	4.8%
Heart failure	34.9%	12.4%	17.3%	5.4%	1.6%	7.2%	6.8%	7.1%	11.2%	1.9%	7.3%	5.1%	5.4%
Stroke or TIA	7.0%	23.6%	2.7%	0.8%	0.4%	1.4%	1.4%	0.9%	2.6%	0.4%	0.9%	1.0%	1.1%
Diabetes	71.6%	41.1%	31.0%	25.5%	15.7%	26.6%	24.7%	28.6%	28.6%	18.5%	26.7%	31.2%	24.6%
Chronic kidney disease	14.1%	2.6%	4.1%	0.9%	0.2%	1.3%	1.5%	5.0%	2.2%	0.3%	1.6%	1.1%	1.1%
High-risk surgery	0%	0%	100%	0%	0%	100%	100%	100%	100%	0%	0%	100%	22.7%
Urgent procedures	n = 2884	n = 879	n = 375	n = 16,006	n = 441	n = 8022	n = 629	n = 223	n = 693	n = 32	n = 789	n = 860	n = 31,833
Age ≥ 65	62.4%	76.0%	91.5%	88.6%	23.4%	64.1%	45.9%	57.4%	73.2%	53.1%	65.5%	58.7%	76.0%
Significant CVD	73.0%	52.2%	47.7%	29.7%	7.3%	23.2%	19.4%	24.7%	47.5%	≤ 5	16.1%	20.6%	32.0%

AAA, abdominal aortic aneurysm; CCS, Canadian Cardiovascular Society; CVD, cardiovascular disease; GI, gastrointestinal; RCRI, revised cardiac risk index.

were low at 10.8% and 27.1% for elective and urgent surgery indicating a large testing gap. We also noted substantial variation in troponin testing by type of surgery. Additional studies are needed to examine how postoperative troponin testing was performed after the Canadian guidelines were published. Most importantly, future studies are needed to evaluate the downstream impact of increasing testing and whether it is associated with better patient outcomes.

To generate insights into why patients are eligible for testing, we found high testing recommendations are mainly related to advanced age and higher RCRI scores. Because most patients undergoing the surgeries we assessed are older than 65 years, most of both elective and urgent surgery patients would be eligible for testing based on the age criteria alone. In addition, for elective surgeries, many patients also meet criteria for testing based on the RCRI criteria, as only a score of 1 is required. Most of these patients meet these criteria via the high-risk criterion, as all intraperitoneal, intrathoracic, or supraingunal vascular surgeries qualify. Of the procedures we assessed, half met this criterion. However, while most patients would meet recommendations for testing in the guidelines, most did not receive testing. Testing rates before the adoption of the guidelines was low overall but varied significantly between surgeries, where higher risk surgeries (ie, vascular) had higher testing rates. This finding may be due to how different specialties perceive and assess cardiovascular risk or differences in patient profiles (ie, vascular surgery patients are sicker than hysterectomy patients). Patients with higher RCRI scores did have higher rates of testing; nevertheless, fewer than half of patients with an RCRI of 4 or more received postoperative testing.

Most of the patients in our cohort underwent noncardiac surgery before the introduction of the CCS guidelines; therefore, we could not assess whether current practice patterns on troponin was discordant with the guidelines. Moreover, guideline adoption into clinical practice is typically a slow process, which is reflected by the lack of change in clinical practice the year after the guidelines were published. Although increased testing will increase detection of MINS and perioperative myocardial infarction, it is not clear if this will translate to better patient outcomes, because evidence for how to best treat such patients is limited. Secondary analyses from the **P**eri**o**perative **Is**chemic **E**valuation (POISE) trial recommend use of acetylsalicylic acid and a statin for patients with MINS.[9] More recently, the **M**anagement of Myocardial Injury **A**fter **N**onc**a**rdiac Sur**ge**ry (MANAGE) trial recommended the use of dabigatran for stable patients with MINS; however, the use of an anticoagulant in a surgical population remains controversial.[8] Future studies are needed to see the downstream impact of increasing testing and whether it is associated with better patient outcomes.

In our cohort, the absolute difference between recommended and observed testing in noncardiac surgery patients was very large at 60.4% for elective and 53.9% for urgent patients. We believe there are several reasons for this gap. First, before the Canadian guidelines, there was no direct Canadian recommendation on how or when to use troponin postoperatively. Second, there is divergence across international guidelines on how to screen surgery patients, especially considering that the American guideline recommends against routine troponin testing unless patients are symptomatic for cardiac

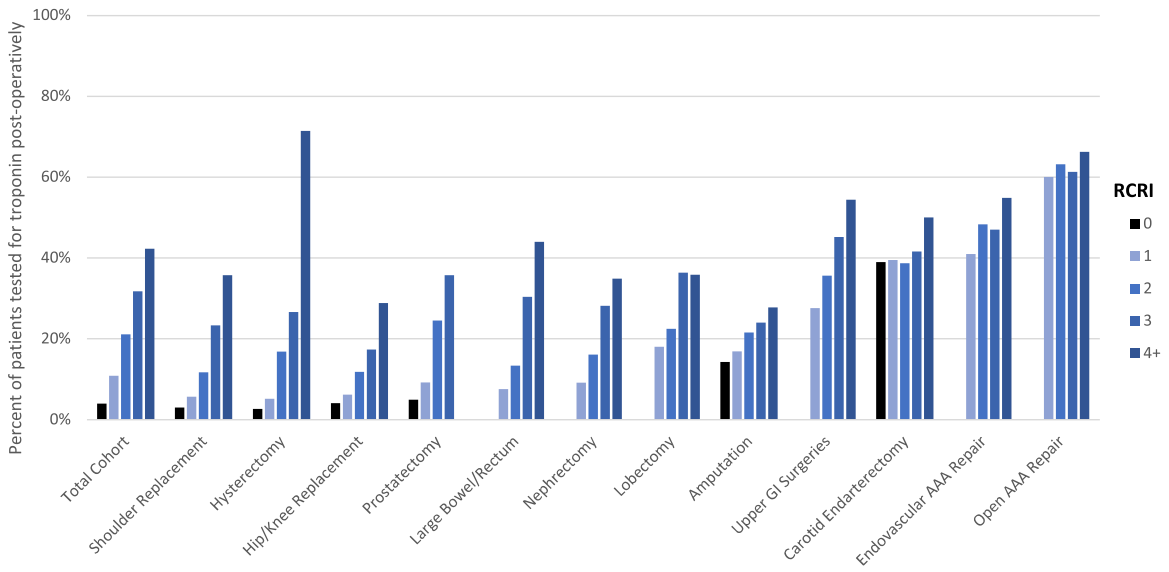

Figure 2. Testing rates by revised cardiac risk index (RCRI) among elective surgery patients. Rate of troponin testing within 2 days of surgery stratified by surgery and RCRI.

ischemia.[13] The European guidelines do recommend routine screening for noncardiac surgery patients, although with more stringent criteria.[12] Applied to our population, only 5.1% of our study population would meet European recommendations in contrast to the 72.4% by the CCS guidelines. Third, how *risk* has been defined has changed. Initially the RCRI was developed in an era without troponins. Now, the CCS has recalibrated the RCRI outcomes with more recent studies in which more sensitive detection methods are available. This finding increases how many patients we identify as high risk. Finally, the optimal way to diagnose and treat patients with postoperative troponin elevations is largely unknown, as they are mostly asymptomatic from a cardiac perspective and have significant noncardiac comorbidities.[19] Additional studies in this field are necessary to evaluate how troponin testing practices are incorporated into routine clinical practice.

Our study is among the first to explore the rate of perioperative troponin testing after noncardiac surgery in Canada and the first in Ontario. Recently, an Alberta study exploring perioperative cardiovascular testing in a major noncardiac

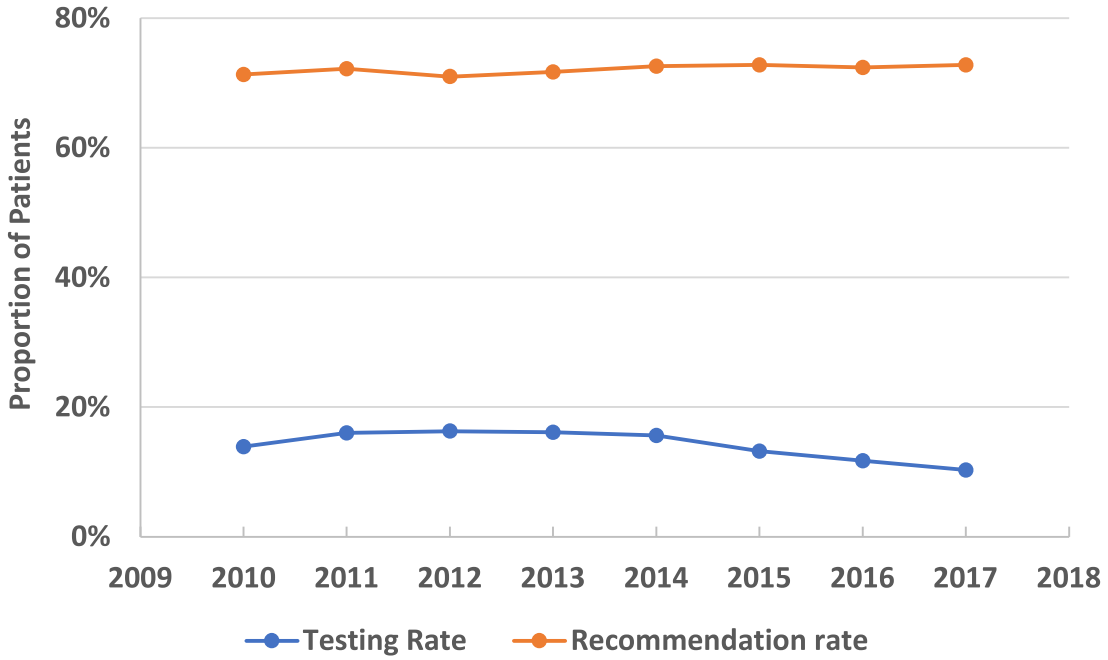

Figure 3. Temporal trends in postoperative troponin use and recommendation rates. The blue line represents the proportion of patients that received troponin testing each year. The orange line represents the proportion of patients that would be recommended to receive postoperative troponin testing if the 2017 Canadian Cardiovascular Society guidelines were applied to them.

population showed 18.8% of their cohort was recommended for perioperative cardiovascular screening.[20] This study differs in that they used modified CCS criteria to select a higher-risk population. Gouda and colleagues[20] did not include age 65 or older as an inclusion criterion; moreover, in the 45-64 age group, RCRI was not used to determine eligibility. Our study found that most patients meet recommendations for testing based on the age 65 or older criterion, followed by the high-risk RCRI score. Despite differences in the risk of the cohort, both of our studies show relatively low rates of postoperative troponin testing before widespread adoption of the CCS guidelines indicating that a large treatment gap exists.

Limitations

This study should be interpreted within the context of its limitations. First, laboratory data included those who were reporting to OLIS at the time of the study and did not include all hospital laboratories. Despite this limitation, we were able to create a cohort that had more than 250,000 patients who underwent noncardiac surgery in Ontario, which allowed for significant insights on the pattern of testing in the province. Second, because this study used administrative and laboratory data, we were unable to capture data on patients' symptom status. As such, we were unable to determine if a patient's troponin was measured because they exhibited symptoms of cardiac ischemia. However, it has been shown that only 6.9% of patients experience ischemic symptoms after noncardiac surgery.[7] Accordingly, we believe the lack of symptoms information was unlikely to alter our conclusions substantially. Third, the CCS guidelines recommend measuring NT-proBNP or BNP in high-risk patients to further guide whether troponin testing is recommended. However, we were unable to examine the impact of NT-proBNP or BNP because of the lack of data. Nevertheless, these assays are currently mostly used in heart failure patients and rarely used to guide noncardiac surgery patients during the study period. Fourth, we lacked medication and creatinine information in our cohort and thus substituted the RCRI definition of "diabetes with preoperative insulin use" with "diabetes" and "preoperative serum creatinine > 177 mmol/L" with "chronic kidney disease." Although the diabetes definition overestimated the number of people who received the criteria, only 5.9% of the elective surgery cohort met indications for testing from diabetes alone, which would not substantially change the conclusions of this study. Finally, our study did not include all noncardiac surgeries; rather, we used a convenience sampling strategy of including 12 commonly performed major noncardiac surgeries that require at least 1 overnight hospital stay. Accordingly, findings from our study should not be generalized to all surgeries but only applied to the surgeries included in our study.

Conclusion

In this large population-based study, we found that under the 2017 CCS practice guidelines on perioperative care, most patients undergoing major noncardiac surgeries we assessed would have met eligibility for indications for postoperative troponin testing, whereas only some received troponin testing before guideline changes. Given the vast changes in how regularly troponin testing is recommended after major noncardiac surgery by the CCS guidelines and how they differ with other international guidelines, further studies are needed to understand the potential clinical and economic impact of routine troponin testing.

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Disclosures

The authors have no conflicts of interest to disclose.

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Supplementary Material

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