Original Article

The Impact of an Accelerated Diagnostic Protocol Using Conventional Troponin I for Patients With Cardiac Chest Pain in the Emergency Department

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ABSTRACT

Background: This study strove to assess the impact of the implementation of an accelerated diagnostic protocol (ADP), using shortened serial-testing intervals and a conventional troponin I (c-TnI) test, on emergency department (ED) length of stay (LOS).

Methods: This retrospective cohort study included adults (aged $\geq$ 18 years) presenting to a Canadian ED with a primary complaint of cardiac chest pain between January 14, 2017 and January 15, 2019. For non-high-risk patients, the troponin delta timing decreased from 6 hours to

RÉSUMÉ

Contexte : Cette étude visait à évaluer les répercussions de la mise en œuvre d'un protocole de diagnostic accéléré avec intervalles plus courts entre les épreuves séquentielles et dosage classique de la troponine I sur la durée du séjour à l'urgence.

Méthodologie : Cette étude de cohortes rétrospective a été menée chez des adultes (âgés de 18 ans ou plus) qui se sont présentés à l'urgence d'un hôpital canadien principalement pour une douleur thoracique cardiaque entre le 14 janvier 2017 et le 15 janvier 2019.

Chest pain is the second most common emergency department (ED) presenting complaint in Canada.[1] It is associated with important practice variation, high cost of investigation,[2,3] frequent consultation, high proportions of admission to hospital,[4,5] and a high rate of 7-day ED relapse requiring hospital admission.[6] Cardiac biomarkers, accelerated diagnostic protocols (ADPs), and scoring systems have gained attention as strategies to reliably exclude acute coronary syndrome (ACS) at the same time as demonstrating safety using 30-day major adverse cardiac events (MACE)[7] outcomes.

Plasma cardiac troponins require time to accumulate to a detectable level after cardiac muscle necrosis. To accommodate for this rise, most acute chest-pain guidelines have recommended a repeat measurement of troponin (Tn) level several hours after the initial test. Assessment of chest pain with a conventional Tn (c-Tn) test historically required at least a 6-hour serial measurement to have adequate sensitivity as a strategy to rule out ACS. Given that the remainder of the ED workup for chest pain may take approximately 1-2 hours, the 6-hour serial Tn test has been identified as one cause of prolonged ED length of stay (LOS).[7-9] Furthermore, patients waiting for a 6-hour repeat Tn measurement often are held in monitored beds, further exacerbating the overcrowding problem in the ED.

Over the past 2 decades, advances have been made in cardiac biomarker assays. Development of higher=sensitivity Tn assays lead to improved sensitivity for measurement of lower troponin concentrations.[8] This lower detection threshold was combined with clinical decision rules to evaluate the safety of ADPs, with shorter serial-measurement intervals. The HEART (**H**istory, **E**CG, **A**ge, **R**isk factors, **T**roponin) pathway is one

3 hours, and a different conventional troponin I level cut-point was implemented on January 15, 2018. The primary outcome was ED LOS. Secondary outcomes included disposition status, consultation proportions, and major adverse cardiac events within 30 days.

Results: A total of 3133 patient interactions were included. Although the overall decrease in median ED LOS was not significant ($P = 0.074$), a significant reduction occurred in ED LOS (-33 minutes; 95% confidence interval: -53.6 to -12.4 minutes) among patients who were discharged in the post-ADP group. Consultations were unchanged between groups (36.1% before vs 33.8% after; $P = 0.17$). The major adverse cardiac events outcomes were unchanged across cohorts (15.9% vs 15.3%; $P = 0.62$).

Conclusions: The implementation of an ADP, with a conventional troponin I test, for cardiac chest pain in a Canadian ED was not associated with a significant reduction of LOS for all patients; however, a significant reduction occurred for patients who were discharged, and the strategy appears safe.

Chez les patients qui n'étaient pas exposés à un risque élevé, l'intervalle de dosage de la troponine (delta) est passé de 6 heures à 3 heures, et une nouvelle valeur seuil a été utilisée pour le dosage classique de la troponine I à compter du 15 janvier 2018. Le critère d'évaluation principal était la durée du séjour à l'urgence. Les critères d'évaluation secondaires comprenaient le statut au moment de la sortie, les proportions de consultation et les événements cardiovasculaires indésirables majeurs dans les 30 jours.

Résultats : Au total, 3 133 interactions avec des patients ont été incluses. Bien que la diminution globale de la durée médiane du séjour à l'urgence n'ait pas été significative ($p = 0{,}074$), une réduction significative du séjour à l'urgence (-33 minutes; intervalle de confiance à 95 % : -53,6 à -12,4 minutes) a été observée chez les patients ayant reçu leur congé appartenant au groupe dans lequel le protocole de diagnostic accéléré a été mis en œuvre. Les consultations étaient inchangées entre les groupes (36,1 % avant vs 33,8 % après; $p = 0{,}17$). Les résultats relatifs aux événements cardiovasculaires indésirables majeurs sont demeurés inchangés dans les cohortes (15,9 % vs 15,3 %; $p = 0{,}62$).

Conclusions : La mise en œuvre d'un protocole de diagnostic accéléré, avec un dosage classique de la troponine I, en cas de douleur thoracique d'origine cardiaque, à l'urgence d'un établissement canadien ne s'est pas traduite par une réduction significative du séjour à l'urgence chez tous les patients. Une réduction significative a néanmoins été observée chez les patients qui ont reçu leur congé, et la stratégie s'est avérée sûre.

such ADP and has particular importance for ED use, as it was validated with an ED population.[9] The original HEART study used a detection threshold of 0.04 ug/L and was able to establish the safety of a 3-hour serial measurement to detect MACE with acceptable negative predictive value for low-risk patients (HEART score: 0-3). Consequently, the 2015 American Heart Association guidelines endorsed the use of this accelerated protocol.[10]

The effect of an ADP for patients with cardiac chest pain on ED patient throughput has been studied inadequately, especially in the Canadian context. Moreover, even when using different Tn assays (including c-TnI, high-sensitivity [hs]-TnT, hs-TnI) employing different threshold values in ADP protocols, these results are relevant to many national and international settings. Therefore, our findings can provide insights into the effectiveness of implementing ADP for chest-pain management in many healthcare settings. The objective of this study was to assess the impact of the shortened serial troponin times after the implementation of an ADP on ED LOS, consultation rates, and patient outcomes.

Methods

Ethics

The study protocol and materials were approved by the University of Alberta Human Research Ethics Board, with a waiver of individual informed consent (reference ID: Pro00096932). Written informed consent was not obtained from any patient or physician due to the minimal level of risk associated with accessing the administrative database. Operational and administrative approvals were provided from

Alberta Health Services (AHS), and a data-sharing agreement was signed. The clinicians practicing during the study periods were unaware of the study at the time of data collection.

Setting

The Royal Alexandra Hospital (RAH) is a tertiary-care, inner-city referral centre in Edmonton, Alberta, Canada that assesses approximately 75,000 adult patients per year, with an admission proportion of approximately 20%.[11] The institution is a teaching hospital for most resident services, including emergency medicine. The ED has 24-hour coverage with full-time emergency physicians, in-house cardiology, and a cardiac catheterization laboratory. No cardiac surgery program is available at the RAH for coronary artery bypass surgeries; however, another hospital with these capabilities is 16 km away.

Pathways

The RAH has experienced several changes in its troponin reporting and accompanying chest-pain protocols; these changes have reflected the ongoing evolution of published recommendations for investigating patients presenting with cardiac chest pain. From January 14, 2017 to January 14, 2018, the RAH used the AccuTnI+3 conventional troponin I assay (Beckman Coulter, Inc, Brea, CA) on a Beckman Coulter DxI 800 analyzer (Beckman Coulter, Inc). The detection limit was set at 0.10 ug/L, and the decision threshold set at 0.15ug/L, with a 6-hour delta serial-measurement interval.[1] From January 15, 2018 to November 8, 2020, RAH kept the same assay but lowered the detection limit and decision threshold to the manufacturer-recommended 99th-percentile upper limit of 0.04 ug/L,
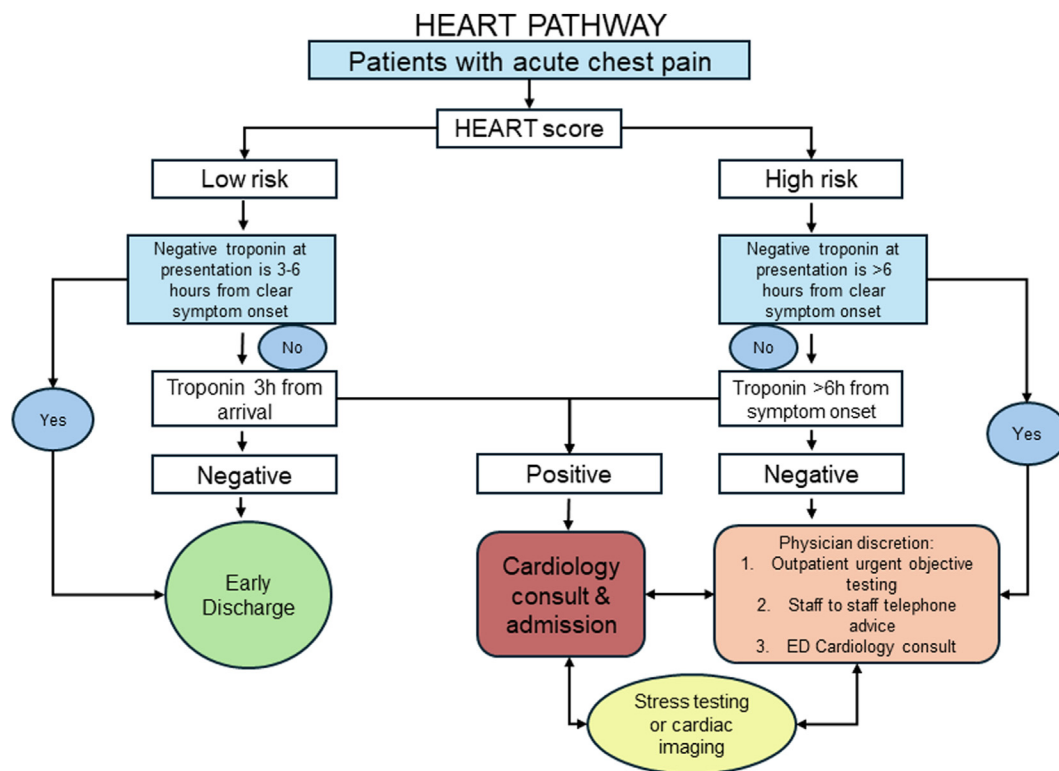
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Figure 1. Pathway illustrating modified HEART (**H**istory, **E**CG, **A**ge, **R**isk factors, **T**roponin) algorithm distributed to emergency department (ED) physicians at the Royal Alexandra Hospital. Modified from Mahler et al.[13]

with a 3-hour delta serial-measurement interval in conjunction with the HEART score. At the same time, a new blood collection tube (BD Barricor tube; Becton Dickinson [BD], Sunnyvale, CA) was introduced to minimize spurious, non-reproducible false elevation in cTnI results, with an assay precision of less than a coefficient of variation of 10% at 0.04 ug/L.[12] The new algorithm was developed by integrating the original HEART pathway[9] and the American Heart Association ACS guidelines.[10] Prior to the introduction of the lower decision threshold, ED physicians at the RAH site were provided with education on the safety of the accelerated chest-pain protocols and encouraged to use 3-hour serial measurements for patients with low-risk pretest probability (HEART score: 0-3). Patients with a HEART score of ≤ 3 have the potential to have ACS ruled out at 3 hours. Patients with a HEART score of > 3 often had a serial 6-hour troponin measurement assessed prior to discharge or cardiology consultation. These protocols are illustrated for reference in Figure 1 (modified from Mahler et al.[13]). HEART scores of 0-3 are considered to indicate individuals are at low risk, 4-6 at intermediate risk, and ≥ 7 at high risk for MACE over the next 5 weeks.

Design

This retrospective cohort study included all adults (aged ≥ 18 years) with a chief complaint of chest pain of cardiac origin. The classification and triaging of presenting complaints are based on the Canadian Emergency Department Information System (CEDIS)[14] chief-complaint list. The Canadian Triage and Acuity Scale (CTAS) is used universally in Canadian EDs and stratifies patients into 5 levels based on acuity, with a

score of 1 being the most acute. Per CTAS guidelines, patients triaged with chest pain of cardiac origin describe visceral chest discomfort, pain radiation to the neck and/or jaw and/or shoulder, and nontraumatic origin; they have cardiac risk factors, and may have associated symptoms (diaphoresis and/or nausea). In this study, patient enrollment was restricted to those with chest pain of cardiac origin and a CTAS score of 2 or 3 between January 14, 2017 and January 15 2019, to explore the data 1 year before and after the implementation of a 3-hour c-TnI level cut-point. Only first index visits were included in cases of patients with multiple ED visits. Any patients with signs of ST-segment elevation myocardial infarction (STEMI) on their initial electrocardiogram were excluded. Patients were required to be registered with Alberta Health Care Insurance Plan (AHCIP) for inclusion.

Implementation strategy

The changes outlined above were disseminated to the hospital clinicians (ED, General and Family Medicine Department, and Cardiology Department) at the RAH through the following methods: updated protocol diagrams e-mailed to the physician group; educational sessions held in person; and lectures to the physician group.

Data sources

We surveyed 8 databases within the population-based linked health administrative data from Alberta Health Services (AHS). All datasets are maintained and updated in the AHS Enterprise Data Warehouse. The data were first accessed for this study on October 7, 2021.

For greater clarity, we used the following systems: the National Ambulatory Care Reporting System (NACRS; which captures all visits to any ED in Alberta with a record of up to 10 diagnostic fields using the International Classification of Diseases, 10th revision, Canadian enhancement [ICD-10-CA] diagnoses per visit); the Emergency Department Information Tracking System (EDIS; which records presenting complaints and requests for consultation for ED visits within Edmonton); the provincial laboratory databases (which capture all general laboratory tests performed across the province); the provincial diagnostic imaging database (which captures all imaging performed across the province within AHS facilities); the Discharge Abstract Database (DAD; which captures all acute-care hospital admissions and includes interventions, discharge destinations, and records of up to 25 diagnoses coded using ICD-10 codes); Vital Statistics (which captures date of death, including out of hospital); the Provincial Registry (which captures Alberta residents with Alberta Health Care Insurance Plan coverage); and the Practitioner Claims database (which captures all physician billing claims and includes up to 3 diagnoses recorded per visit using ICD-9th revision and a Schedule of Medical Benefits [SOMB] billing code). ICD coding has known limitations with respect to misclassification; however, cardiac causes seem to have relatively high accuracy compared to chart review.[15] Additionally, differential misclassification between study periods is unlikely to have occurred.

Outcomes

Descriptive statistics were calculated for both groups. In addition, baseline data are reported on physician initial assessment (PIA) and patients leaving without being seen (LWBS), to compare ED crowding metrics.

The primary outcome of this study was ED LOS. Secondary outcomes focused on several operational outcomes, including consultation proportions and disposition status (ie, admission or discharge). Additionally, we examined the proportion of patients experiencing MACE within 30 days of the index ED visit, to evaluate patient safety. The composite MACE score is defined as all-cause death, hospitalization for heart failure, hospitalization and/or ED visit for myocardial infarction (MI) or stroke, or cardiac interventions (eg, coronary artery bypass graft surgery [CABG], percutaneous coronary intervention [PCI]).

Patients who received c-TnI testing were classified into 1 of 3 subgroups: negative, indeterminate, and high-risk (Fig. 2). To examine whether patient groups were balanced with respect to baseline comorbidity status, we identified comorbidities for each patient using previously validated case definitions based on ICD-10 and ICD-9 codes for all hospitalizations and ED visits in the 2 years prior to the index ED visit (and including the index ED visit) and at least 2 hits in the Practitioner Claims database.[16] We used these data to calculate a modified Charlson Comorbidity Index score.[17] Additional covariates included imaging received while in the ED, and mode of arrival.

Statistical analysis

Descriptive data are reported using proportions, means with standard deviations, or medians with interquartile range,

as appropriate. Baseline characteristics were compared between groups using the Pearson χ^2 test for categorical variables, the Student t test for normally distributed variables, and the Mann-Whitney test for non-normally distributed variables for continuous variables. Multivariable stepwise Cox proportional hazard regression was used to quantify the relationship between periods (pre-ADP period as reference category) and MACE, adjusting for age, sex, and covariates that were statistically significant after using stepwise selection (entry criterion $P < 0.2$; retention criterion $P < 0.05$). Adjusted hazard ratios with 95% confidence intervals (CIs) are reported. Median differences with 95% CIs are reported for continuous variables. Statistical significance for our primary outcome was set at $P < 0.05$. For all other tests, significance was set at $P < 0.001$, due to the performance of multiple tests. All analyses were conducted using SAS, version 9.4 (SAS Institute, Cary, NC).

Results

Demographics

The characteristics of the patient presentations are reported in Table 1. A total of 3133 patient interactions were included in the study period, with 1531 (49%) in the pre-ADP group, and 1602 (51%) in the post-ADP group. The median age was 58 years (interquartile range: 46, 71), and 57.1% of the included patients were male. No statistically significant differences were present in patient demographics, timing, or severity of presentation between the groups. Additionally, patients were balanced with respect to comorbidities, with a median score of 1 on the Charlson Comorbidity Index. The proportion of patients who left without being seen by a physician was temporally stable, 3.6% pre-ADP, and 3.2% post-ADP ($P = 0.53$). Finally, PIA times (60 minutes pre-ADP vs 64 minutes post-ADP; $P = 0.10$) were similar between the time periods.

Investigations

In the post-ADP cohort, more patients received a single troponin measurement (51.8% vs 47.1%; $P = 0.008$), compared to the number in the pre-ADP period (Table 2). No significant differences were present in the proportion of patients classified as negative between the groups (pre-ADP = 47.3% vs post-ADP = 47.5%). Differences were found between the previously described categories of indeterminate vs high-risk. Those stratified as indeterminate decreased from 41.9% to 36.5% ($P = 0.003$), whereas those stratified as high-risk increased significantly from 10.9% to 15.4% ($P < 0.001$). No significant differences were present between the proportion of patients undergoing computed tomography vs pulmonary ventilation and perfusion (VQ) scans to evaluate for pulmonary embolism and other causes of chest pain. No increase occurred in the number of patients receiving specialist consultation in the ED (36.1% before and 33.8% after; $P = 0.17$).

Outcomes

The final patient dispositions were similar between groups (Table 3). Overall, most patients (71.1%) were discharged

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Conventional troponin without accelerated diagnostic protocol

Negative AMI	Indeterminate AMI	High Risk
0 hr Trop < 0.15 µg/L AND Symptoms > 6 hours	0 hr Trop ≤ 0.15 µg/L AND Symptoms < 6 hours AND 6 hr Trop ≤ 0.15 µg/L	Trop > 0.15 µg/L at either measurement
↓	↓	↓
Rule-out	Rule-out / Outpatient testing at physician discretion	Cardiology Consult

Conventional troponin accelerated diagnostic protocol

Negative AMI	Indeterminate AMI	High Risk
0 hr Trop < 0.04 µg/L AND Symptoms > 3 hours AND HEART Score ≤ 3	0 hr Trop < 0.04 µg/L AND Symptoms < 3 hours AND 3 hr Trop < 0.04 µg/L	Trop > 0.04 µg/L at either measurement

HEART score ≤ 3

HEART score > 3 / Ensure trop >6 hr from symptom onset

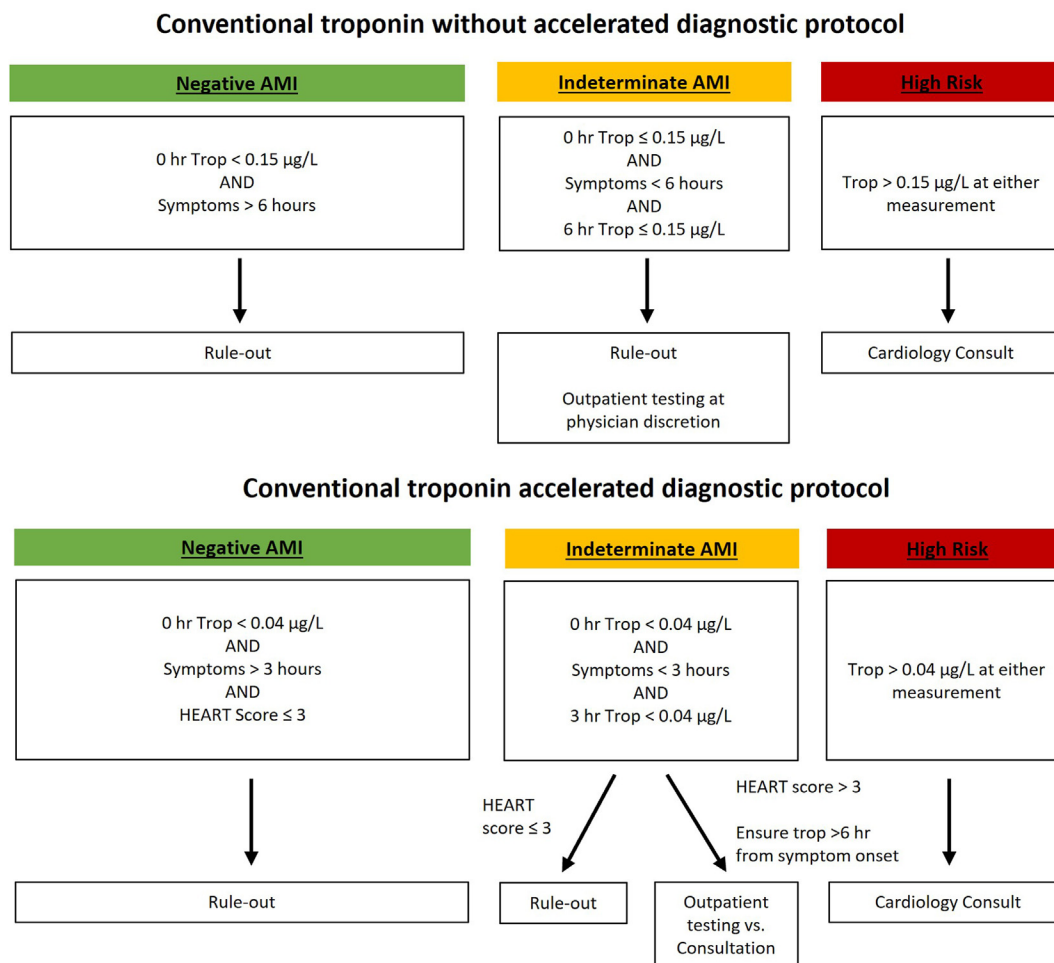| Rule-out | Rule-out | Outpatient testing vs. Consultation | Cardiology Consult |

Figure 2. Illustration of the retrospective classification of patients using chest-pain protocols before and after introduction of an accelerated diagnostic protocol. AMI, acute myocardial infarction; HEART, **H**ealing and **E**arly **A**fterload **R**educing **T**herapy; Trop, troponin.

home. No significant decrease occurred ($P = 0.074$; Table 3) in the median ED LOS in the post-ADP group (median difference = 30 minutes; 95% CI: 11.2, 48.8). Among patients who were discharged, a significant decrease occurred ($P = 0.035$; Table 3) in median LOS in the post-ADP group (median difference = 33.5 minutes; 95% CI: 12.4, 53.6). In the high-risk group, a trend occurred toward a decreased ED LOS, from a median of 470 minutes down to 395 minutes after the ADP was introduced; however, this decrease was not statistically significant ($P = 0.071$).

Safety

The 30-day clinical outcomes mostly were similar between the groups; however, a trend occurred toward decreasing readmissions due to heart failure, from 4.0%, to 2.4% after ADP introduction ($P = 0.01$). Although a small increase occurred in myocardial infarction (10.2% vs 9.3%) between the study periods, this difference was not statistically significant. The majority of these events were detected in the group who were classified as high-risk; this association was more common in the post period (78.7% vs 62.2%). The MACE outcomes did not change following the implementation of an

ADP (15.9% vs 15.3%; $P = 0.62$; Fig. 3). Adopting a posthoc subanalysis using the Mills et al.[18] approach (negative < 0.05 ng/mL; indeterminate: 0.05-0.19 ng/mL; positive ≥ 0.20 ng/mL), MACE outcomes decreased in the post period for negative cases (33.6% to 16.7%) and increased for positives cases (41.4% to 62.9%). Further examination of events occurring exclusively postdischarge again reveals no significant difference in MACE, with 25 patients (1.6%) in the pre-ADP group, and 33 in the post-ADP group (2.1%; $P = 0.37$).

Discussion

This retrospective study was designed to evaluate the impact of introducing an ADP on ED operational efficiency, clinical outcomes, and patient safety. The pathway employed a new c-TnI level cut-point (≤ 0.15 ug/L to ≤ 0.04 ug/L), shortened serial-measurement interval (from 6 to 3 hours), and a clinical decision rule (HEART) to improve efficiency. Although many tertiary-care EDs are transitioning to hs-Tn assays, some Canadian and many international EDs still rely on conventional assays for troponin testing. Patient characteristics were similar

Table 1. Characteristics of patients presenting to the emergency department with chest pain before and after the introduction of an accelerated pathway using a new troponin cutoff level and 3-hour serial troponin testing

Characteristic	Total N = 3133	Pre n = 1531	Post n = 1602
Age, y	58 (46, 71)	59 (47, 72)	58 (46, 70)
Male sex	1788 (57.1)	908 (59.3)	880 (54.9)
Mode of arrival			
No ambulance	1741 (55.6)	848 (55.4)	893 (55.8)
Ambulance	1372 (43.8)	670 (43.8)	702 (43.8)
Other	18 (0.6)	12 (0.8)	6 (0.4)
CTAS score			
2	3084 (98.4)	1508 (98.5)	1576 (98.4)
3	49 (1.6)	23 (1.5)	26 (1.6)
Time of day			
Daytime (8:01 AM–4:00 PM)	1392 (44.4)	664 (43.4)	728 (45.4)
Evening (16:01 PM–12:00 AM)	1162 (37.1)	584 (38.1)	578 (36.1)
Early morning (12:01 AM–8:00 AM)	579 (18.5)	283 (18.5)	296 (18.5)
Preexisting conditions			
Hypertension	1676 (53.5)	817 (53.4)	859 (53.6)
CAD	1317 (42.0)	658 (43.0)	659 (41.1)
Diabetes mellitus	767 (24.5)	390 (25.5)	377 (23.5)
Atrial fibrillation	697 (22.2)	352 (23.0)	345 (21.5)
Stroke	591 (18.9)	301 (19.7)	290 (18.1)
Asthma	379 (12.1)	165 (10.8)	214 (13.4)
Heart failure	404 (12.9)	212 (13.8)	192 (12.0)
COPD	534 (17.0)	270 (17.6)	264 (16.5)
Dementia	151 (4.8)	77 (5.0)	74 (4.6)
Charlson Comorbidity Index score	1 (0, 2)	1 (0, 2)	1 (0, 2)

Values are median (interquartile range) or n (%).

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CTAS, Canadian Triage and Acuity Scale.

Table 2. Testing and outcomes of patients presenting to a high-volume urban Canadian emergency department (ED) with cardiac chest pain before and after the introduction of an accelerated pathway using a new troponin level cutoff and 3-hour serial troponin testing

Variable of interest	Total N = 3133	Pre n = 1531	Post n = 1602	P
Troponin tests				
0	279 (8.9)	149 (9.7)	130 (8.1)	0.112
1	1551 (49.5)	721 (47.1)	830 (51.8)	0.008
2	1241 (39.6)	633 (41.3)	608 (38.0)	0.052
≥ 3	62 (1.9)	28 (1.9)	34 (2.1)	0.555
Troponin results				
Negative	1352/2854 (47.4)	653/1382 (47.3)	699/1472 (47.5)	0.900
Indeterminate	1116/2854 (39.1)	579/1382 (41.9)	537/1472 (36.5)	0.003
High	377/2854 (13.2)	150/1382 (10.9)	227/1472 (15.4)	**< 0.001**
Chest imaging				
Chest X-ray	2402 (76.7)	1176 (76.8)	1226 (76.5)	0.851
Chest CT scan (CTPE)	208 (6.6)	109 (7.1)	99 (6.2)	0.291
V/Q scan	41 (1.3)	16 (1.0)	25 (1.6)	0.204
ED consultation				
Yes	1094 (34.9)	553 (36.1)	541 (33.8)	0.168
Number of ED consultation	1 (1, 1)	1 (1, 1)	1 (1, 1)	0.605
Consult service				
Cardiology	786 (71.8)	390 (70.5)	396 (73.2)	0.326
General medicine	229 (20.9)	128 (23.1)	101 (18.7)	0.069
General practitioner	53 (4.8)	22 (4.0)	31 (5.7)	0.225
Gastroenterology	45 (4.1)	20 (3.6)	25 (4.6)	0.403
General surgery	31 (2.7)	14 (2.5)	17 (3.1)	0.543

Values are n (%) or median (interquartile range). Boldface indicates significance.

CTPE, computed tomography for pulmonary embolism; V/Q scan, pulmonary ventilation and perfusion scan.

between the identical 1-year seasonally matched study periods. Following the implementation of the ADP, a slight increase occurred in the proportion of patients receiving one troponin measurement, with fewer patients receiving 2 troponin measurements in the post-ADP group. This difference could be explained partially by the fact that many patients in the conventional workup group would have their initial troponin drawn before 6 hours after the onset of chest pain had elapsed; these patients would require a second troponin measurement by protocol. Comparatively fewer

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Table 3. Patient outcomes before and after the implementation of an accelerated pathway using a new troponin level cutoff and 3-hour serial troponin testing in an urban, high-volume emergency department (ED)

Outcome	Total N = 3133	Pre n = 1531	Post n = 1602	P	Median differences with 95% CI
Disposition					
Admitted	769 (24.5)	388 (25.3)	381 (23.8)	0.310	N/A
Discharged	2228 (71.1)	1072 (70.0)	1156 (72.2)	0.186	N/A
LWBS	106 (3.4)	55 (3.6)	51 (3.2)	0.527	N/A
LAMA	29 (0.9)	15 (1.0)	14 (0.9)	0.757	N/A
Died	1 (0.0)	1 (0.1)	0 (0.0)	N/A	N/A
ED physician initial assessment time	62 (33, 114)	60 (31, 113)	63 (34, 114)	0.102	−4.0 (−9.0 to 1.0)
ED length of stay					
Overall	383 (260, 523)	401 (261, 528)	371 (257, 513)	0.074	30.0 (11.2 to 48.8)
Negative	306 (228.5, 415)	304 (226, 420)	307 (229, 408)	0.814	−3.0 (−18.7 to 12.7)
Indeterminate	494.5 (414, 596)	502 (428, 604)	490 (406, 585)	0.090	12.0 (−5.1 to 29.1)
High	420 (250, 566)	470 (275, 604)	395 (241, 555)	0.071	74.0 (6.1 to 141.9)
Admitted	392 (234, 566)	399.5 (224.5, 778)	376 (239, 561)	0.784	23.0 (−26.7 to 72.7)
Discharged	396 (284.5, 515.5)	412 (286, 521)	378.5 (282, 509.5)	0.035	33.0 (12.4 to 53.6)
Readmissions within 30 d (all-cause)	900 (28.7)	458 (29.9)	442 (27.6)	0.151	N/A
Readmissions within 30 d (heart failure)	99 (3.2)	61 (4.0)	38 (2.4)	0.010	N/A
Clinical outcomes within 30 d					
Stroke	13 (0.4)	8 (0.5)	5 (0.3)	0.360	N/A
MI	307 (9.8)	143 (9.3)	164 (10.2)	0.399	N/A
Cardiac interventions*	268 (8.6)	128 (8.4)	140 (8.7)	0.705	N/A
Death	55 (1.8)	26 (1.7)	29 (1.8)	0.811	N/A
MACE[†]	489 (15.6)	244 (15.9)	245 (15.3)	0.620	N/A

Values are n (%) or median (interquartile range).

CI, confidence interval; LAMA, leaving against medical advice; LWBS, leaving without being seen; MACE, major adverse cardiac events; MI, myocardial infarction; N/A, not applicable.

*Cardiac interventions include coronary artery bypass graft surgery (CABG) and percutaneous coronary intervention (PCI).

[†] MACE is defined as a composite of all-cause death, hospitalization for heart failure, hospitalization and/or ED visit for stroke or MI, or cardiac interventions.

patients will have troponin drawn sooner than 3 hours after the onset of chest pain, and thus, a negative initial test may be sufficient to rule out ACS. In addition, a more formal chest pain protocol and education may have impacted physician behaviour.

Previous research focused largely on ED LOS for all patients receiving troponin testing.[13,19] In our estimation, this focus may underestimate the impact of decreasing the serial troponin measurement interval. To account for this possibility, we stratified patients into 1 of 3 groups: negative, indeterminate, and high-risk (Fig. 2). The proportion of patients classified as negative was stable between groups, whereas the proportion of those in the indeterminate or high-risk groups changed (Table 2). In some ways, this finding was anticipated, as in patients with chest pain and some degree of cardiac ischemia, troponin values between 0.04 and 0.15 ug/L would result in differential classification, depending on the cohort being studied. An important point to emphasize is that despite this variability, this patient group remains at an increased risk for adverse cardiac outcomes. Conversely, patients presenting with chest pain from a noncardiac source are likely equally and temporally represented, and thus, they will not have a demonstrable troponin level rise, even with the change in detection threshold.

Surprisingly, no significant reduction occurred in median ED LOS after the change to a 3-hour serial troponin measurement and its associated ADP. Patients in the negative group receive only a single troponin measurement, and as such, their ED LOS would be unaffected by changes in repeat measurement intervals, as borne out by our results, as the LOS was unchanged between the pre and post groups (Table 3). All

patients in the indeterminate group received serial troponin measurement. Despite a 3-hour decrease in serial troponin-measurement intervals, these patients remained in the ED for similar median durations before vs after the introduction of an ADP. The high-risk group did see a trend toward decreased ED LOS, but it was not statistically significant, likely due to extremely high variability in LOS.

Evidently, the overall ED LOS has more nuance than that captured within the serial troponin-measurement interval. Dispositional challenges may play a role in this lack of demonstrated effect; patients may require ongoing pain management, advanced imaging, arrangements for outpatient testing, or other time-consuming interventions. Additionally, lack of protocol adherence could be a contributor to the modest reductions.

The only subgroup that experienced a significant decrease in median LOS were patients who were discharged, with a 33-minute decrease (95% CI: 12.4, 53.6; P = 0.035). Discharged patients theoretically could come from any of the low, indeterminate, or high-risk groups. This process is outlined in the Figure 2. An ADP appears to help streamline the discharge process in at least 2 ways—by decreasing serial-measurement timing and by diminishing the cognitive burden of how to interpret results. Proactive physicians can be ready to execute a disposition plan as soon as the repeat troponin measurement is reported.

Despite the increased proportion of patients in the high-risk group, the proportion of cardiology consults remained stable between groups. Based on the data, about 35% of all patients have a consultation as part of their visit; this group likely would be composed largely of a mix of the high-risk
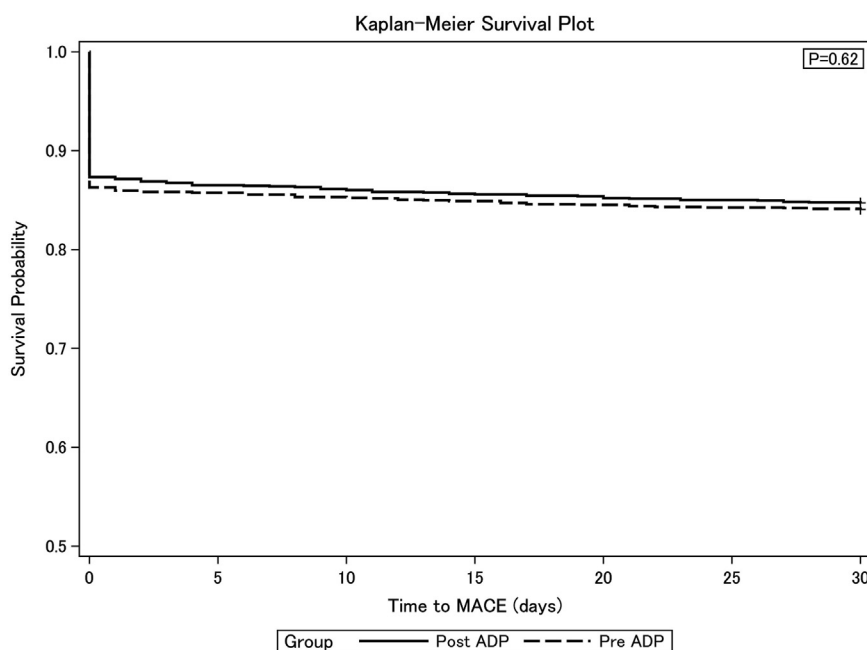
Figure 3. Kaplan-Meier survival curves for major adverse cardiac events (MACE) in patients presenting to a high-volume urban Canadian emergency department with cardiac chest pain before and after the introduction of an accelerated pathway using a new troponin level cutoff and 3-hour serial troponin testing. ADP, accelerated diagnostic protocol.

and the intermediate-risk groups. In the post-ADP group, the increase in the high-risk group was mirrored almost exactly by a decrease in the intermediate-risk group. A reasonable inference is that clinician gestalt can identify higher-risk cardiac patients (based on history or risk factors) and consult cardiology despite potentially reassuring troponin values. If the proportion of patients presenting with concerning histories remains stable between groups, then the fact that the consults stay stable as well makes sense. The post-ADP group eliminates the need to apply gestalt for patients who would have had a troponin value between 0.04 ug/L and 0.15 ug/L.

Readmissions for heart failure had a relative decrease of nearly 50%. This decrease is encouraging and suggests that the benefits of an ADP may extend beyond operational efficiency. Other safety outcomes, such as MACE and all-cause readmissions within 30 days, were unchanged after the ADP. This finding is consistent with the growing body of literature on this topic, including ADPs involving cTn and hs-Tn assays.[18,20,21]

Limitations

Our research has some limitations, given the retrospective design of the study; however, these system-wide changes needed to be comprehensive and hospital-based, meaning that randomization at the individual patient level was not feasible. In our defense, applying valid quality metrics, this study rates strongly for a before-vs-after study.[22] Due to ED crowding, wait times could have changed between the 2 periods of data collection, and this may be confounding our results; however, comparing the PIA and LWBS proportions between groups is a valid surrogate. Typically, in periods of increased ED wait times, a corresponding increase occurs in the number of patients who are in the LWBS group. Reassuringly, these

standard ED crowding metrics (PIA and LWBS) were unchanged in the pre- vs post-study periods.

Physician adherence to protocol is another area for consideration. Some physicians do not use serial troponin measurements, as recommended in all situations, and this is difficult to control for. Moreover, in a retrospective study, adherence measurement is complicated by missing information. Our data are drawn exclusively from a single Canadian ED, where healthcare is administered without consideration for payment, which may limit its external validity to regions without public healthcare systems. Enrollment was limited to patients triaged with symptoms of chest pain that was deemed to be of cardiac origin; patients presenting with atypical chest pain may have been excluded. We assumed that the turnaround time (sample collection to result reporting) remained stable in both groups; however, we did not have data to confirm or refute this. Finally, the databases do not record detailed behavioural factors (eg, smoking, vaping, and cannabis use; alcohol intake; exercise; diet; etc.), management factors (eg, medication, adherence, etc.), and/or sociodemographic factors (eg, race, employment, income, etc.) that may impact acute and longer-term health outcomes.

Notwithstanding the above concerns, we believe the large sample size, the pragmatic design, and the comprehensive reporting of outcomes provides a valid assessment of the efficiency and safety of the implementation of this 3-hour approach using an ADP and a c-TnI test. Moreover, the results compare favourably with those of a recently completed systematic review (J. Hill et al, Unpublished data, 2024).

Conclusion

The implementation of an ADP for chest pain in a tertiary-care Canadian ED was not associated with a significant

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reduction of overall ED LOS for all patients; however, a significant reduction occurred among discharged patients. In the current era of ED overcrowding, even modest reductions in ED LOS for frequent conditions are important contributors to improved ED throughput. This strategy also has wider applicability to sites that may not yet have access to hs-Tn assays. Conventional troponin assays are becoming increasingly rare; however, for hospitals that still use conventional assays, this study provides evidence for safely switching to shorter serial Tn testing. Review of admissions, MACE outcomes and deaths, which remained the same following the protocol implementation, demonstrated the safety of this approach.

Ethics Statement

The research reported has adhered to the relevant ethical guidelines. The study protocol and materials were approved by the University of Alberta Human Research Ethics Board, with a waiver of individual informed consent (reference ID: Pro00096932). Written informed consent was not obtained from any patient or physician due to the minimal level of risk associated with accessing the administrative database. Operational and administrative approvals were provided from Alberta Health Services (AHS), and a data-sharing agreement was signed.

Patient Consent

The authors confirm that patient consent is not applicable to this article. This is a retrospective case report using de-identified data; therefore, the IRB did not require consent from the patient.

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Disclosures

The authors have no conflicts of interest to disclose.

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