CJC Open 7 (2025) 103–109

Original Article

Management of Patients with Myocardial Injury After Noncardiac Surgery: A Retrospective Chart Review

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ABSTRACT

Background: Myocardial injury after noncardiac surgery (MINS) is associated with an increased incidence of cardiac morbidity and mortality. Little is known about how these patients are managed.

Methods: We performed a single-centre retrospective chart review of patients referred to a postoperative clinic with the diagnosis of MINS. Patients were included if they attended the clinic at least once between September 2018 and December 2019. We extracted preoper-

RÉSUMÉ

Contexte : Les lésions myocardiques après une intervention chirurgicale non cardiaque (LMIN) augmentent le risque de morbidité cardiaque et de mortalité. On ne sait pas grand-chose sur la manière dont ces patients sont pris en charge.

Méthodologie : Nous avons procédé à une étude rétrospective des dossiers de patients d'un seul centre qui avaient été orientés vers une clinique postopératoire après avoir reçu un diagnostic de LMIN. Les

Myocardial injury after noncardiac surgery (MINS) is defined as an elevation in troponin level deemed to be ischemic in nature within the first 30 days after noncardiac surgery.[1,2] Routine postoperative monitoring has demonstrated that MINS is common after inpatient noncardiac surgery (up to 18%) and, even when it is not associated with ischemic symptoms or electrocardiographic changes, is associated with increased risks of both short-term and long-term morbidity and mortality.[1] A survey of physicians involved in the care of patients with MINS showed that substantial variability was present in provider preferences for using cardiac risk-stratification testing and prescribing cardiovascular preventative medications.[3] Furthermore, although 90% of survey respondents agreed that a follow-up visit with a specialist within 1 to 2 months was appropriate for patients with MINS, a lack of consensus had been reached regarding the need for a longer-term follow-up.[3] Variabilities in practice preferences could reflect a lack of certainty regarding how patients with MINS should be managed optimally, or different perceptions of the long-term risk of adverse outcomes of these patients.

Few studies in the literature have described how patients with MINS are managed while they are in the hospital; even less is

Received for publication August 3, 2024. Accepted October 7, 2024.

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See page 109 for disclosure information.

https://doi.org/10.1016/j.cjco.2024.10.004

ative, in-hospital, and postdischarge data on cardiac investigations and medication use.

Results: Of the 152 patients with MINS who were included, 34% had a history of coronary disease before MINS. The median peak high-sensitivity troponin I (hsTnI) level was 122 ng/L (interquartile range, 51−259), and 78% had no associated ischemic symptoms or electrocardiographic changes. Patients underwent echocardiography and nuclear stress imaging in 87% and 30% of cases, respectively. Of those who had cardiac investigations performed and no prior history of coronary artery disease, 23% (19 of 84) had $\geq$ 1 regional wall-motion abnormality on echocardiogram, and 39% (13 of 34) had evidence of ischemia on nuclear stress imaging. More patients were prescribed an antithrombotic and lipid-lowering drug at discharge (79%) and at their final clinic visit (86%), compared to the number before surgery (30%). A total of 57% of patients had changes made to $\geq$ 1 cardiovascular medication during clinic follow-up.

Conclusions: Patients with MINS followed in a postoperative clinic frequently had abnormal cardiac investigations and received medical optimization. Our findings suggest that postoperative clinics may represent an opportunity for risk mitigation after MINS, a possibility that deserves further evaluation.

patients retenus devaient avoir fréquenté la clinique au moins une fois entre septembre 2018 et décembre 2019. Nous avons extrait les données sur les examens cardiaques et la médication avant l'intervention, à l'hôpital et après le congé de l'hôpital.

Résultats : Parmi les 152 patients de l'étude présentant une LMIN, 34 % avaient des antécédents de coronaropathie avant la LMIC. Le taux maximal médian de troponine I hypersensible était de 122 ng/L (écart interquartile : 51−259), et 78 % des patients ne présentaient aucun symptôme ischémique ni aucun changement à l'électrocardiogramme. De plus, 87 % des patients se sont prêtés à une échocardiographie et 30 %, à un examen d'imagerie nucléaire à l'effort. Parmi les patients qui se sont prêtés à des examens cardiaques et qui n'avaient pas d'antécédents de coronaropathie, 23 % (19 patients sur 84) présentaient $\geq$ 1 anomalie localisée du mouvement pariétal à l'échocardiogramme, et 39 % (13 patients sur 34), des signes d'ischémie à l'examen d'imagerie nucléaire à l'effort. Les patients ont été plus nombreux à se voir prescrire un antithrombotique et un hypolipidémiant au moment du congé de l'hôpital (79 %) et lors de leur dernière visite en clinique (86 %) qu'avant l'intervention chirurgicale (30 %). Au moins un médicament cardiovasculaire a été changé pendant le suivi clinique chez 57 % des patients au total.

Conclusions : Les patients présentant une LMIN suivis dans une clinique postopératoire ont souvent obtenu des résultats anormaux aux examens cardiaques et leur traitement médicamenteux a été optimisé. Les résultats de notre étude indiquent que les cliniques postopératoires offrent la possibilité d'atténuer les risques en cas de LMIN, ce qui mérite une évaluation plus poussée.

known about the care they receive after they are discharged.[4-6] To further elucidate this subject, we performed a retrospective chart review of patients who were diagnosed with MINS and referred to a postoperative clinic at a tertiary-care hospital in Hamilton, Canada. The primary objective of our study was to describe the use of cardiac investigations and medications in patients with MINS, both at the time of their hospital discharge and during their follow-up at the postoperative clinic. A secondary objective was to explore the yield of cardiac investigations for evidence of cardiac ischemia or infarction.

Methods

We undertook a single-centre retrospective chart review of patients with MINS who were referred to a postoperative medicine clinic established at the Juravinski Hospital (Hamilton, Ontario, Canada) in September 2018 and had attended the clinic at least once. At the time of this study, the clinic most typically received referrals for patients with MINS; however, patients could be referred for other common postoperative medical complications also (eg, atrial fibrillation, hypertension, diabetes optimization).

Patients diagnosed with MINS at the Juravinski Hospital were referred routinely by treating physicians to the postoperative clinic as part of a clinical care pathway. A minority of patients also were referred to the clinic from another tertiary-care facility, the Hamilton General Hospital. Patients at the postoperative care clinic were managed by cardiologists and general internists who had an interest and competencies in perioperative medicine; however, they were not required to follow any institutional protocol for the management of MINS.

We excluded from our analyses patients who were referred to our clinic for reasons other than MINS, including non-ischemic troponin-level elevations. We limited our chart review to those patients who were referred to the clinic before December 2019, and we collected data until February 2020, to remove the possible effects of systemic changes that occurred during the COVID-19 pandemic, including the transition of patient visits to virtual assessments, and alterations in the timing and availability of clinical investigations.

The study received ethics approval from the Hamilton Integrated Research Ethics Board.

Data extraction

We extracted data from hospital electronic medical records using standardized data collection forms, including data on medical history, characteristics of the index MINS event (including peak levels of high-sensitivity troponin I [hsTnI]), use of cardiac medications, and use of cardiac investigations, including the findings they yielded. The hsTnI levels were measured using the Abbott ARCHITECT STAT hsTnI assay (99th percentile: female, 17 ng/L; male, 35 ng/L; Chicago, IL). All data extractors underwent standardized training during an initial pilot phase. Data were extracted in duplicate. We extracted data related to the baseline history before surgery, the hospitalization during which the index MINS event occurred, and each visit to the postoperative clinic. For each patient, we also extracted data on all cardiac investigations performed after the final postoperative clinic visit, until February 2020.

Patients were considered to have a *preoperative history of coronary disease* if they had a history of $\geq$ 1 of the following: coronary artery disease; myocardial infarction; coronary artery

revascularization (either coronary artery bypass surgery or percutaneous coronary angioplasty); coronary stenosis > 50% on coronary angiogram; positive cardiac stress test demonstrating ischemia; or any regional wall-motion abnormality (rWMA) on echocardiogram. We determined the proportion of cardiac investigations with *new evidence of coronary disease,* based on whether findings were consistent with coronary stenosis > 50%, myocardial ischemia, or rWMA across any cardiac testing done after MINS, or a coronary revascularization performed after MINS. These findings were determined among the following 2 subsets of patients: (i) those who had *no preoperative history of known coronary disease* according to the a priori definition (that is, based on pre-MINS cardiac investigation or any clinical record); and (ii) those who had pre-MINS cardiac testing, demonstrating no signs of coronary disease.

Statistical analyses

We used proportions and percentages to describe categorical variables, and median and interquartile range (IQR) to describe continuous variables. We used the Mann−Whitney *U* test to compare the troponin value distribution between groups. We conducted exploratory post hoc analyses using the Mann−Whitney *U* test, and the χ^2 test to determine whether age and sex were associated with ≥ 1 changes in cardiac medication made in the postoperative clinic. We considered findings with $P < 0.05$ to be statistically significant. All statistical analyses were performed using STATA, version 16.1 (StataCorp LLC, College Station, TX).

Results

Patient population

Of the 252 patients referred to the postoperative clinic, 152 met our eligibility criteria, after the exclusion of 72 patients who were referred for a reason other than MINS and 28 patients with MINS who never attended the clinic. The median time to follow-up between discharge and the first clinic visit was 23 days (IQR, 13-35). A total of 71 patients (47%) attended the postoperative clinic ≥ 2 times. Of these 71 patients, the median follow-up time between the first and last clinic visits was 63 days (IQR, 35−105).

Baseline characteristics

The baseline patient characteristics are summarized in Table 1. The median age of included patients was 74 years (IQR, 66-81), and 46% were male. The most represented type of surgery after which MINS occurred was orthopedic (43%); MINS occurred after urgent or emergent procedures in 48% of cases. Patients had a known history of coronary artery disease before MINS in 34% of cases. The median peak troponin level was 122 ng/L (IQR, 51−259; range, 31−8576), and 78% of patients had no ischemic symptoms or electrocardiographic changes associated with MINS. The baseline characteristics of patients with MINS who did not attend the postoperative clinic are shown in Supplemental Table S1.

Cardiac investigations

A total of 139 patients (91%) had ≥1 cardiac investigations performed during their postsurgical follow-up. Supplemental Table S2 provides the distribution of patient characteristics in those who did vs did not undergo cardiac testing. The most common cardiac investigations performed were resting transthoracic echocardiograms (132 patients; 87%) and nuclear stress imaging (45 patients; 30%). Of the patients who had at least 1 echocardiogram, the first echocardiogram was done during the index hospitalization in 63 cases (48%). Ten of all the other 119 stress or perfusion noninvasive cardiac investigations performed (8%), and 2 of the 16 coronary angiograms (13%), were done during the index hospitalization.

Among patients who underwent ≥ 1 cardiac test, 49 (35%) had ≥ 1 test with findings suggestive of either preexisting or new coronary disease (Table 2).

The median peak hsTnI level was 120 ng/L (IQR, 55−258) in those who underwent echocardiography, compared to 146 ng/L (IQR, 46−414) in those who did not undergo echocardiography (Mann−Whitney *U* test, $P = 0.99$). The median peak hsTnI level was 111 ng/L (IQR, 47−242) in those who did undergo other cardiac testing (ie, excluding echocardiography), compared to 137 ng/L (IQR, 64−277) in those who did not undergo other testing (Mann−Whitney *U* test, $P = 0.26$). The percentage of patients who had an echocardiogram or other cardiac testing performed, stratified by peak troponin level, is shown in Supplemental Figure S1.

Among the 132 patients who underwent echocardiography, 26 (20%) had ≥ 1 rWMA detected. Among the subset of 84 patients who underwent echocardiography after MINS and had no known history of coronary disease, 19 (23%) had ≥ 1 rWMA. Among the 45 patients who underwent nuclear stress imaging, 17 (38%) had evidence of cardiac ischemia. Among the subset of 34 patients who underwent nuclear stress imaging after MINS and had no known history of coronary disease, 13 (39%) had evidence of ischemia. When we considered only those patients with ≥ 1 pair of preoperative cardiac tests, and a cardiac test in the same modality performed after MINS (n = 53), 8 (15%) had new findings consistent with coronary artery disease or myocardial ischemia (Table 3).

The median peak hsTnI levels in patients with vs without ≥ 1 rWMA at the post-MINS echocardiogram were 158 ng/L (IQR, 67−1169) and 102 (IQR, 51−244), respectively (Mann−Whitney *U* test, $P = 0.09$). The median peak hsTnI levels in patients with vs without evidence of ischemia on nuclear stress imaging were 192 ng/L (IQR, 73−512) and 96 ng/L (IQR, 46−228), respectively (Mann−Whitney *U* test, $P = 0.08$).

Cardiovascular medications

Cardiovascular medication use before surgery, at hospital discharge, and at the final clinic visit is shown in Figure 1. The combined use of an antithrombotic drug (ie, either antiplatelet or anticoagulant) and a lipid-lowering agent (ie, either statin or ezetimibe) increased from 30% before surgery to 79% at the time of hospital discharge, and to 86% by the final postoperative clinic visit. A total of 96% of patients were

Table 1. Preoperative patient characteristics, characteristics of the index myocardial injury after a noncardiac surgery event, and clinic attendance

N = 152	n (%) or median (IQR)
Sex, male	70 (46)
Age, y	74 (66–81)
Medical history	
Hypertension	112 (74)
Atrial fibrillation	27 (18)
Chronic obstructive pulmonary disease	11 (7)
Asthma	12 (8)
Active cancer	47 (31)
Chronic kidney disease	15 (10)
Diabetes	45 (30)
Vascular disease	75 (49)
Coronary artery disease†	52 (34)
Previous myocardial infarction	28 (18)
Previous coronary stent or bypass surgery	21 (14)
Stroke or transient ischemic attack	24 (16)
Peripheral arterial disease	18 (12)
Congestive heart failure	7 (5)
Current or ex-smoker	82 (54)
Current	22 (14)
Ex	60 (40)
Preoperative creatinine, μmol/L	82 (69–105)
Preoperative hemoglobin, g/L	129 (114–139)
Revised Cardiac Risk Index score*	1 (1–2)
Functional dependence (≥ 1 BADL or IADL)	25 (16)
Surgical characteristics	
Urgent and/or emergent surgery	73 (48)
Type of surgery	
Orthopedic surgery	66 (43)
General surgery	44 (29)
Urologic or gynecologic surgery	22 (15)
Vascular surgery	14 (9)
Other surgery	6 (4)
Myocardial injury	
Peak high-sensitivity troponin I level, ng/L	122 (51–259)
Ischemic symptoms or ECG changes	33 (22)
Length of hospital stay, d	5 (3–8)
Length between discharge and first clinic visit, d	23 (13–35)
≥ 2 visits to the postoperative clinic	71 (47)

bADL, basic activities of daily living; ECG, electrocardiogram; hsTnI, high-sensitivity troponin I; iADL, instrumental activities of daily living; IQR, interquartile range.

*Preoperative laboratory data on the following are missing: hemoglobin (n = 9); creatinine (n = 10). For a missing revised cardiac risk index score, n = 10.

†Coronary artery disease was defined as follows: any of history of coronary artery disease; history of myocardial infarction; previous coronary artery bypass surgery or cardiac stent; coronary stenosis > 50% on coronary angiogram; positive cardiac stress test; or any regional wall-motion abnormality on echocardiogram.

taking at ≥ 1 antithrombotic drug or lipid-lowering agent at the final clinic visit. The number of patients using ≥ 3 medications from 4 major cardiovascular medication classes (ie, an antithrombotic drug, a lipid-lowering agent, an angiotensin-converting enzyme inhibitor, or an angiotensin receptor blocker or beta-blocker) increased from 42% before surgery to 67% at the time of discharge, and to 73% by the final postoperative clinic visit.

Table 2. Cardiac investigations performed following the occurrence of myocardial injury after noncardiac surgery

N = 152	n (%)
Patients with ≥ 1 test performed	
Echocardiogram	132 (87)
LVEF < 50%	15 (11)
Regional wall-motion abnormalities	26 (20)
Nuclear stress test	45 (30)
EMI	17 (38)
Cardiac PET	9 (6)
EMI	5 (56)
Cardiac CT	4 (3)
Evidence of coronary disease	2 (50)
Exercise stress test	3 (1)
EMI	2 (66)
Echocardiogram stress test	2 (1)
EMI	0
Coronary angiogram	16 (11)
Evidence of coronary artery disease of any extent and severity	16 (100)
Coronary stenosis > 70%	12 (75)
Stenosis treated with PCI	2 (13)
Cardiac surgery recommended	4 (25)

Data include investigations performed during the index hospitalization after the occurrence of myocardial injury after noncardiac surgery and during the outpatient follow-up period.

CT, computed tomography; EMI, evidence of myocardial ischemia; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; PET, positron emission tomography.

Changes made to cardiovascular medications at the postoperative clinic visits are shown in Figure 2. A total of 49% of patients had a drug initiation or dose intensification, 25% had a drug discontinuation, 1% had a dose reduction, and 5% had a medication change within the same drug class. No statistically significant associations occurred between either age ($P = 0.91$) or sex ($P = 0.73$) and having ≥ 1 change in cardiac medication at the postoperative clinic.

Discussion

In this single-centre retrospective chart review of 152 patients with MINS who were referred to and attended a postoperative clinic at least once after discharge, we found that 91% of patients underwent ≥ 1 type of cardiac testing, with echocardiography being the type performed most commonly. Among patients with no known history of coronary disease, 23% of those who underwent echocardiography had rWMAs, and 39% of those who underwent nuclear stress testing had evidence of ischemia. During the postoperative hospital stay and subsequent clinic visits, 57% had modifications to their cardiovascular therapy, and 73% were receiving ≥ 3 medications from major cardiovascular drug classes by the end of the follow-up period, compared to only 41% before surgery.

The role of cardiac testing in patients with MINS has not been well established.[7] In particular, currently, no clear evidence or guidance is available on how patients with MINS should undergo risk stratification. Even when MINS does not meet the universal definition of myocardial infarction, it is associated with future cardiovascular complications, and risk stratification may be useful for guiding short-term and long-term risk reduction in this population. In our study, echocardiography was performed in most patients and

Table 3. Findings suggestive of new coronary disease or myocardial ischemia on postoperative cardiac investigations

Definition of new myocardial ischemia on postoperative cardiovascular investigations	Patients with preoperative and postoperative investigation available	Patients with new findings	Patients with no previous history of coronary artery disease and investigations available	Patients with new findings
New regional wall-motion abnormalities on echocardiography	47	6 (13)	28	4 (14)
New abnormality at the myocardial perfusion or functional cardiac test	10	3 (33)	7	3 (43)
New coronary stenosis > 50% at the angiogram	3	0	0	—
≥ 1 type of evidence of new coronary disease or myocardial ischemia on postoperative cardiovascular investigations*	53	8 (15)	31	6 (19)

Values are n or n (%).

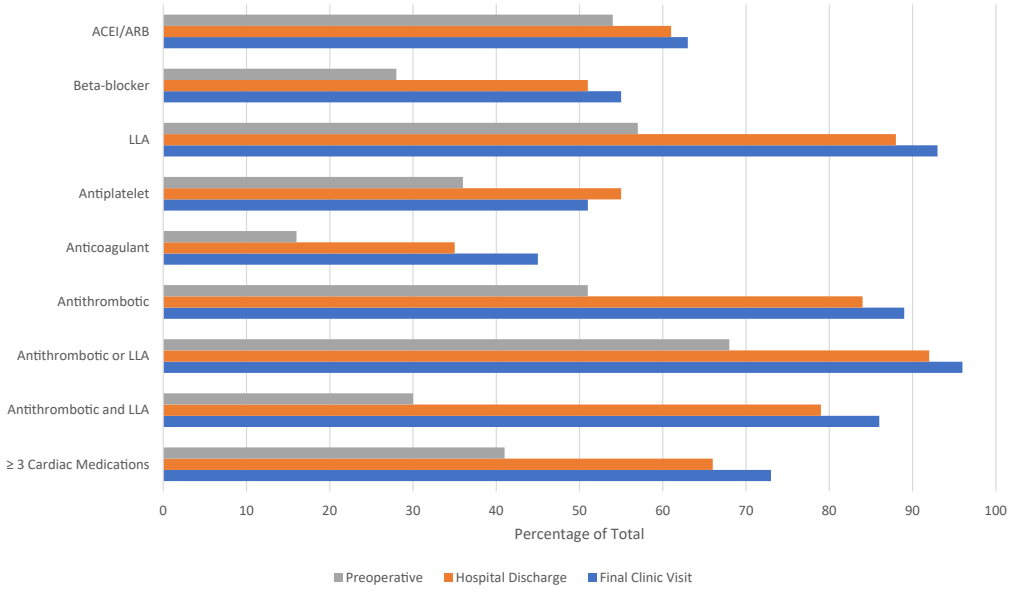
LVEF, left ventricular ejection fraction.

*The analyses included all patients with ≥ 1 pair of a normal preoperative cardiac test and a matching (ie, same modality) postoperative cardiac test.

demonstrated new rWMAs, in 13%-23% of cases, depending on the definition we used and the subset of patients we analyzed (ie, patients with a preoperative echocardiogram available vs patients with no preoperative history of known coronary disease). This frequency is higher than that reported previously in the literature.[6,8] In a single-centre Spanish cohort study of high-risk patients undergoing noncardiac surgery, patients who had postoperative myocardial injury that was identified through systematic troponin-level monitoring demonstrated a new rWMA on echocardiogram in 11% of cases.[6] This difference could be real, and possibly can be explained by differences in the case mix. For instance, our cohort had greater representation of patients with MINS who had undergone urgent or emergent procedures, which may be associated with greater stress than elective surgery and may increase the risk of a more severe myocardial injury in the presence of underlying coronary artery disease of the same extent.[9] Alternatively, the difference could be due to a different case selection. Whether echocardiography needs to be performed in all patients with MINS is unclear. Echocardiography could identify MINS events that are more likely to represent a major coronary event, and that might convey a higher risk of clinical deterioration, due to reduced heart function. We found that the troponin-level elevation in patients with ≥ 1 rWMA was numerically greater than that in patients without an rWMA; our findings were similar for patients with vs without evidence of ischemia on nuclear stress testing. In our study, the extent of troponin-level elevation did not seem to be a criterion that could be used appropriately to decide whether to perform echocardiography.

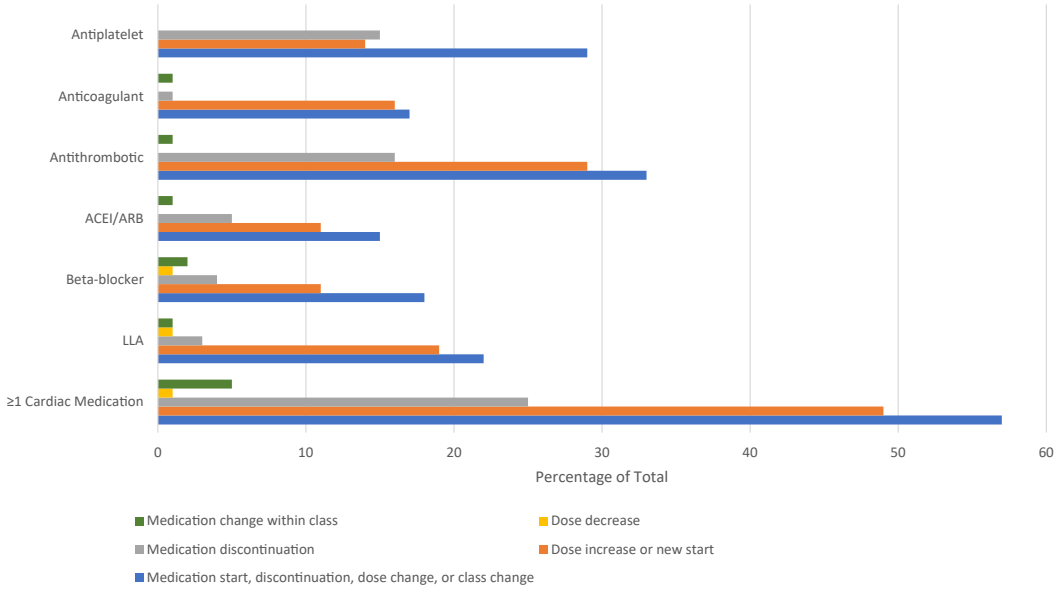
The initiation of new cardiovascular medications was more common in our population than it was in previous studies.[4,5,10,11] The proportion of patients receiving both an antithrombotic drug and a lipid-lowering agent increased from 30% preoperatively to 79% at hospital discharge, despite the median length of hospital stay being only 5 days. Half of patients had further modifications made to their cardiovascular medications during subsequent visits to the postoperative clinic, including dose titration and delayed drug initiation. For some patients, modifications did not include drug intensification but rather discontinuation or dose adjustment. Although our study was not designed to assess the benefits of these therapeutic changes, our findings do suggest that an opportunity exists for further medical optimization during the follow-up of these high-risk patients after their discharge. Continuing to follow these patients after they are discharged may offer the opportunity to optimize their long-term outcomes, as patients are less vulnerable to hemodynamic compromise or bleeding later on, compared to in the immediate postoperative state, and the level of concern for the initiation of medications with antihypertensive or antithrombotic effects likely is lower during postdischarge clinic visits.

Our study has important limitations. First, our study reflects the management of only a selected population of patients with MINS at a single institution, where most patients already had been seen in the hospital by a perioperative care service, after surgery. The use of cardiac investigations and medications in our study may not reflect the practice patterns at other centres, especially where perioperative specialists are not available. Second, patients with high-risk features may have been underrepresented in our clinic, as the greater severity of their condition could have impeded their ability to attend the clinic. Indeed, patients that never attended the clinic tended to be older, were more likely to have undergone nonelective surgery, and had longer (and possibly more complicated) hospital stays (Supplemental Table S1). Third, the retrospective design, with possible underreporting in patient records, and the small sample size, limited our ability to either reliably determine the results of cardiac testing in patients with MINS or identify potential predictors of ischemia on cardiac testing that could guide risk stratification. In particular, for the calculation of the frequency of new coronary artery disease or myocardial ischemia, we used 2 different approaches, both of which have limitations and have either overestimated or underestimated that frequency. Moreover, in patients with a previous history of coronary artery disease or positive cardiac testing, we could not rely accurately on historic records related to the anatomic site and/or extent of preexisting disease when ascertaining new cases of coronary disease or myocardial ischemia. Therefore, our calculation of the diagnostic yield of post-MINS cardiac testing could not account fully for the relevance of post-MINS cardiac testing in such patients. Finally, although we found that many patients with MINS had changes in their medications following cardiac investigations, whether these



≥3 cardiovascular medications: defined as 3 or more among 4 medication types – antithrombotic, LLA, ACEI/ARB, beta-blocker. Antithrombotic: any antiplatelet or anticoagulant; ACEI: angiotensin converting enzyme inhibitor; ARB: angiotensin receptor blocker; ASA: acetylsalicylic acid; LLA: lipid lowering agent (statin or ezetimibe).

Figure 1. Medication use before surgery, at hospital discharge, and at the final clinic visit. ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin-receptor blocker; LLA, lipid lowering agent.



≥1 cardiovascular medication change: defined as modification to 1 or more medications among 4 classes including antithrombotic, LLA, ACEI/ARB, beta-blocker. Antithrombotic: any antiplatelet or anticoagulant; ACEI: angiotensin converting enzyme inhibitor; ARB: angiotensin receptor blocker; ASA: acetylsalicylic acid; LLA: lipid lowering agent.

Figure 2. Medication changes during follow-up at the postoperative clinic. ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin-receptor blocker; LLA, lipid lowering agent.

changes made in the postoperative clinic led to better clinical outcomes remains unknown. Larger interventional studies are needed to determine whether care delivered in postoperative clinics improves long-term cardiovascular outcomes for patients with MINS.

Conclusion

Patients with MINS who are followed in a postoperative clinic often have findings suggestive of ischemia on cardiac testing, even without having any preoperative history of cardiovascular disease, and they may benefit from medical optimization. Dedicated postoperative clinics may be useful for the follow-up and management of this high-risk patient population.

Acknowledgements

During the conduct of the study, M.K.W. was supported by the PSI Foundation Research Trainee Award and the Canadian Consortium of Clinical Trials Training Platforms Doctoral Studentship Award. During the conduct of the study, M.M. was supported by a Physicians' Services Incorporated Foundation Clinical Research Career award. F.K.B. is a recipient of an Early Career Award from Hamilton Health Sciences.

Ethics Statement

The study received ethics approval from the Hamilton Integrated Research Ethics Board.

Patient Consent

This study is a retrospective chart review using deidentified data. Therefore, patient consent was not required by the Research Ethics Board.

Funding Sources

This study was funded by a McMaster University Division of General Internal Medicine Alternative Funding Program Grant.

Disclosures

D.C. has received research grants from the Canadian Institutes of Health Research, speaker fees from Servier outside of the current study, and advisory board fees from Roche Diagnostics and Trimedic outside of the current study. P.J.D. is a member of a research group with a policy of not accepting honoraria or other payments from industry for their own personal financial gain. They do accept honoraria and payments from industry to support research endeavours and help cover the costs of participating in meetings. Based on study questions that P.J.D. originated, and grants he has written, he has done the following: received grants from Abbott Diagnostics, AOP Orphan Pharmaceuticals AP, AstraZeneca, Bayer, Boehringer Ingelheim, Bristol Myers Squibb, Cloud DX, Covidien, Octapharma Plasma, Philips Healthcare, Roche Diagnostics, Siemens, and Stryker; participated in advisory board meetings for Glaxosmithkline, Boehringer Ingelheim, Bayer, and Quidel Canada; attended an expert panel meeting with AstraZeneca and Boehringer Ingelheim; was a consultant for a call with Roche Pharmaceuticals; performed consultant work with Abbott Diagnostics, AstraZeneca, Renibus Therapeutics, Roche Canada, and Trimedic; and been invited to be a speaker by Bayer Inc and Novartis Pharmaceuticals Canada. All the other authors have no conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at https://www.cjcopen.ca/ and at https://doi.org/10.1016/j.cjco.2024.10.004.