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Original Article

Implementation of a High-sensitivity Troponin Assay for Adult Patients Who Present to the Emergency Department With Chest Pain: The Role of Clinical Decision Support

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ABSTRACT

Background: The objective of this study was to assess the health outcomes for patients who present to the emergency department (ED) with cardiac chest pain after the implementation of an accelerated diagnostic protocol using a high-sensitivity troponin assay (hs-TnI).

Methods: This prospective before-after cohort study used population-based linked health administrative data for adult patients who presented to a Canadian urban ED with chest pain of suspected cardiac origin over a 2-year study period. The primary outcome was ED length of stay (LOS). Secondary outcomes included operational and clinical outcomes within 30 days of the index ED visit.

Results: During the study period, 4339 patients were included, with 2031 in the conventional troponin group and 2308 in the hs-TnI group. Overall, the median age was 56 years and 52% were male. The me-

RÉSUMÉ

Contexte : L'objectif de cette étude était d'évaluer les conséquences sur la santé des patients qui se présentent au service des urgences (SU) pour une douleur thoracique d'origine cardiaque, après la mise en œuvre d'un protocole de diagnostic accéléré utilisant un dosage de troponine à haute sensibilité (TnI-hs).

Méthodes : Cette étude de cohorte prospective avant/après a utilisé des données administratives de santé liées à la population pour des patients adultes qui se sont présentés à un SU urbain canadien avec des douleurs thoraciques d'origine cardiaque présumée au cours d'une période d'étude de deux ans. Le principal critère d'évaluation était la durée du séjour (DS) au SU. Les critères d'évaluation secondaires comprenaient les conséquences opérationnelles et cliniques dans les 30 jours suivant la visite au SU.

Chest pain is the second most common cause of all emergency department (ED) visits, with nearly 7.2 million encounters annually in the United States.[1] In assessment of acute chest pain, the key objective is to identify acute myocardial infarction (AMI), accurately identify or rule out acute coronary syndromes (ACS), and stratify patients at risk for coronary artery disease. Because only 1 in 8 patients with symptoms suggestive of ACS are eventually diagnosed with ACS, evaluations should be sensitive and specific.[2-4]

Emergency clinicians rely on a history, physical examination, electrocardiogram (ECG), and laboratory testing including troponin (Tn) levels. Biomarkers like Tn can accumulate in blood after cardiac muscle damage to indicate the presence of AMI; however, in cases of unstable angina no Tn elevations are detected. Serial Tn testing is a critical tool for detecting small elevations of Tn in some patients with AMI, despite possible elevations from other conditions like pericarditis, trauma, or renal failure. Tn requires time to reach detectable levels; thus, the ability to identify smaller amounts allows for faster detection of potential ACS. Conventional Tn (c-Tn) detection thresholds used at our region range from

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dian ED LOS was reduced from 430 minutes to 400 minutes after protocol implementation (median difference, -30.0; 95% confidence interval, -47.8 to -12.3). For discharged patients who underwent serial troponin tests, the LOS was 89 minutes shorter (95% confidence interval, -110.8 to -67.2). The proportion of patients discharged increased from 73% to 78% after implementation ($P = 0.0001$). At 30 days, there were no differences in hospital readmission or major adverse event outcomes.

Conclusions: Using clinical decision support, the implementation of a new hs-TnI and accelerated diagnostic protocol was associated with shorter ED LOS and fewer hospitalizations for adult patients with chest pain who were assessed in the ED. These results suggest that the protocol is effective and safe in real-world clinical settings.

Résultats : Au cours de la période d'étude, 4 339 patients ont été inclus, dont 2 031 dans le groupe troponine conventionnelle et 2 308 dans le groupe TnI-hs. Dans l'ensemble, l'âge médian était de 56 ans et 52 % des patients étaient des hommes. La durée médiane de DS-SU a été réduite de 430 minutes à 400 minutes après la mise en œuvre du protocole (différence médiane, -30,0; intervalle de confiance à 95 %, -47,8 à -12,3). Pour les patients sortis qui ont subi des tests sériels de troponine, la durée de séjour a été réduite de 89 minutes (intervalle de confiance à 95 %, -110,8 à -67,2). La proportion de patients sortis de l'hôpital est passée de 73 % à 78 % après la mise en œuvre du protocole ($p = 0,0001$). À 30 jours, il n'y avait pas de différences dans les taux de réadmission à l'hôpital ou dans les événements indésirables majeurs.

Conclusions : Grâce à l'aide à la décision clinique, la mise en œuvre d'un nouveau protocole de diagnostic accéléré et de dosage de la TnI-hs a été associée à une réduction de la DS-SU et du nombre d'hospitalisations chez les patients adultes souffrant de douleurs thoraciques et évalués au SU. Ces résultats suggèrent que le protocole est efficace et sûr dans un contexte clinique réel.

0.04 μg/L to 0.10 μg/L, whereas high-sensitivity Tn (hs-Tn) assays (hs-TnI) have significantly enhanced detection capabilities with a threshold as low as 3 ng/L. This advancement has resulted in a significant decrease in the time interval between serial Tn testing, reducing it from the suggested 6 hours associated with use of c-Tn assays (c-TnI) to as low as 1 hour with certain hs-TnI.[5-7] In addition, these new assays have the potential to improve the detection and rule-out of AMI.

Risk-stratifying tools have also been developed including the New Vancouver Chest Pain Rule, **H**istory, **E**CG, **A**ge, **R**isk factors, and **T**roponin (HEART) score, and North American Chest Pain Rule.[8,9] All have similar sensitivities for ACS, although the HEART score and modified **T**hrombolysis **i**n **M**yocardial **I**nfarction (TIMI) Score have superior specificity.[10,11] High-risk modified TIMI or HEART scores are reasonably predictive of short-term adverse cardiac event risk and might be useful to quantify short-term risk. Combined with ECG and hs-Tn testing, ED physicians can achieve sensitivity similar to the HEART score.[12] With initial studies verifying the sensitivity and safety of early rule-out protocols using hs-Tn,[13,14] these findings have led to widespread adoption of this approach in EDs worldwide.

Previous studies showed that accelerated diagnostic protocol (ADP) using hs-TnI have the potential to safely reduce ED length of stay (LOS); however, evidence is heterogeneous and limited. Systematic review evidence confirms that LOS is impacted by the baseline LOS and the strategies used to implement the ADP, rather than the Tn assays used.[15] In this study we aimed to evaluate the effect of the introduction of an hs-TnI and its associated ADP on ED outcomes for patients who present with chest pain of suspected cardiac origin.

Methods

Setting

The study was conducted at the University of Alberta Hospital (UAH), an urban academic tertiary care hospital in Edmonton, Alberta, Canada. The UAH is a referral centre for pediatric and adult cardiology. The UAH has a catheterization unit, as well as access to cardiac surgery. The adult ED assesses approximately 64,000 patients per year with an admission proportion of 29% (Esther Yang, personal communication, AHS Analytics), and is staffed by full-time emergency physicians.

Study design and population

This was a prospective cohort study using retrospective data collection. We included all adult Albertans who presented to the ED with chest pain of suspected cardiac origin and a Canadian Triage and Acuity Scale score of 2 or 3 between January 2015 and December 2021. The Canadian Triage and Acuity Scale score is a valid and reliable scale that is used in most EDs in Canada and chest pain of suspected cardiac origin is assessed on the basis of the presenting symptoms (eg, visceral chest discomfort; pain radiation to neck, jaw, or shoulder; nontraumatic origin; and presence of cardiac risk factors that might have associated symptoms [diaphoresis and/or nausea]). We focused on the period from November 8, 2019, and November 9, 2021, to compare a year before and after the implementation of hs-TnI testing in an ADP that was implemented on November 9, 2020.

Patients with a clear diagnosis of ST-segment elevation myocardial infarction (MI) were excluded. Those who died during ED transport or upon arrival, and non-Alberta residents or those who were not registered with the Alberta Health Care Insurance Plan were also excluded. When patients had multiple ED visits, we included only their first index visit.

Data sources

In this study we used linked provincial population-based health administrative data sets. Eight data sets were linked via encrypted unique health identifier numbers to create the final study cohort.

The National Ambulatory Care Reporting System captures data on all visits to any ED in Alberta and up to 10 diagnostic fields are recorded per visit according to the International Classification of Disease (ICD) 10th Revision, Canadian

Enhancement. Whereas ICD coding has limitations with respect to misclassification, cardiac causes seem to have relatively high accuracy compared with chart review.[16] Moreover, the hospital records are coded by medical record nosologists, and no significant changes occurred between the study periods, so differential misclassification would be unlikely.

The Emergency Department Information Tracking System captures all ED visit data in Edmonton, Alberta, and presenting complaints and consultation services are recorded. The provincial laboratory databases capture all general lab test data performed across the province. The provincial diagnostic imaging database captures data on all imaging performed across the province within Alberta Health Services facilities. The Discharge Abstract Database captures data on all acute care hospital admissions and includes data on interventions, discharge destinations, and up to 25 diagnoses according to the ICD 10th revision (ICD-10) codes. Vital Statistics captures data on the date of death including out of hospital deaths. The Provincial Registry captures data on Alberta residents with Alberta Health Care Insurance Plan coverage. The Practitioner Claims database captures data for all physician billing claims and includes up to 3 diagnoses recorded per visit according to the ICD ninth revision (ICD-9) and a Scheduled of Medical Benefits billing codes.

Pathways

The participating hospital had a longstanding chest pain protocol on the basis of 6-hour c-TnI laboratory reporting. From November 9, 2019, to November 8, 2020, the participating hospital used a c-TnI (Beckman AccuTnI+3, Beckman Coulter, Brea, CA) with 0.10 μg/L as a detection limit and 0.15 μg/L as decision cutoff. The new protocol was designed by a multidisciplinary committee of laboratory medicine leaders and clinicians from emergency medicine, internal medicine, and cardiology across the region. It coincided with the implementation of the hs-TnI (Beckman Access hs-TnI, Beckman Coulter) and a 3-hour testing interval. The rapid rule-out arm was adapted from a previous study[8] and internal analytical evaluation of the assay.[17] The rapid rule-in arm was on the basis of >5 times of the upper reference limit of the assay.[18] The limit of detection was set at 3 ng/L (used for rule-out decisions) and the 99th percentile upper limit was 20 ng/L. From November 9, 2020, to November 9, 2021, the participating hospital used the ADP using the Beckman hs-TnI cut points. Patients who underwent at least 1 hs-TnI test were categorized into 3 subgroups: negative, indeterminate, and high-risk on the basis of the reference ranges (Fig. 1). No sex-specific cutoff values were used for hs-TnI at the time of this study.

This centre generally relies on traditional community-based treadmill exercise stress testing post ED discharge for Tn-negative cases with low to moderate risk of coronary artery disease, despite questions about its predictive accuracy.[19,20] Although available, coronary computed tomography angiography is not routinely offered at this centre. Because a rapid chest pain assessment clinic does not exist, patients at high risk for ACS, even with negative serial Tn measures, are routinely referred to Cardiology for further investigations in the ED.

Implementation strategy

Before introducing the hs-TnI protocol, substantial consultations and dissemination strategies were undertaken to inform those clinicians most impacted by the changes (eg, Emergency Medicine, Internal Medicine, and Cardiology) across the hospital. Protocol champions in each department presented the protocol at group meetings. A 10-minute instructional video outlining the new protocol was created and made accessible online to all clinician groups. A comprehensive paper-based "Survival Guide" was created by the collaborative implementation team, which included the background information on ADP and hs-TnI testing. It also offered a thorough explanation of the new hs-TnI protocol, including clinical scenarios and sample laboratory reports.[21] A paper-based version of the protocol was distributed to the ED, whereas the hospital clinical teams received training sessions led by the 2 lead ED clinicians (B.H.R., S.D.). Shortly before the implementation, a Laboratory Bulletin was circulated via secure e-mail channels within Medical Affairs to remind staff about the upcoming changes. The introduction of the new assay did not include a run-in period. Instead, hs-TnI results, delta values, which indicate the absolute change in hs-TnI levels between consecutive readings, and interpretive comments specific to cutoff values were embedded as a clinical decision support (CDS) tool in the electronic health record (EMR).

Outcomes

Our primary outcome was ED LOS, measured as the time from triage to ED departure (discharge or departure to the floor). Secondary outcomes included consultation proportions, disposition status (ie, admission or discharge), and major adverse cardiac events (MACE), defined as a composite of all-cause death, hospitalization for heart failure, hospitalization and/or ED visit for MI or stroke, or cardiac interventions (eg, coronary artery bypass graft surgery, percutaneous coronary intervention) within 30 days of the index ED visit.

Covariates

We identified patient comorbidities using previously validated case definitions on the basis of ICD-10 and ICD-9 codes for all hospitalizations and ED visits in the 2 years before the index ED visit (and including index ED visit) and at least 2 physician claims in the Practitioner Claims database.[22]

Statistical analysis

Descriptive data are reported using proportions, mean with standard deviation, or median with interquartile range, as appropriate. Baseline characteristics were compared between groups using Pearson χ^2 test for categorical variables, Student t test for normally distributed variables, and Mann-Whitney test for non-normally distributed variables for continuous variables. Median differences with 95% confidence intervals (CIs) are also reported for continuous variables. The multivariable model was used to assess the association between hs-TnI use (reference = c-TnI use) and MACE. The Cox proportional hazard regression was used for MACE, adjusted for age, sex, and Charlson Comorbidity Index score. Unadjusted and adjusted hazard ratios with 95% CIs are reported. This analysis was specifically focused on the subgroup of patients who had at least 1 Tn test. Statistical significance for all tests (except the multivariable Cox regression analysis) was set at $P < 0.001$ because of the multiple

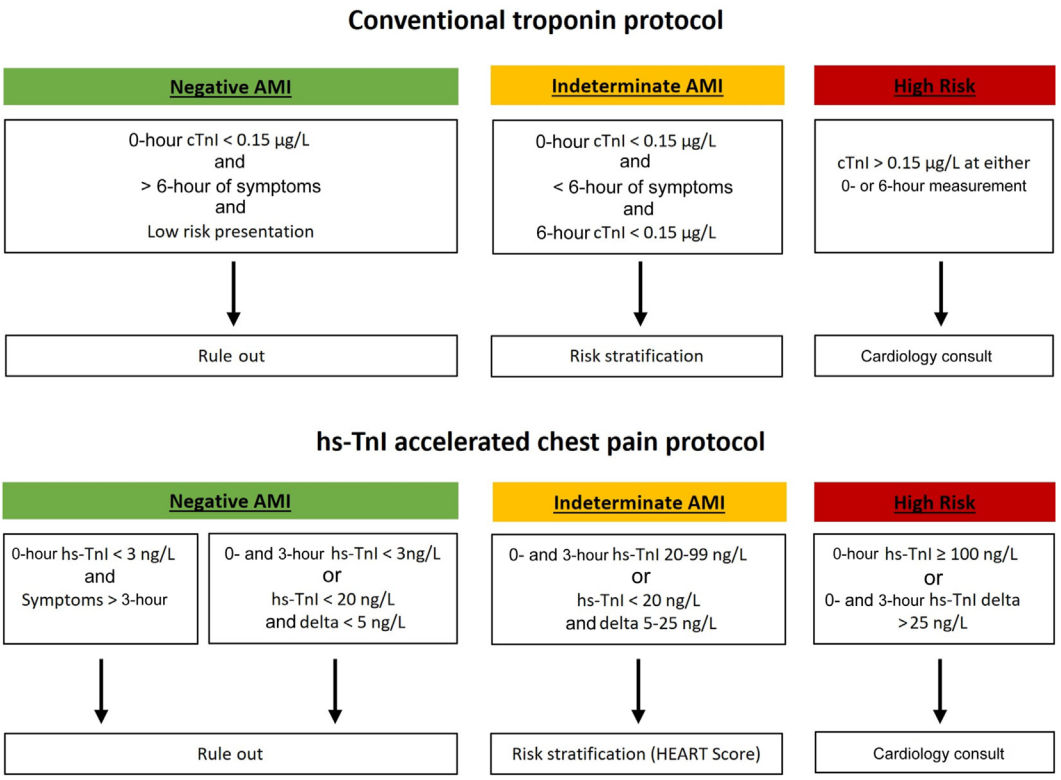

Figure 1. Chest pain protocol before and after the introduction of the high-sensitivity troponin assay. cTnI, conventional troponin assay; HEART, **H**istory, **E**CG, **A**ge, **R**isk factors, and **T**roponin; hs-TnI, high-sensitivity troponin assay.

tests performed. All analyses were conducted using SAS, version 9.4 (SAS Institute, Cary, NC).

Ethics

The study was approved by the University of Alberta research ethics board (Pro00096932), with a waiver of individual informed consent, because we were provided only deidentified data after linkage to conform with provincial privacy regulations. Clinicians, patients, and laboratory staff were unaware of the protocol evaluation during the study period.

Results

Patient demographic characteristics

A total of 4339 patients who presented with chest pain were included in the study period; 2031 (46.8%) in the c-TnI group and 2308 (53.2%) in the hs-TnI group (Fig. 2). The characteristics of the patient presentations are reported in Table 1. The median age of all included patients was 56 (interquartile range, 41-69) years, and 52.2% were male. There were no important differences in patient demographic characteristics, timing, severity of presentation, or patient comorbidities between the study periods.

ED management

Among all patients who presented with chest pain of presumably of cardiac origin, 88.5% underwent Tn testing (Table 2). After the introduction of the hs-TnI, patients were more likely to have 2 Tn tests ordered (36.3% vs 28.7%; $P < 0.001$). The proportion of patients classified as negative, indeterminate, or high-risk remained unchanged between study periods. Patients in the hs-TnI group were more likely to receive D-dimer testing (40.8% vs 35.6%; $P = 0.0004$); however, there were no significant differences between the proportions of patients who underwent chest imaging investigations. Consultation occurred in 21.2% of patient presentations in the c-TnI group and 18.5% in the hs-TnI group ($P = 0.03$).

Primary outcome

The median ED LOS was 430 minutes for the c-TnI group and 400 minutes for the hs-TnI group (median difference, -30 minutes; 95% CI, -47.8 to -12.3;Table 3). Whereas patients in the group with a negative result experienced longer ED LOS (median difference, 46 minutes; 95% CI, 27.6-64.5 minutes); those in the indeterminate risk had a shorter ED LOS (mean difference, -162 minutes; 95% CI, -188.8 to -135.2 minutes). Among patients who underwent repeat testing and were discharged, their LOS was shorter by 89 (95% CI, -110.8 to -67.2) minutes after the implementation of the hs-TnI. Moreover, the difference in time to physician initial assessment between study periods was small, albeit significantly different, with median times of 100.5 and 88 minutes, before and after hs-TnI introduction, respectively (median difference, -12.0 minutes; 95% CI, -21.2 to -2.9 minutes).

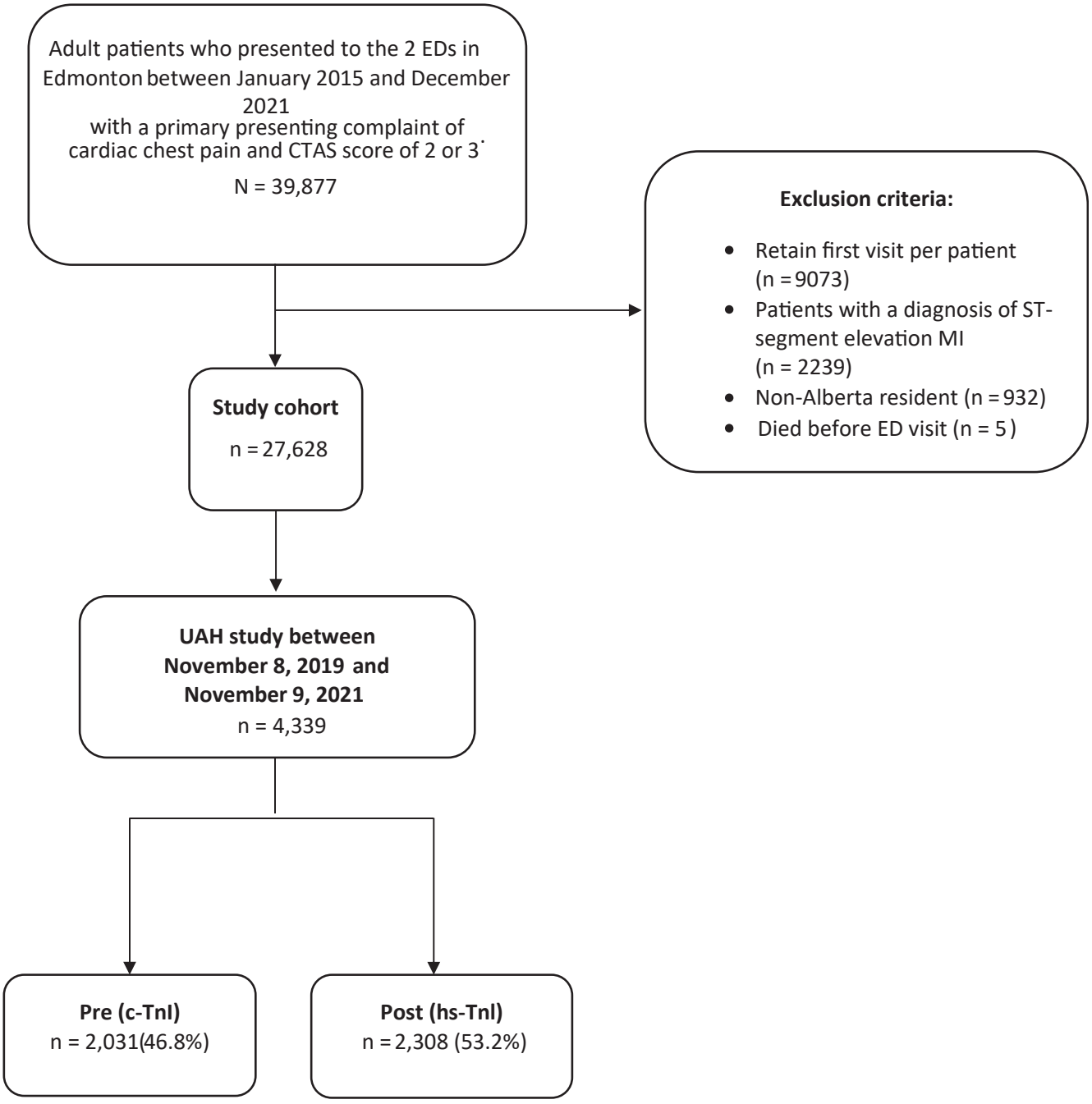

Figure 2. Identification of patients who presented to a tertiary care Canadian emergency department (ED) with cardiac chest pain before and after the implementation of a high-sensitivity troponin assay (hs-TnI) and rapid testing protocol. CTAS, **C**anadian **T**riage and **A**cuity **S**cale; c-TnI, conventional troponin; MI, myocardial infarction; UAH, University of Alberta Hospital.

Secondary outcomes

The proportion of patients who were discharged increased (78.1% vs 73.0%; $P = 0.0001$) after the pathway changes. The overall 30-day clinical outcomes were similar between the study periods. The MACE outcomes did not change after the implementation of the hs-TnI test (9.4% vs 8.1%; $P = 0.13$). After adjustment, no overall difference in MACE was noted in the hs-TnI group compared with the c-TnI group (adjusted hazard ratio, 1.21; 95% CI, 0.97-1.50; Table 4).

Discussion

Advances in diagnostic prediction rules, biomarkers, and protocols have improved the outcomes and safety of chest pain assessments in the ED setting. Despite these advances, the effectiveness of implementing standardized protocols for diagnosing AMI and ACS have been limited.[23-25] What research is available has often been completed only in the United States or European countries, not focused on the effectiveness of the change from c-TnI to hs-TnI, with comprehensive outcomes

Table 1. Characteristics of patients who presented to a tertiary care Canadian emergency department with chest pain before and after the implementation of an hs-TnI and rapid testing protocol

Characteristic	Total (N = 4339)	c-TnI (n = 2031)	hs-TnI (n = 2308)
Median age (IQR), years	56 (41-69)	57 (42-69)	56 (41-69)
Male sex, n (%)	2266 (52.2)	1028 (50.6)	1238 (53.6)
Mode of arrival, n (%)			
No ambulance	2971 (68.5)	1382 (68.1)	1589 (68.9)
Ground ambulance	1351 (31.1)	638 (31.4)	713 (30.9)
Air ambulance	16 (0.4)	11 (0.5)	5 (0.2)
CTAS score, n (%)			
2	4256 (98.1)	1988 (97.9)	2268 (98.3)
3	83 (1.9)	43 (2.1)	40 (1.7)
Time of day, n (%)			
Daytime (08:01-16:00)	2066 (47.6)	962 (47.4)	1104 (47.8)
Evening (16:01-24:00)	1539 (35.5)	726 (35.8)	813 (35.2)
Early morning (00:01-08:00)	734 (16.9)	343 (16.9)	391 (16.9)
Preexisting conditions, n (%)			
Hypertension	1589 (36.6)	766 (37.7)	823 (35.7)
CAD	954 (22.0)	475 (23.4)	479 (20.8)
Diabetes mellitus	818 (18.9)	399 (19.7)	419 (18.2)
Atrial fibrillation	606 (14.0)	284 (14.0)	322 (14.0)
Stroke	416 (9.6)	204 (10.0)	212 (9.2)
Asthma	278 (6.4)	141 (6.9)	137 (5.9)
Heart failure	351 (8.1)	181 (8.9)	170 (7.4)
COPD	251 (5.8)	112 (5.5)	139 (6.0)
Dementia	116 (2.7)	56 (2.8)	60 (2.6)
Renal disease	209 (4.8)	112 (5.5)	97 (4.2)
Median Charlson Comorbidity Score (IQR)	0 (0-2)	0 (0-2)	0 (0-2)

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CTAS, **C**anadian **T**riage and **A**cuity **S**cale; c-TnI, conventional troponin; hs-TnI, high-sensitivity troponin assay; IQR, interquartile range.

that are important to clinicians not reported. This study was designed to assess an ADP involving a new hs-TnI by comparing ED LOS, as well as operational and clinical outcomes 1 year before and after the transition for patients who present with cardiac-related chest pain in an urban Canadian ED. We matched time periods and presenting complaints at a tertiary care ED in an effort to ensure similar cohorts. Moreover, we had a comprehensive change management implementation strategy that involved multiple partners in an effort to fully engage clinicians. Finally, we endeavored to ensure complete outcomes capture in the ED and at 30 days.

Table 2. Testing and outcomes of patients who presented to a tertiary care Canadian ED with chest pain before and after the implementation of an hs-TnI and rapid testing protocol

	Total (N = 4339)	c-TnI (n = 2031)	hs-TnI (n = 2308	*P*
Troponin tests				
0	497 (11.5)	266 (13.1)	231 (10.0)	0.001
1	2313 (53.3)	1121 (55.2)	1192 (51.7)	0.019
2	1420 (32.7)	583 (28.7)	837 (36.3)	**< 0.0001**
≥ 3	109 (2.5)	61 (3.0)	48 (2.1)	0.052
Troponin results				
Negative	2336 (60.8)	1063 (60.2)	1273 (61.3)	0.501
Indeterminate	1212 (31.6)	560 (31.7)	652 (31.4)	0.823
High-risk	294 (7.7)	142 (8.1)	152 (7.3)	0.398
D-dimer	1664 (38.4)	722 (35.6)	942 (40.8)	0.0004
eGFR	3811 (87.8)	1746 (86.0)	2065 (89.5)	0.0004
Chest imaging				
Chest radiograph	3518 (81.1)	1609 (79.2)	1909 (82.7)	0.003
Chest CTPE	472 (10.9)	217 (10.7)	255 (11.1)	0.701
VQ scan	87 (2.0)	31 (1.5)	56 (2.4)	0.035
ED consultation				
Yes	856 (19.7)	430 (21.2)	426 (18.5)	0.025
Median number of ED consultations (IQR)	1 (1-1)	1 (1-1)	1 (1-1)	0.537
Consult service				
Cardiology	532 (62.1)	268 (62.3)	264 (62.0)	0.078
Internal Medicine	123 (14.4)	68 (15.8)	55 (12.9)	0.056
Gastroenterology	53 (6.2)	27 (6.3)	26 (6.1)	0.544
General Surgery	22 (2.6)	9 (2.1)	13 (3.1)	0.578
Others	126 (14.7)	58 (13.5)	68 (16.0)	0.859

Data are presented as n (%) except where otherwise noted. Bolded *P*-values represented a significant difference.

c-TnI, conventional troponin assay; CTPE, computed tomography for pulmonary embolism; ED, emergency department; eGFR, estimated glomerular filtration rate; hs-TnI, high sensitivity troponin assay; IQR, interquartile range; VQ scan, pulmonary ventilation and perfusion.

Table 3. Outcomes of patients who presented to a tertiary care Canadian ED with chest pain before and after the implementation of an hs-TnI and rapid testing protocol

	Total (N = 4339)	c-TnI (n = 2031)	hs-TnI (n = 2308)	Median differences with 95% CI or *P*
Disposition				
Admitted	781 (18.0)	407 (20.0)	374 (16.2)	0.001
Discharged	3285 (75.7)	1483 (73.0)	1802 (78.1)	**0.0001**
Transferred	28 (0.7)	13 (0.6)	15 (0.7)	0.968
LWBS	183 (4.2)	99 (4.9)	84 (3.6)	0.043
LAMA	56 (1.3)	26 (1.3)	30 (1.3)	0.954
Died	6 (0.1)	3 (0.2)	3 (0.1)	0.875
ED PIA*	91 (39-185)	100.5 (39-208)	88 (39-170)	**-12.0 (-21.2 to -2.86)**
ED LOS				
Overall	411 (288-563)	430 (281-591)	400 (293-533)	**-30.0 (-47.8 to -12.3)**
Negative	404 (301-529.5)	376 (276-527)	422 (330-532)	**46.0 (27.6-64.5)**
Indeterminate	515.5 (374.5-661.5)	580.5 (490.5-723.5)	417.5 (304-581.5)	**-162.0 (-188.8 to -135.2)**
High-risk	389.5 (207-623)	435.5 (182-681)	364 (220.5-550)	-70.0 (-166.0 to 26.0)
Admitted	462 (258-688)	481 (257-750)	428 (259-635)	-53.0 (-114.4 to 8.3)
Discharged	419 (307-553)	438 (302-579)	407 (312-522)	**-31.0 (-49.3 to -12.7)**
Discharged (single troponin test)†	363 (273-481.5)	364 (268.5-499.5)	363 (273-471.5)	-1.0 (-19.2 to 17.2)
Discharged (repeat troponin tests)‡	526 (422-658)	575 (492-702)	486 (390-624)	**-89.0 (-110.8 to -67.2)**
All-cause readmissions within 30 days	834 (19.2)	364 (17.9)	470 (20.4)	0.042
HF-related readmissions within 30 days	83 (1.9)	31 (1.5)	52 (2.3)	0.081
Clinical outcomes within 30 days				
Stroke	9 (0.2)	1 (0.1)	8 (0.4)	0.032
MI	192 (4.4)	84 (4.1)	108 (4.7)	0.385
Cardiac interventions§	196 (4.5)	86 (4.2)	110 (4.8)	0.400
Death	53 (1.2)	23 (1.1)	30 (1.3)	0.617
MACE‖	380 (8.8)	164 (8.1)	216 (9.4)	0.136

Data are presented as n (%) or median (interquartile range) except where otherwise noted. Bolded *P*-values represented a significant difference.

CI, confidence interval; c-TnI, conventional troponin assay; ED, emergency department; HF, heart failure; hs-TnI, high-sensitivity troponin assay; LAMA, left against medical advice; LOS, length of stay; LWBS, left without being seen; MACE, major adverse cardiac event; MI, myocardial infarction; PIA, physician initial assessment.

* n = 4107.

† n =1924.

‡ n = 1159.

§ Cardiac interventions include coronary artery bypass graft surgery and percutaneous coronary intervention.

‖ MACE is defined as a composite of all-cause death, hospitalization for HF, hospitalization or/and ED visit for stroke or MI, or cardiac interventions.

Using a large, comprehensive and valid set of databases and selecting a group of patients with chest pain at risk for ACS and serious outcomes, there were no significant differences in demographic characteristics and ED management between the pre- and post-implementation periods. Using a robust implementation strategy incorporating a CDS tool within the EMR for clinician guidance, the protocol was associated with a clinically important and statistically significant decrease in the overall ED LOS, the LOS of patients who required serial testing, and an increase in the proportion of patients discharged from the ED.

Additional observations are important to discuss. First, a small percentage of patients in the pre- and post-implementation period did not receive any biomarker testing. This suggests that clinicians assigned patients with a more likely alternative diagnosis and/or low-risk presentation and a normal cardiogram did not order biomarker testing at all. In fact, evidence from using the HEART score without a Tn measure (HEAR) is a safe strategy for this population.[26,27] Second, more than half of the patients in both groups received a single Tn test, which suggests clinicians used a strategy in which single testing was appropriate for patients with normal ECG and prolonged duration of chest pain (> 3 hours). Despite the increased sensitivity of the hs-TnI, the proportion of patients categorized as negative, indeterminate, and high-risk remained consistent. Third, there was a significant increase in the number of patients who underwent repeat testing after the implementation of the protocol using the hs-TnI. This trend is consistent with data

Table 4. Major adverse cardiac events outcomes of patients who presented to a tertiary care Canadian emergency department with chest pain before and after the implementation of a high-sensitivity troponin assay and rapid testing protocol

	Unadjusted		Adjusted	
Variable	HR (95% CI)	*P*	HR (95% CI)	*P*
Age	1.04 (1.04-1.05)	< 0.0001	1.04 (1.03-1.05)	< 0.0001
Male sex	2.04 (1.64-2.53)	< 0.0001	1.95 (1.54-2.46)	< 0.0001
Charlson Comorbidity Score	1.22 (1.19-1.26)	< 0.0001	1.14 (1.10-1.19)	< 0.0001
Implementation of high-sensitivity troponin test	1.16 (0.95-1.43)	0.144	1.21 (0.97-1.50)	0.095

Adjusted HR represents the adjusted HR for the Cox regression model.

CI, confidence interval; HR, hazard ratio.

from Australia and the United States indicating more frequent repeat testing after the implementation of hs-TnI testing.[7,28] This is likely influenced by differences in retrospective classification methods as well as increased detection of clinically insignificant Tn levels. In the c-TnI group, patients with initially undetectable Tn or those who experienced symptoms for a prolonged duration before ED arrival could be categorized as negative or low-risk; however, in the hs-TnI group, patients who underwent serial Tn testing in 3 hours could also be classified as low-risk if their Tn was between 4 and 19 ng/L and they had changes in Tn levels between serial measurements of < 5 ng/L. Consequently, the negative or low-risk group experienced an increased LOS after the implementation of hs-TnI test.

Overall, the hs-TnI and rapid testing protocol resulted in a significant 30-minute reduction in ED LOS for all patients who presented with chest pain. The increase in the median LOS in the negative group likely represents an increase in the number of people with very low levels of Tn in their blood who required serial testing.

Notably, those in the indeterminate group experienced the largest decrease in ED LOS after the implementation of the hs-TnI, with a median difference of -162 (95% CI, -188.8 to -135.2) minutes. Patients in this group who did not meet the criteria for ruling out or confirming cardiac damage required serial measurements, and depended on risk evaluation using the HEAR(T) score (Fig. 1). This significant difference was likely because of key changes introduced in the new pathway including a lower Tn cut point, use of a single test to rule out, a decreased interval for serial measurements from 6 hours to 3 hours, and incorporation of a clinical decision tool. It is not possible to determine the contributions of each component in the protocol. There was also a significant reduction in the median time interval between the first and second Tn tests (c-TnI, 334 minutes vs hs-TnI, 189.5 minutes), which likely had the greatest effect on ED LOS. Furthermore, there was a trend toward a decrease in ED LOS for admitted patients although it did not reach statistical significance and the rate of cardiology consultation remained unchanged. These results are consistent with studies that indicate that the implementation of hs-TnI does not increase resource utilization.[29,30]

Importantly, the 30-day clinical outcomes such as MACE, death, and hospital readmission were unchanged after the implementation.[31-33] We also showed no change in clinical outcomes in those initially discharged from the ED before and after protocol implementation. These findings suggest that implementation of an ADP incorporating a hs-TnI provides an acceptable level of safety even in clinical practice environments with significant operational challenges.[34,35]

Limitations

This study has several limitations. First, this was a single-centre study, and the data were taken from a Canadian health care system, potentially limiting its applicable to other health care settings. Moreover, this centre relies on exercise stress testing for follow-up of patients in the community setting. Although coronary computed tomography angiography might be more effective in identifying patients at risk for MI or death,[36,37] it can lead to prolonged ED LOS, increased resource utilization, and more invasive procedures without significantly reducing the risk of MI or death.

Second, the inclusion criteria focused on patients triaged with symptoms specifically indicating cardiac-related chest pain; therefore, patients who described their symptoms differently or with atypical chest pain presentations might not have been included. This is particularly common for patients who identify as women, and additional work is under way to explore this. Third, comorbidities and clinical outcomes were defined using administrative data, which lacks the depth of clinical information often used to fully assess illness severity. Despite this limitation, validated ICD-10 and ICD-9 codes and case definition algorithms were used for comorbidity index scores, and the outcomes evaluated remained across varying clinical contexts. Fourth, data on behavioural and sociodemographic factors, which might impact acute and long-term health outcomes (eg, diet, exercise, cannabis use, vaping and cigarette inhalation, drinking behaviours, etc), were not comprehensively captured in the administrative data.

Fifth, there was no run-in period between the two study periods, potentially impacting the results as physicians gradually became more comfortable with the new protocols over time. The use of an EMR notification to clinicians likely enhanced uptake, and we found no evidence of a time effect. Sixth, a substantial portion of patients were not evaluated according to the recommended serial Tn pathway; approximately 46% in the hs-TnI study period received only a single Tn test despite the guideline suggesting results that would mandate serial testing. This might be because of several factors such as a quicker decision-making process, ongoing symptoms, early presentations, or staffing. It is important to note that this variation from local pathway is reflective of real-world clinical practice and should be considered in that context when assessing its importance as a potential limitation.[38]

Seventh, an ADP used in our participating hospital used hs-TnI cut points on the basis of published guidelines.[21] The cutoff points for the c-Tn assay were adjusted after discussions among laboratory leaders and clinicians to rectify issues with assay performance such as false positive results and imprecision near the 99th percentile for the AccuTnI+3 assay. Enhanced education and the introduction of a new collection tube (Barricor, Becton Dickinson, Franklin Lakes, NJ), however, helped resolve these problems with the c-TnI assay. Other protocols and cut points vary according to Tn type (I vs T) and assay manufacturer. This variability should be taken into consideration when applying these data to alternative ADPs.

Finally, like most EDs in Canada,[39] the protocol did not include a sex-specific cut point for hs-TnI and current research suggests such a revision should be implemented.[40] Moreover, we did not report an age-stratified sex-based analyses; however, we recognize the importance of this analysis and future analysis of sex-based differences are planned.

Conclusion

The introduction of an ADP using an hs-TnI using a CDS tool embedded within an EMR in a tertiary care ED in Canada resulted in a significant reduction in the ED LOS. This reduction in ED LOS was particularly significant for

patients categorized as indeterminate and who required repeated testing and were discharged. Furthermore, clinical outcomes within 30 days including hospital admissions, MACE, and mortality showed no significant change after the implementation. These findings indicate the protocol is effective and safe in clinical practice. Future research is warranted to perform age-stratified and sex-based analysis for a more comprehensive understanding of its effect.

Ethics Statement

This study was approved by a duly-constituted health research ethics board affiliated with the University of Alberta.

Patient Consent

The authors confirm that patient consent is not applicable to this article, because we were provided only deidentified data after linkage to conform to provincial privacy regulations.

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