Can J Anesth/J Can Anesth (2021) 68:1135–1145
https://doi.org/10.1007/s12630-021-02026-x

REPORTS OF ORIGINAL INVESTIGATIONS

Implementation of the Canadian Cardiovascular Society guidelines for perioperative risk assessment and management: an interrupted time series study

Mise en œuvre des lignes directrices de la Société canadienne de cardiologie pour l'évaluation et la prise en charge des risques périopératoires : une étude de série chronologique interrompue

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Received: 18 December 2020 / Revised: 1 March 2021 / Accepted: 2 March 2021 / Published online: 24 May 2021

Abstract

Purpose *The Canadian Cardiovascular Society (CCS) guidelines for patients undergoing non-cardiac surgery address the lack of standardized management for patients at risk of perioperative cardiovascular complications. Our interdisciplinary group evaluated the implementation of these guidelines.*

Methods *We used an interrupted time series design to evaluate the effect of implementation of the CCS guidelines, using routinely collected hospital data. The study population consisted of elective, non-cardiac surgery patients who were: i) inpatients following surgery and ii) age ≥ 65 or age 45–64 yr with a Revised Cardiac Risk Index ≥ 1. Outcomes included adherence to troponin I (TnI) monitoring (primary) and adherence to appropriate consultant care for patients with elevated TnI (secondary). Exploratory outcomes included cost measures and clinical outcomes such as length of stay.*

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12630-021-02026-x.

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Results *We included 1,421 patients (706 pre- and 715 post-implementation). We observed a 67% absolute increase (95% confidence interval, 55 to 80; P < 0.001) in adherence to TnI testing following the implementation of the guidelines. In patients who had elevated TnI following guideline implementation (n = 64), the majority (85%) received appropriate follow-up care in the form of a general medicine or cardiology consult, all received at least one electrocardiogram, and half received at least one advanced cardiac test (e.g., cardiac perfusion scan, or percutaneous intervention).*

Conclusions *Our study showed the ability to implement and adhere to the CCS guidelines. Large-scale multicentre evaluations of CCS guideline implementation are needed to gain a better understanding of potential effects on clinically relevant outcomes.*

Résumé

Objectif *Les lignes directrices de la Société canadienne de cardiologie (SCC) concernant les patients subissant une chirurgie non cardiaque ont été conçues pour pallier l'absence de standardisation dans la prise en charge des patients à risque de complications cardiovasculaires périopératoires. Notre groupe interdisciplinaire a évalué la mise en œuvre de ces lignes directrices.*

Méthode *Nous avons utilisé une méthodologie de série chronologique interrompue pour évaluer l'effet de la mise en œuvre des lignes directrices de la SCC, à l'aide des données hospitalières habituellement recueillies. La population à l'étude se composait de patients de chirurgies non cardiaques non urgentes qui étaient : i) hospitalisés après leur chirurgie et ii) âgés de ≥ 65 ans ou de 45 à 64 ans avec un Indice de risque cardiaque révisé ≥ 1. Les critères d'évaluation comprenaient l'observance du monitorage de la troponine I (TnI) (critère d'évaluation primaire) et l'observance des soins spécialisés appropriés aux patients présentant un taux élevé de TnI (critère secondaire). Les critères exploratoires comprenaient des mesures de coûts et des résultats cliniques tels que la durée de séjour.*

Résultats *Nous avons inclus 1421 patients (706 avant et 715 après la mise en œuvre). Nous avons observé une augmentation absolue de 67 % (intervalle de confiance de 95 %, 55 à 80; P < 0,001) de l'observance des tests de la TnI suite à la mise en œuvre des lignes directrices. Parmi les patients présentant un taux élevé de TnI suite à la mise en œuvre des lignes directrices (n = 64), la majorité (85%) a reçu des soins de suivi appropriés sous la forme d'une consultation en médecine générale ou en cardiologie; tous ont subi au moins un électrocardiogramme, et la moitié ont passé au moins un examen cardiaque subséquent (p. ex., évaluation de la perfusion myocardique par scintigraphie ou cathétérisme percutané).*

Conclusion *Notre étude a montré qu'il est possible de mettre en œuvre et d'adhérer aux nouvelles lignes directrices de la SCC. Des évaluations multicentriques à grande échelle portant sur la mise en œuvre des lignes directrices de la SCC sont nécessaires pour mieux comprendre ses effets potentiels sur les devenirs cliniquement pertinents.*

Keywords quality improvement · guideline implementation · myocardial injury after non-cardiac surgery · perioperative myocardial infarction · interrupted time series

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Cardiovascular complications are a leading cause of mortality after non-cardiac surgery.[1–4] Specifically, myocardial injury after non-cardiac surgery (MINS) is the complication with the second highest attributable fraction of death (15.9%) within 30 days of surgery, behind only major bleeding (17.0%).[5] Most MINS events are asymptomatic,[6] thus routine postoperative monitoring of troponins is required to ensure detection.[7] For those patients diagnosed with MINS, early cardiology assessment and subsequent intervention (such as anticoagulants in select patients)[8] may reduce the risk of

death.[9] Nevertheless, an evidence base is still being developed with regards to management of MINS.[6]

Risk assessment and management of patients with cardiac risk factors undergoing non-cardiac surgery is complex. Therefore, structured guidelines were recommended in 2016 by the Canadian Cardiovascular Society (CCS).[6] Unlike previous guidelines,[10] which largely focused on preoperative risk stratification using expensive non-invasive cardiac testing, the newest guidelines focus on possibly more cost-effective use of biomarkers for postoperative monitoring of at-risk patients. This permits early identification and management of patients at increased risk of short-term cardiac complications (e.g., routine postoperative troponin I [TnI] testing). Given the burden of perioperative cardiac complications, the implementation of evidence-based guidelines to better identify and treat high-risk patients is a key priority for patients, clinicians, and the healthcare system.

Evidence-based clinical practice guidelines can improve patient care[11]; however, their implementation in clinical practice is often unpredictable, slow, complex,[12,13] and can be associated with significant costs.[14–16] Moreover, successful implementation of CCS guidelines requires engagement of multiple stakeholders (e.g., cardiology, internal medicine, nursing, surgery, anesthesiology). Given these complexities, real-world evaluation of implementation is necessary to understand rates of adherence, resource utilization, and effects on patient care and outcomes.[17–19] Without such evidence, physicians may only adopt certain aspects, leading to heterogeneous and uneven levels of care provided to similar patients within an institution.[20]

To fill this knowledge gap, we performed a quasi-experimental study to evaluate the effect of implementation of the CCS guidelines for perioperative cardiac risk assessment on post-implementation processes and outcomes at a large Canadian academic institution. Adherence to routine troponin monitoring was assessed, as well as healthcare resource utilization, and clinical outcomes.

Methods

Prior to initiation of the study, research ethics approval was obtained from The Ottawa Hospital Research Ethics Board (REB #20180527-01H). This manuscript follows reporting recommendations for interrupted time series.[21] The protocol for this study was posted on Open Science Framework.[22]

Setting and design

We conducted an interrupted time series (ITS) design, evaluating implementation of the CCS guidelines at The Ottawa Hospital (TOH) General Campus (Ottawa, ON, Canada). The Ottawa Hospital is a large, tertiary care, academic institution serving a catchment area of approximately 1.2 million people. Perioperative care is provided for major orthopedic, general surgery, hepatobiliary, oncology, gynecology, urology, and thoracic patients. The study period was seven months (August 2018 to January 2019); the pre-implementation phase (12 weekly timepoints), the implementation phase (four weekly timepoints), and the post-implementation phase (12 weekly timepoints). The implementation period was specified *a priori* to allow time for the intervention to be fully implemented, and data from those weeks were censored from all analyses.

Participants

The study population consisted of all patients undergoing elective, non-cardiac surgery who met the following criteria: 1) anticipated admission to hospital following surgery, and 2) age $\geq$ 65 or age 45–64 with a Revised Cardiac Risk Index[23] (RCRI) $\geq$ 1. All non-cardiac surgical patients were screened for eligibility. The standard of care at TOH in the pre-implementation phase included preoperative cardiac risk stratification at the discretion of clinicians, limited TnI and electrocardiogram (ECG) screening (ordered at discretion of clinician), no *a priori* determined thresholds of TnI elevation to trigger consultations to either internal medicine or cardiology, and no protocolized monitoring, treatment, or follow-up of patients found to have elevated TnI. Patients in the post-implementation period received care according to the CCS guidelines for perioperative cardiac risk assessment as detailed below.

Data sources

Data for this study were obtained in three ways, with consistency across study phases. First, a prospective screening log registry was maintained to identify all participants meeting CCS criteria for screening in the pre- and postoperative phase. Next, labs, interventions, and outcomes were captured from the Ottawa Hospital Data Warehouse (OHDW) by linking our prospective registry to all sources of clinical, laboratory and administrative data at TOH. At TOH, all patients can be linked across OHDW data sources using their hospital unique identifier, allowing perioperative data to be captured from our Surgical Management Information System (Optum, Eden Prairie,

MN, USA), labs and tests from the electronic health record (vOacis, Telus, Montreal, QC, Canada) and admission level data from the Canadian Institute for Health Information Discharge Abstract Database (DAD). The OHDW undergoes standardized data normalization, quality controls and audit, and has been used extensively in peer-reviewed research. The OHDW also contains a case costing system, which links financial, clinical, and patient activity information to define costs associated with each patient. Finally, clinical processes (i.e., consultations, cardiac testing) were independently captured using duplicate retrospective chart review by two authors (S.F., M.M.).

Guideline implementation

The pathway of care adopted by our institution is outlined in Fig. 1. Prior to implementation, our multidisciplinary team (anesthesiology, cardiology, general internal medicine, surgery, nursing) identified key stakeholders. Members from these stakeholder groups were interviewed to identify and address anticipated barriers to guideline implementation. A summary of the identified barriers can be found in the Electronic Supplementary Material (ESM; eAppendix Methods).

Preoperative CCS guideline assessment and testing

Surgical patients at TOH are seen for in-person preoperative assessment (versus a nursing telephone assessment) based on standard screening criteria in a devoted pre-assessment unit. For patients meeting criteria for in-person assessment, our institution did not perform routine natriuretic peptide testing; therefore, risk stratification relied on RCRI criteria (as recommended by the guidelines). New orders sheets were developed and signed for TnI screening (preoperative baseline value, postoperatively within six hours, and then postoperative days [POD] POD 1, 2, and 3) as well as a routine ECG (postoperatively within six hours), where patients met screening criteria based on the CCS guidelines. Care pathways were co-developed with input from physicians (anesthesia, internal medicine, cardiology) and perioperative nurses. During the study period, no other changes were made to perioperative pathways at TOH.

Postanesthesia care unit

Postoperatively, patients meeting screening criteria had a TnI test and an ECG in the postanesthesia care unit (PACU). Patients with a positive TnI or abnormal ECG who were hemodynamically unstable or had other indications for continuous monitoring remained in the PACU, as per usual care. Patients in the PACU with a positive TnI or abnormal ECG who were asymptomatic and stable with no other indication for monitoring were discharged to the ward as per usual standard of care and were followed by internal medicine or cardiology (i.e., TnI and ECG testing in isolation did not impact patient flow or monitoring without clinical indication).

Postoperative ward care

Once on the surgical ward, patients received daily TnI tests until discharge, or until postoperative day (POD) 3, whichever occurred first. If either a PACU or ward TnI test was above normal limits (TnI > 45 ng·mL^{-1}), the patient received either an internal medicine consult (TnI 45–1,000 ng·L^{-1}) or a cardiology consult (TnI $>$ 1,000 ng·L^{-1}); thresholds were established *a priori* based on multidisciplinary team meetings. Postoperative consults and the postoperative care pathways of the patients were standardized by the cardiology and internal medicine divisions. Consultations included a complete review of systems and investigations to identify underlying causes of TnI elevation.

Formal cardiac testing and follow-up

For patients who had an elevated TnI (TnI > 45 ng·L^{-1}), nuclear stress myocardial perfusion imaging was performed within one week of discharge, and a follow-up appointment with either a cardiologist or internist within two weeks of discharge.

Primary outcome

Our primary outcome was adherence to troponin monitoring in patients meeting screening criteria based on CCS guidelines. Adherence was defined by the proportion of eligible patients that have TnI drawn according to the following criteria: 1) for patients with a length of hospital stay $\geq$ three days, at least three of their four eligible TnI drawn, 2) for patients with a length of stay of two days, at least two of the three eligible TnI drawn, and 3) for patients with a length of stay of one day, at least one of two eligible TnI drawn. The data for all eligible patients were aggregated on a weekly basis and expressed as a proportion.

Secondary and exploratory outcomes

Our secondary outcome was the adherence to appropriate follow-up care. This was defined by the proportion of patients with positive TnI that had a general internal medicine or cardiology consult in-hospital or as an

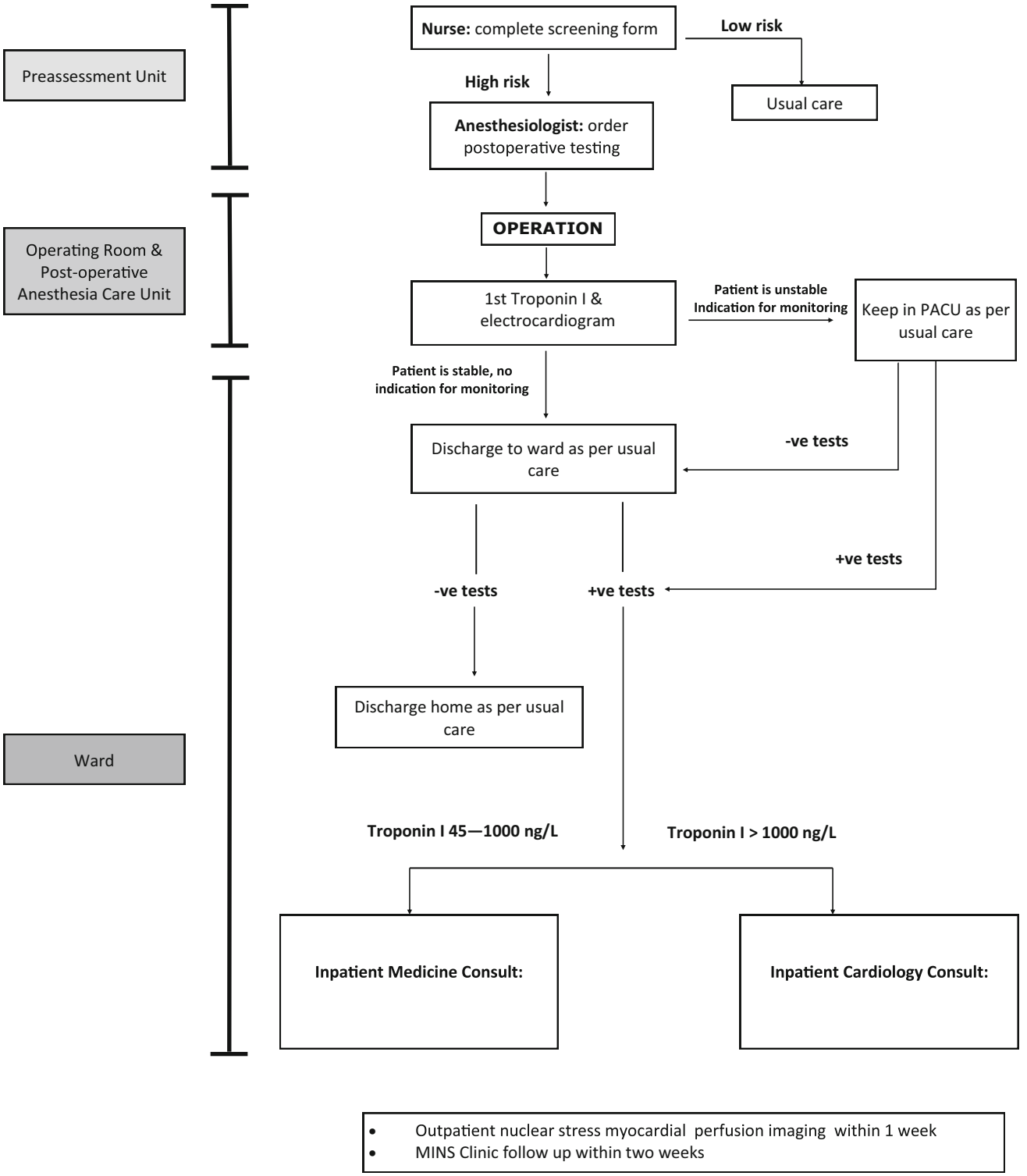

Fig. 1 Pathway of care flowchart

outpatient within 30 days of discharge. Exploratory outcomes included: 1) utilization of services in TnI positive patients such as echocardiograms, ECGs, nuclear stress myocardial perfusion imaging, angiograms, percutaneous interventions, and cardiac computed tomography, 2) resource-use outcomes (mean weekly hospitalization costs, mean weekly length of stay), and 3) clinical outcomes (weekly proportion with a postoperative complication [using validated patient safety indicators applied to the DAD] and mortality).

Statistical analyses

All analyses were conducted using SAS v9.4 (SAS Institute, Cary, NC, USA). Descriptive statistics were compiled to compare patient characteristics between the pre- and post-implementation phase (*t* tests for continuous normal variables, Wilcoxon for skewed continuous variables and Chi squared tests for binary and categorical variables).

To test for changes from pre- to post-implementation, we used an ITS design. This allowed us to assess for a change in outcome from pre- to post-implementation while accounting for the underlying temporal trend across the study period. Analysis of all outcomes used linear segmented regression with terms for baseline intercept and baseline slope, as well as terms for change in intercept and change in slope after implementation of the intervention. Our main measure of interest was the total change from pre- to post-implementation, which is the sum of the change in intercept and change in slope. Observations obtained during the four-week implementation period were censored from analysis. Typically, ITS designs require 12 time periods during each phase, with at least 40 observations per period.[24] In our study, each period was seven days and we had 12 periods in each phase. The model was estimated using restricted maximum likelihood estimation and accounted for first-order autocorrelation. The effect of the intervention was described as intercepts and slope changes, together with 95% confidence intervals (CI). To test the impact of possible deviations from assumptions of linear regression, we repeated our segmented regression analyses after transformation of weekly values on the natural logarithm scale. As part of a post-hoc analysis, the number needed to evaluate (NNE) was calculated to determine the number of patients needing to have TnI testing to detect one incident of MINS.

Results

Study population

During the 24-week period, 1,421 patients were included in the study (706 during the 12 weeks pre-implementation, and 715 during the 12 weeks post-implementation period). The baseline demographics of the pre- and post-implementation period patients are shown in Table 1. Both groups were similar with respect to age, sex, American Society of Anesthesiologists physical classification, surgical service rendered, duration of surgical procedure, and baseline comorbidities. Orthopedic, urologic, thoracic, and general surgeries accounted for roughly 80% of the procedures performed.

Primary outcome

The results of the ITS analysis are presented in Table 2, while additional TnI testing results are summarized in Table 3. Overall, adherence was 5.8% in the pre-implementation period compared with 69.4% in the post-implementation period, with 95 (13.5%) of pre-implementation patients receiving at least one TnI test, while in the post-implementation phase, 530 (74.1%) patients received at least one TnI test (Fig. 2). Using linear segmented regression, we identified a significant change in total TnI adherence in the post-implementation phase (+67%; 95% CI, 55 to 80; $P < 0.0001$). Results of the log-transformed analysis are presented in the ESM (eTable 1).

Secondary outcome

In the pre-implementation period, 19 patients had elevated TnI levels (2.7%), compared with 64 patients in the post-implementation period (9.0%). In the post-implementation period, 54 patients (84.4%) received follow-up care in accordance with our care pathway, meaning a general internal medicine consult (TnI 45–1,000 $ng{\cdot}L^{-1}$) or a cardiology consult (TnI > 1,000 $ng{\cdot}L^{-1}$) in-hospital or as an outpatient within 30 days of discharge (Table 4), compared with just eight (42.1%) during the pre-implementation period. Using the TnI-positive data, the NNE was calculated to be 15.9.

Exploratory outcomes

The number of TnI-positive patients receiving at least one advanced cardiac test (e.g., computed tomography angiogram) also increased significantly in the post-implementation period. In contrast, the number of TnI-positive patients receiving at least one echocardiogram and at least one ECG and the mean number of ECGs per TnI positive patient remained unchanged post-implementation (Table 4). Full results of our exploratory segmented regression analyses are provided in Table 2. We found no evidence of a change in costs, length of stay, or complication rates between phases (ESM eFigs 1–3). Sensitivity analyses using log-transformed weekly rates were consistent with the primary analyses (ESM eTable 1).

TABLE 1 Baseline demographics of included patients

	Pre-implementation	Post-implementation	*P* value
Number of patients	706	715	–
Age (mean, SD)	65.9 (10.1)	66.0 (9.8)	0.85
Sex (*n*, %)			
Male	368 (52.1)	357 (49.9)	0.41
Female	338 (47.9)	358 (50.1)	
Surgical service (*n*, %)			
Orthopedic	214 (30.3)	220 (30.8)	0.8
Urology	154 (21.8)	141 (19.7)	
Thoracic	99 (14.0)	118 (16.5)	
General	110 (15.6)	107 (15.0)	
Otolaryngology	57 (8.1)	56 (7.8)	
Gynecology	60 (8.5)	60 (8.4)	
Other	12 (1.7)	13 (1.8)	
Duration of surgery (min) (mean, SD)	222.6 (141.4)	213.9 (124.4)	0.22
American Society of Anesthesiologists physical status classification			
I	10 (1.4)	7 (1.0)	0.48
II	163 (23.1)	147 (20.6)	
III	485 (68.7)	517 (72.3)	
IV	48 (6.8)	44 (6.2)	
Comorbidities (*n*, %)			
Elixhauser Index* (mean, SD)	3.56 (4.87)	3.48 (4.84)	0.76
Arrhythmia	7 (1.0)	12 (1.7)	0.25
Diabetes, uncomplicated	58 (8.2)	73 (10.2)	0.19
Diabetes, complicated	28 (4.0)	25 (3.5)	0.62
Metastatic cancer	86 (12.2)	78 (10.9)	0.44
Solid tumour (no metastasis)	342 (48.4)	344 (48.1)	0.91

*The Elixhauser Comorbidity Index is a method of categorizing comorbidities of patients based on the International Classification of Diseases diagnosis codes found in administrative data, such as hospital abstracts data. Each comorbidity category is dichotomous—it is either present or not present. SD = standard deviation

Discussion

In a single-centre implementation study, we found increased adherence to the CCS perioperative guidelines recommending postoperative TnI screening using a multidisciplinary engagement strategy. These findings suggest that similar approaches in other centres could increase adherence to best-practice guidelines. Nevertheless, multicentre studies adequately powered for clinical and patient-centred outcomes will be required to evaluate the effectiveness of the CCS guidelines.

Our study is not without limitations. First, our evaluation was limited to a single Canadian centre in the province of Ontario, so the generalizability of our findings to other centres (e.g., non-teaching hospitals and non-Canadian centres) is unknown. Furthermore, while our TnI testing data and length of stay outcome were directly captured from source data, our cost data were limited to in-hospital (excluding physician services) costs only and our complications outcome is not well-suited to identify specific complications types (such as major adverse cardiac events). Furthermore, mortality rates were low, precluding any formal analysis for death as an outcome. The ITS design is considered to have the lowest risk of bias for evaluating health system interventions when randomization isn't feasible,[25] and our analysis was based on data collected in a close temporal period with no measurable differences between pre- and post-implementation populations. Nevertheless, ITS designs can still be subject to biases. Specifically, while we were not able to identify any concurrent changes to care, unidentified temporal changes could influence results and would not be accounted for by our model.

TABLE 2 ITS analysis results

Outcome	Pre-implementation (mean, SD)	Post-implementation (mean, SD)	Intercept change (95% CI)	Slope change (95% CI)	Total change (95% CI)
Primary outcome					
TnI adherence	5.9% (3.6%)	67.9% (8.6%)	67.5% (54.9 to 80.0)	− 0.1% (− 0.2 to 0.2)	67.4% (54.8 to 79.9)
Exploratory outcomes					
Total cost (CAD)	14,529 (5,966)	11,259 (969)	144 (− 9,373 to 9,661)	1,953 (− 1,779 to 5,686)	4,589 (− 7,420 to 11,614)
Length of stay (days)	4.9 days (2.2)	3.9 days (0.7)	0.2 days (− 4 to 4)	0.7 days (− 1 to 2)	0.9 days (− 3 to 5)
Complication rate	11.7% (2.6%)	11.8% (5.3%)	0% (− 4 to 5)	0% (0 to 0)	0% (− 4 to 5)

CAD = Canadian dollars; CI = confidence interval; ITS = interrupted time series; SD = standard deviation; TnI = troponin I

Intercept and slope changes represent the change in the linear segmented regression model between the pre- and post-implementation time periods

TABLE 3 Clinical outcomes

	Pre-implementation	Post-implementation	*P* value
Number of patients	706	715	–
Total TnI tests ordered	195	1747	< 0.0001
Elevated TnI tests	19	201	< 0.0001
45–1000 $ng{\cdot}L^{-1}$	19	173	
> 1000 $ng{\cdot}L^{-1}$	0	28	
Patients with at least one TnI test	95 (13.5%)	530 (74.1%)	< 0.0001
Patient with elevated TnI	19 (2.7%)	64 (9.0%)	< 0.0001
45–1000 $ng{\cdot}L^{-1}$	19	60	
> 1000 $ng{\cdot}L^{-1}$	0	4	

TnI = troponin I

Successful implementation of evidence-based guidelines is a complex and challenging process, which depends on effectively developing strategies to overcome recognized barriers.[15,16] At our centre, we involved key stakeholders in a multidisciplinary group (i.e., cardiologists, internists, surgeons, nurses, anesthesiologists, residents, and clinical research staff). We then performed semi-structured interviews with key stakeholder groups to identify barriers, which included organizational constraints, lack of resources, and concerns about increasing workload.[26–28] This allowed us to design screening forms more efficiently, optimize workflow to minimize burden on clinical staff, and identify areas of particular concern among stakeholder groups (i.e., evening/weekend operations). Perioperative leadership also disseminated information within their departments on multiple occasions to help prepare staff and detail upcoming changes. A similar approach to implementing the CCS guidelines has recently been described.[29]

Implementation of guidelines often increases inputs of healthcare resources (e.g., testing, evaluation); therefore, guideline implementation can lead to increased resource use if resulting outputs are not improved (e.g., clinical outcomes, patient flow). In our study, we did not find strong evidence that either length of hospitalization or overall costs increased with guideline implementation, despite performing a significantly higher number of postoperative tests, and significantly increasing the number of TnI-positive patients receiving an appropriate consultation. A previous study, based on cost-consequence modelling rather than direct resource use measurement, suggested that the incremental costs associated with a missed MINS event was 1,632 CAD in 2015.[30] Although we did not observe cost savings with routine monitoring,

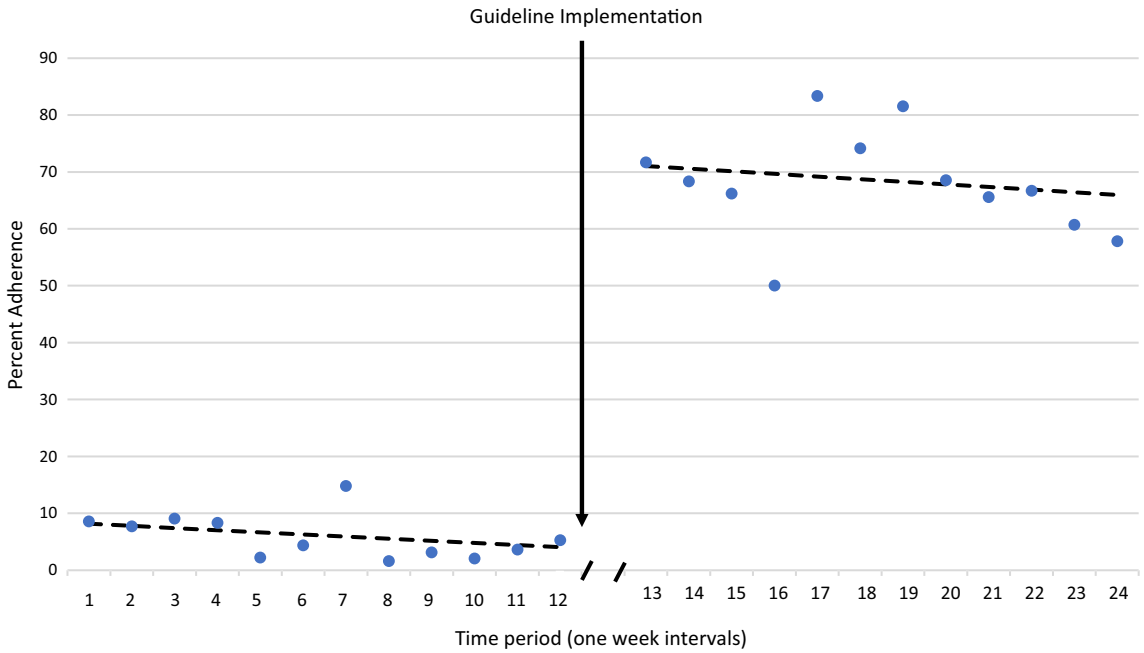

Fig. 2 Adherence to TnI testing guidelines. The dashed line represents the adjusted regression line. TnI = troponin I

TABLE 4 Resource utilization in TnI-positive patients

	Pre-implementation	Post-implementation	*P* value
Number of patients	706	715	–
TnI testing adherence	41 (5.8%)	496 (69.4%)	< 0.0001
Elevated TnI	19 (2.7%)	64 (9.0%)	< 0.0001
Received appropriate follow-up care (of elevated TnI patients)	8 (42.1%)	54 (84.4%)	0.0002
Received at least one ECG (of elevated TnI patients only)	6 (31.6%)	19 (29.7%)	0.87
Received at least one ECG (of elevated TnI patients only)	18 (94.7%)	64 (100%)	0.064
ECGs per patient, mean (SD)	3.5 (2.6)	3.8 (2.8)	0.68
At least one advanced cardiac test (e.g., CT angiogram, percutaneous interventions)	2 (10.5%)	33 (51.6%)	0.0015

CT = computed tomography; ECG = electrocardiogram; SD = standard deviation; TnI = troponin I

our finding that implementation was cost neutral suggests that the perspective of a health economic analysis must be considered. Our data captured hospital costs (therefore, in-hospital tests and diagnostics were included). Nevertheless, any physician services (e.g., consultation with a cardiologist or internist in- or out-of-hospital) and post-discharge interventions were not captured and could have increased costs at the health system level. Future multicentre implementation studies should capture all associated costs. With methods to better identify high-risk patients,[31] and emerging new therapies for MINS,[8] further benefits to routine testing could be realized. Future multicentre evaluations of CCS guideline implementation adequately powered to capture important differences in clinical and patient-centred outcomes will ultimately be required to determine the effectiveness of CCS guideline-based care. Nevertheless, such studies will be informed by effective implementation strategies developed in studies such as ours.

Conclusion

Our study showed the ability to implement a locally adapted clinical care pathway to increase adherence to the CCS guidelines for perioperative cardiac risk assessment without increasing either length of stay or in-hospital costs. Nevertheless, the clinical impact of the guidelines remains

unclear, and large-scale multicentre evaluations of CCS guideline implementation are needed to gain a better understanding of the potential implications on clinically relevant outcomes.

Author contributions Daniel I. McIsaac, Sylvain Gagne, Chris Johnson, Jacelyn Ernst, Samantha Halman, Jeffrey Oake, James Chan, Susan Madden, Monica Taljaard, Dean A. Fergusson, and Manoj M. Lalu contributed to the conception and design of the study. Joshua Montroy, Simon Feng, Michelle Moody, Cedric Godbout Simard, and Madison Foster contributed to the acquisition of data. Daniel I. McIsaac, Joshua Montroy, Monica Taljaard, and Manoj M. Lalu contributed to the analysis of the data. All listed authors contributed to the interpretation of data. Daniel I. McIsaac, Joshua Montroy, and Manoj M. Lalu drafted the initial version of the manuscript, while all additional authors contributed to the critical revision of the manuscript and gave final approval of the submitted version.

Disclosures None.

Funding statement The work presented in this manuscript was funded by a grant from The Ottawa Hospital Academic Medical Organization (TOHAMO).

Editorial responsibility This submission was handled by Dr. Philip M. Jones, Deputy Editor-in-Chief, *Canadian Journal of Anesthesia/ Journal canadien d'anesthésie.*

References

1. *Vascular Events in Noncardiac Surgery Patients Cohort Evaluation (VISION) Study Investigators; Devereaux PJ, Chan MT, Alonso-Coello P, et al.* Association between postoperative troponin levels and 30-day mortality among patients undergoing noncardiac surgery. JAMA 2012; 307: 2295-304.
2. *Southern DA*, *Burnand B*, *Droesler SE*, *et al*. Deriving ICD-10 codes for patient safety indicators for large-scale surveillance using administrative hospital data. Med Care 2017; 55: 252-60.
3. *McIsaac DI*, *Hamilton GM*, *Abdulla K*, *et al*. Validation of new ICD-10-based patient safety indicators for identification of in-hospital complications in surgical patients: a study of diagnostic accuracy. BMJ Qual Saf 2020; 29: 209-16.
4. *Devereaux PJ*, *Sessler DI*. Cardiac complications in patients undergoing major noncardiac surgery. N Engl J Med 2015; 373: 2258-69.
5. *Vascular Events in Noncardiac Surgery Patients Cohort Evaluation (VISION) Study Investigators; Spence J, LeManach Y, Chan MT, et al.* Association between complications and death within 30 days after noncardiac surgery. CMAJ 2019; 191: E830-7.
6. *Duceppe E*, *Parlow J*, *MacDonald P*, *et al*. Canadian Cardiovascular Society Guidelines on perioperative cardiac risk assessment and management for patients who undergo noncardiac surgery. Can J Cardiol 2017; 33: 17-32.
7. *Weber M*, *Luchner A*, *Seeberger M*, *et al*. Incremental value of high-sensitive troponin T in addition to the revised cardiac index for peri-operative risk stratification in non-cardiac surgery. Eur Heart J 2013; 34: 853-62.
8. *Devereaux PJ*, *Duceppe E*, *Guyatt G*, *et al*. Dabigatran in patients with myocardial injury after non-cardiac surgery (MANAGE): an international, randomised, placebo-controlled trial. Lancet 2018; 391: 2325-34.
9. *Hua A*, *Pattenden H*, *Leung M*, *et al*. Early cardiology assessment and intervention reduces mortality following myocardial injury after non-cardiac surgery (MINS). J Thorac Dis 2016; 8: 920-4.
10. *Fleisher LA*, *Fleischmann KE*, *Auerbach AD*, *et al*. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation 2014; 130: e278-333.
11. *Fischer F*, *Lange K*, *Klose K*, *Greiner W*, *Kraemer A*. Barriers and strategies in guideline implementation-a scoping review. Healthcare (Basel) 2016; DOI: https://doi.org/10.3390/healthcare4030036.
12. *Woolf SH*, *Grol R*, *Hutchinson A*, *Eccles M*, *Grimshaw J*. Clinical guidelines: potential benefits, limitations, and harms of clinical guidelines. BMJ 1999; 318: 527-30.
13. *Grol R*. Successes and failures in the implementation of evidence-based guidelines for clinical practice. Med Care 2001; 39(8 Suppl 2): II46-54.
14. *Richter-Sundberg L*, *Kardakis T*, *Weinehall L*, *Garvare R*, *Nystrom ME*. Addressing implementation challenges during guideline development - a case study of Swedish national guidelines for methods of preventing disease. BMC Health Serv Res 2015; DOI: https://doi.org/10.1186/s12913-014-0672-4.
15. *Baiardini I*, *Braido F*, *Bonini M*, *Compalati E*, *Canonica GW*. Why do doctors and patients not follow guidelines? Curr Opin Allergy Clin Immunol 2009; 9: 228-33.
16. *Grol R*, *Wensing M*. What drives change? Barriers to and incentives for achieving evidence-based practice. Med J Aust 2004; 180: S57-60.
17. *Grol R*. Personal paper. Beliefs and evidence in changing clinical practice. BMJ 1997; 315: 418-21.
18. *Gagliardi AR, Alhabib S; Members of Guidelines International Network Implementation Working Group*. Trends in guideline implementation: a scoping systematic review. Implement Sci 2015; DOI: https://doi.org/10.1186/s13012-015-0247-8.
19. *Grol R*, *Grimshaw J*. From best evidence to best practice: effective implementation of change in patients' care. Lancet 2003; 362: 1225-30.
20. *Cabana MD*, *Rand CS*, *Powe NR*, *et al*. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA 1999; 282: 1458-65.
21. *Jandoc R*, *Burden AM*, *Mamdani M*, *Lévesque LE*, *Cadarette SM*. Interrupted time series analysis in drug utilization research is increasing: systematic review and recommendations. J Clin Epidemiol 2015; 68: 950-6.
22. *Lalu M, Gagne S, Johnson C, et al*. Changes to the pathway of care following implementation of locally adopted Canadian Cardiovascular Society guidelines: an interrupted time series analysis, a study protocol; 2019. Available from URL: https://osf.io/t97jx/ (accessed March 2021).
23. *Lee TH*, *Marcantonio ER*, *Mangione CM*, *et al*. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999; 100: 1043-9.
24. *Zhang F*, *Wagner AK*, *Ross-Degnan D*. Simulation-based power calculation for designing interrupted time series analyses of health policy interventions. J Clin Epidemiol 2011; 64: 1252-61.
25. *Kontopantelis E*, *Doran T*, *Springate DA*, *Buchan I*, *Reeves D*. Regression based quasi-experimental approach when randomisation is not an option: interrupted time series analysis. BMJ 2015; DOI: https://doi.org/10.1136/bmj.h2750.
26. *Lugtenberg M*, *Burgers JS*, *Westert GP*. Effects of evidence-based clinical practice guidelines on quality of care: a systematic review. Qual Saf Health Care 2009; 18: 385-92.

27. *Dijkstra RF*, *Braspenning JC*, *Uiters E*, *van Ballegooie E*, *Grol RT*. Perceived barriers to the implementation of diabetes guidelines in hospitals in The Netherlands. Neth J Med 2000; 56: 80-5.
28. *de la Sierra A*, *Zamorano JL*, *Ruilope LM*. Application of hypertension guidelines in clinical practice: implementation of the 2007 ESH/ESC European practice guidelines in Spain. J Hypertens Suppl 2009; 27: S27-32.
29. *Pelland A*, *Chau A*, *Shin HJ*, *Prabhakar C*. Improving adherence to a monitoring protocol for myocardial injury after non-cardiac surgery. Can J Anesth 2020; 67: 1475-7.
30. *Buse GL*, *Manns B*, *Lamy A*, *et al*. Troponin T monitoring to detect myocardial injury after noncardiac surgery: a cost-consequence analysis. Can J Surg 2018; 61: 185-94.
31. *Duceppe E*, *Patel A*, *Chan MT*, *et al*. Preoperative N-terminal pro-B-type natriuretic peptide and cardiovascular events after noncardiac surgery: a cohort study. Ann Intern Med 2020; 172: 96-104.