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ORIGINAL RESEARCH

Cardiology

Is rapid acute coronary syndrome evaluation with high-sensitivity cardiac troponin less costly? An economic evaluation

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Abstract

Objective: Protocols to evaluate for myocardial infarction (MI) using high-sensitivity cardiac troponin (hs-cTn) have the potential to drive costs upward due to the added sensitivity. We performed an economic evaluation of an accelerated protocol (AP) to evaluate for MI using hs-cTn to identify changes in costs of treatment and length of stay compared with conventional testing.

For the RACE-IT Research Group (Shane Bole, Jacob Tuttle, Nicole Xu, Sophie Wittenberg, Thayer Morton, Ziad Affas, Kutiba Tabbaa, Parth Desai, Ahmed Oudeif, Ayman Alsaadi, Elian Abou Asala, Shazil Mahmood, Andrew Schock, Nicholas Konowitz, Joshua Fuchs, Kate Joyce, Lance Shamoun, Mustafa Mohammed, Ahmed Kazem, Kelly Malette, Gulmohar Singh-Kucukarslan, Jacob Babel, Andrew Broome, Geoffrey Digiacinto, Gale Darnell, Gregory Muller, Gerard Heath, Gust Bills, Jason Vieder, Steven Rockoff, Brian Kim, Anthony Colucci, Elizabeth Plemmons)

Methods: We performed a planned secondary economic analysis of a large, cluster randomized trial across nine emergency departments (EDs) from July 2020 to April 2021. Patients were included if they were 18 years or older with clinical suspicion for MI. In the AP, patients could be discharged without further testing at 0 h if they had a hs-cTnI < 4 ng/L and at 1 h if the initial value were 4 ng/L and the 1-h value ≤7 ng/L. Patients in the standard of care (SC) protocol used conventional cTn testing at 0 and 3 h. The primary outcome was the total cost of treatment, and the secondary outcome was ED length of stay.
Results: Among 32,450 included patients, an AP had no significant differences in cost (+$89, CI: −$714, $893 hospital cost, +$362, CI: −$414, $1138 health system cost) or ED length of stay (+46, CI: −28, 120 min) compared with the SC protocol. In lower acuity, free-standing EDs, patients under the AP experienced shorter length of stay (−37 min, CI: −62, 12 min) and reduced health system cost (−$112, CI: −$250, $25).
Conclusion: Overall, the implementation of AP using hs-cTn does not result in higher costs.

1 | INTRODUCTION

1.1 | Background

The evaluation of patients in the emergency department (ED) with chest pain or symptoms suggestive of myocardial infarction (MI) is common and often resource intensive.[1–3] Published guidelines in Europe and the United States recommend the use of high-sensitivity cardiac troponin (hs-cTn) assays for rapid diagnosis of MI, and their optimal use has been a topic of intense investigation.[4,5] Accelerated protocols (APs) using hs-cTn at ED presentation and 1 h have shown low death and MI rates at 30 days.[6] Current guidelines recommend the use of APs to discharge low-risk MI patients from the ED without further cardiac testing.[5]

1.2 | Importance

While studies continue to explore the clinical optimization of APs, the economic impact of these protocols is uncertain within the United States. A health system could experience higher costs implementing a hs-cTn AP due to recategorization of patients previously deemed to have negative troponin testing to have positive hs-cTn results (abnormal but below the 99th percentile). Westwood et al.[7] summarized recent studies conducted in United Kingdom, Canada, and Denmark. They found that hs-cTn testing may be cost effective when compared with standard troponin testing. In the context of the Australian healthcare system, APs using hs-cTn had fewer adverse clinical events but higher incremental cost effectiveness ratio values compared with conventional cTn protocols.[7] Analysis of a recent international trial testing use of a 1-h algorithm showed reduction in ED length of stay, resource utilization, and overall diagnostic costs,[8] but results vary significantly based on adherence to such protocols.

1.3 | Goals of this investigation

In this study, we sought to address the economic uncertainty surrounding adoption of hs-cTn testing within a health system. Between July 2020 and March 2021, we implemented a hs-cTn AP protocol within a large United States healthcare system using a stepped-wedge, pragmatic approach. As a planned secondary analysis of this implementation trial, we sought to quantify economic outcomes of an AP using hs-cTn compared with prior conventional use of cTn.

2 | METHODS

2.1 | Study design and setting

RACE-IT (Rapid Acute Coronary Syndrome Exclusion using high-sensitivity cardiac I Troponin) was a stepped-wedge, randomized controlled trial enrolling consecutive patients evaluated for possible MI in nine EDs within Henry Ford Health (Detroit, Michigan) between July 2020 and April 2021. Of the nine EDs, five were associated with hospitals and four were free-standing. Details of the clinical study methodology have been previously published.[9] Within the trial, the ED was the unit of randomization. The study's intent is to evaluate the cost to health system, hospital, and patient during the initial visit. The study also evaluates the length of stay during the initial visit. Subgroup analyses were conducted by payer type, ED type, disposition, and specific site. We followed the Consolidated Health Economic Evaluation Reporting Standards 2022 for this analysis.[10]

2.2 | Selection of participants

Patients were eligible for the study if they were ≥18 years of age and there was clinical suspicion for MI as evidenced by the clinician ordering cTn and an electrocardiogram. For the AP, all EDs used the hs-cTnI Access assay by Beckman Coulter (Brea, CA). The standard of care (SC) arm also used the same assay but results below the 99th percentile (18 ng/L) were not reported. Clinicians saw the result reported as "<18 ng/L" or numeric values in ng/L above 18 ng/L. While the high-sensitivity results were available for 4 months prior to the stepped implementation of the AP, operational leadership chose to withhold such results until the agreed upon AP was designed and educational materials disseminated in a stepwise approach within this pragmatic trial. Sex-specific cutoff values were not used in the study. Exclusion criteria included ST-segment elevation MI, trauma as cause of symptoms, transfer from another facility, primary residence outside of the state of Michigan, or enrollment in hospice. We also excluded patients in the SC and AP arms if any cTn during the first 3 h was at or exceeded the 99th percentile (18 ng/L), as these patients would not have benefited from hs-cTn testing. Patients were enrolled in the study only once upon their first ED visit during the study period. The study was approved by the institutional review board and granted a waiver of consent. The study was funded by Beckman Coulter.

2.3 | Intervention

The SC prior to implementation of an AP required cTn testing at 0 and 3 h to exclude MI and application of a HEART score to determine ED discharge or observation placement. Patients that had cTn values <18 ng/L at 0 and 3 h and had a HEART score <4 were eligible for ED discharge.

In the AP, patients could have MI excluded within 1 h if they met one of two criteria: hs-cTnI < 4 ng/L at time 0 or hs-cTnI = 4 ng/L at time 0 with hs-cTnI ≤ 7 ng/L at 1 h. All patients had a 1-h hs-cTnI test unless their time 0 hs-cTnI was <4 ng/L. Patients that had MI excluded at presentation or within 1 h were eligible for early discharge from the ED without further cardiac testing or application of a HEART score. If patients did not rule-out within 1 h, they had further testing with a 3-h hs-cTnI and application of a HEART score < 4 to be eligible for ED discharge. As little data were available specific to this hs-cTnI at the time of development of this AP, we developed it through consultation with a group of experts in the field and took a conservative approach in using the 4 ng/L threshold and the small delta at 1 h for early rule-out.

2.4 | Outcomes

The primary economic outcome of this analysis was the total cost of treatment of the initial visit. The objective of the economic evaluation was to determine whether the AP yielded total cost savings, either to the patient, insurer, or hospital system. Data collection included

The Bottom Line

The advent of high sensitivity troponin use in the emergency department (ED) for evaluation of chest pain could lead to increased costs due to their enhanced sensitivity. Fortunately, secondary analysis of randomized controlled trial (RCT) data (32,450 patients) showed no increase in cost. Additionally, the use of such troponins actually led to shorter length of stay in a subset of EDs that were free-standing.

visit-level billing and reimbursement records for each individual for inpatient, observation, and ED-based care.

The total cost of treatment, the primary outcome, was approximated by three measures: total cost as estimated by the hospital, total payments received by the hospital from insurance and patient, and total payment received from patient. Costs included those associated with hospitalization for those requiring such during their primary encounter. Additional outcomes included length of patient ED stay, defined by minutes in the ED. For those admitted into the hospital, their ED length of stay ended once a patient was transferred to a room outside of the ED. For those admitted to the hospital, we also recorded overall hospital length of stay in days beginning from ED presentation to discharge from the hospital.

2.5 | Analysis

Analyses compared average adjusted differences between patients managed under the AP and SC. We first used bivariate analyses without adjustments to compare the two cohorts. For the primary outcome, we used ordinary least squares to adjust average differences in outcomes of interest and included age, sex, and race/ethnicity as covariates. Since payments differed by insurance type, the analyses also included adjustments for payer by type (Medicare, Medicaid, commercial, or other). To account for time-invariant socioeconomic determinants of health, we included indicators for zip code of patient's residence (first three digits). The stepped-wedge study design means that the identifying variation in our analysis stems from a comparison between patients seen in facilities that have implemented AP and those seen in facilities that are in baseline SC data collection period. We design the analysis with an eye for relying on this cross-facility variation. At the same time, however, the study period occurred during the COVID-19 pandemic, posing an additional challenge to access to care and treatment, necessitating careful accounting of time in months. Therefore, our preferred analysis includes time and location fixed effects: our analysis includes hospital fixed effects allowing for removal facility-level characteristics such as practice culture, patient composition, and provider mix that are time-invariant during the study weeks; our analysis also includes month fixed effects that allow us to remove time-sensitive

TABLE 1 Patient characteristics and unadjusted comparison of economic data.

	All	Accelerated protocol	Standard care		
	N = 32,450	N = 18,988	N = 13,462	Difference	p Value
Race/ethnicity, no. (%)					<0.001
White	19,416 (59.5%)	9157 (67.8%)	10,259 (53.7%)	14.1%	
Black	9392 (28.8%)	3047 (22.6%)	6345 (33.2%)	10.84%	
Other	3801 (11.7%)	1301 (9.6%)	2500 (13.1%)	0.29%	
Female, no. (%)	57.40%	57.12%	57.79%	−0.67%	0.223
Age, mean (years)	58.0	57.5	58.7	−1.2	<0.001
Unadjusted cost, mean (USD)					
Total	$3118	$3435	$2671	$764	<0.001
Hospital revenue	$3158	$3461	$2723	$731	<0.001
Patient payment	$254	$261	$244	$17	0.0265
Length of stay, mean					
Minutes	430	453	397	56	<0.001
Days	0.95	1.05	0.82	0.22	<0.001

Notes: Other race/ethnicity inclusive of Hispanic, Middle Eastern, Asian, American Indian or Alaska Native, and patients that declined or had missing data.
Abbreviation: USD, United States dollar.

compositional changes in clinical practice and patient composition that affects all facilities in the similar fashion. Thus, the combination of these two fixed effects allows us to compare patients across facilities within the same month, adjusting for the facility-specific average treatment characteristics. We do not include facility interacted by month fixed effects, which would absorb the identifying variation. Standard errors were clustered at the site level.

We also replicated the above analyses divided into several subgroups. First, we analyzed based on insurance payer type. Second, we stratified analysis based on whether the location was a hospital-based or free-standing ED.

We did not base the trial sample size on economic outcomes. We report results with standard errors and 95% confidence intervals. We performed all analyses with Stata 16 (StatCorp, College Station, TX). All tests were two sided with a *p* value < 0.1 representing statistical significance.

3 | RESULTS

3.1 | Characteristics of study subjects

There were 47,831 patients screened, of whom 12,098 were excluded for hs-cTnI values >18 ng/L. Other reasons for exclusion were transfers (1409), traumatic chest pain (655), hospice (466), STEMI (224), and residence out of state (371). An additional 158 patients were not included in this analysis due to missing economic data. We analyzed 18,988 patients in the AP group and 13,462 in the SC group. Overall, 9148 (28.0%) inpatient admissions and 4308 (13.2%) observation placements occurred in the study population.

The mean age of patients in the trial was 58.0 years and 57.4% were female. Table 1 summarizes patient demographic and visit characteristics. Black patients comprised 22.6% of patients in the AP group, compared with 33.2% of SC arm participants. Within the AP, there were 9015 (47.5%) patients with initial hs-cTnI <4 ng/L, 1430 (7.5%) patients with a value of 4 ng/L, and 8546 (45.0%) patients with values between 5 and 18 ng/L. In unadjusted analysis, cost and length of stay were higher in the AP group. The average treatment cost for the index encounter in the AP cohort was $3117 or $763 higher on average than in the SC cohort. In unadjusted analysis, patient payments were also higher for the AP cohort by $17 on average. Participants in the AP experienced on average 56 min or 0.22 days longer stay than SC.

3.2 | Adjusted analyses

For the primary outcome, there was no significant difference in adjusted economic outcomes between the AP and SC cohorts. Table 2 shows the adjusted differences between these cohorts for total cost, hospital revenue, and patient payment. The AP group had a larger total average cost (+$89) and hospital revenue (+$362), while average patient payments were slightly lower (−$7). None of these differences met statistical significance, including differences in length of stay. These differences are sensitive to adjustments as seen in Table S1. The full adjustment values are presented in Table S2.

3.3 | Subgroup analyses

We report analyses stratified by payer, hospital, and discharge characteristics in Table 3. We found no significant difference in cost by

TABLE 2 Adjusted differences in total cost, hospital revenue, patient payment, and length of stay.

	Total cost	Hospital revenue	Patient payment	Length of stay	
	USD	USD	USD	Minutes	Days
Mean difference (95% CI)	$89 (−$714, $893)	$362 (−$414, $1138)	−$7 (−$42, $28)	46 (−28, 120)	0.14 (−0.09, 0.36)

Notes: Covariates in adjusted model include age, sex, race, ethnicity, patient zip code (restricted to first three digits), month of year, emergency department location, and insurance payer.
Abbreviation: USD, United States dollar.

TABLE 3 Adjusted differences in total cost, hospital revenue, patient payment, and length of stay between patients managed under accelerated protocol versus standard care. Differences stratified by defined subgroups. Negative values represent cost savings estimates with accelerated protocol.

Subgroup	Total cost USD (95% CI)	Hospital revenue USD (95% CI)	Patient payment USD (95% CI)	Length of stay Minutes (95% CI)	Days (95% CI)
Payer					
Medicare	$197 (−$1091, $1485)	$382 (−$1003, $1767)	$9 (−$64, $82)	64 (−18, 145)	0.25 (−0.21, 0.71)
Medicaid	$560 (−$437, $1557)	$629 ($−97, $1357)	$35 (−$8, $77)	28 (−31, 88)	0.29 (−0.13, 0.70)
Commercial	−$322 (−$1402, $758)	$165 (−$977, $1307)	−$60 (−$97, −$24)	47 (−46, 137)	−0.07 (−0.37, 0.22)
ED type					
Hospital based	$71 (−$970, $1111)	$441 (-$697, $1579)	−$6 (−$57, $46)	70 (−17, 157)	0.16 (−0.18, 0.49)
Free-standing	−$13 (−$380, $354)	−$112 (−$250, $25)	−$11 (−$41, $19)	−37 (−62, −12)	0.02 (−0.03, 0.07)
ED disposition					
Discharge	−$4 (−$136, $128)	−$47 (−$122, $28)	−$2 (−$13, $9)	6 (−25, 38)	−0.01 (−0.06, 0.05)
Observation	−$394 (−$1702, $913)	−$139 (−$895, $616)	$2 (−$64, $67)	81 (14, 147)	0.01 (−0.40, 0.41)
Admission	−$623 (−$2460, $1183)	−$81 (−$1768, $1605)	−$99 (−$207, $8)	63 (−96, 224)	−0.15 (−0.69, 0.38)

Notes: Covariates in adjusted model include age, sex, race, ethnicity, patient zip code (restricted to first three digits), month of year, emergency department location, and insurance payer.
Abbreviations: ED, emergency department; USD, United States dollar.

payer. Patients with Medicaid coverage generated $629 additional revenue for the hospital and incur $35 additional patient out-of-pocket cost on average under the AP, but these findings did not reach statistical significance. There was a statistically significant reduction in out-of-pocket cost for patients with commercial insurance in the AP compared with SC. There were no significant differences among AP and SC by patient discharge characteristics. We find no significant differential in cost, payment, or length of stay between observation and admission. Although patients in observation and admission stay longer in the AP arm, only the observation sample has statistically significant estimates.

Different ED locations were associated with some variance in cost and length of stay. Patients seen and managed under the AP in a hospital-based ED stayed 70 min longer than SC patients in a similar setting; however, this was not a statistically significant difference. Among patients seen in free-standing EDs, those in the AP cohort stayed 37 fewer minutes and generated $112 less hospital revenue, although both of these differences were not statistically significant. The absence of statistical difference fits the analysis presented in Table S3, which shows that patient acuity was well-balanced across AP and SC arms in both hospital-based and standalone EDs.

We explore cite-specific differences in greater detail in Figures 1 and 2 where we display the adjusted difference in costs and encounter length of stay metrics. Sites included suburban free-standing EDs, and urban or suburban hospital-based EDs. The figures show no statistically significant differences between study arms in any of the cites for costs and payments, and significantly lower length of stay in minutes at most sites in the AP arm. Although there is some variation between hospital-based and standalone EDs, these differences are consistent with overall results.

4 | LIMITATIONS

Due to the real-world nature of the study, there was a heterogeneous population of presenting complaints and diagnoses included in the study. Unlike many prior trials using APs that included randomization at the patient level and selected patients primarily with chest pain, patients were included in the RACE-IT trial in a pragmatic manner if a clinician had any suspicion for MI. The use of the AP in relationship to the timing of symptoms onset was at the discretion of the treating physician, and it is possible that initial hs-cTnI testing may have been insensitive when symptoms began just before arrival. This
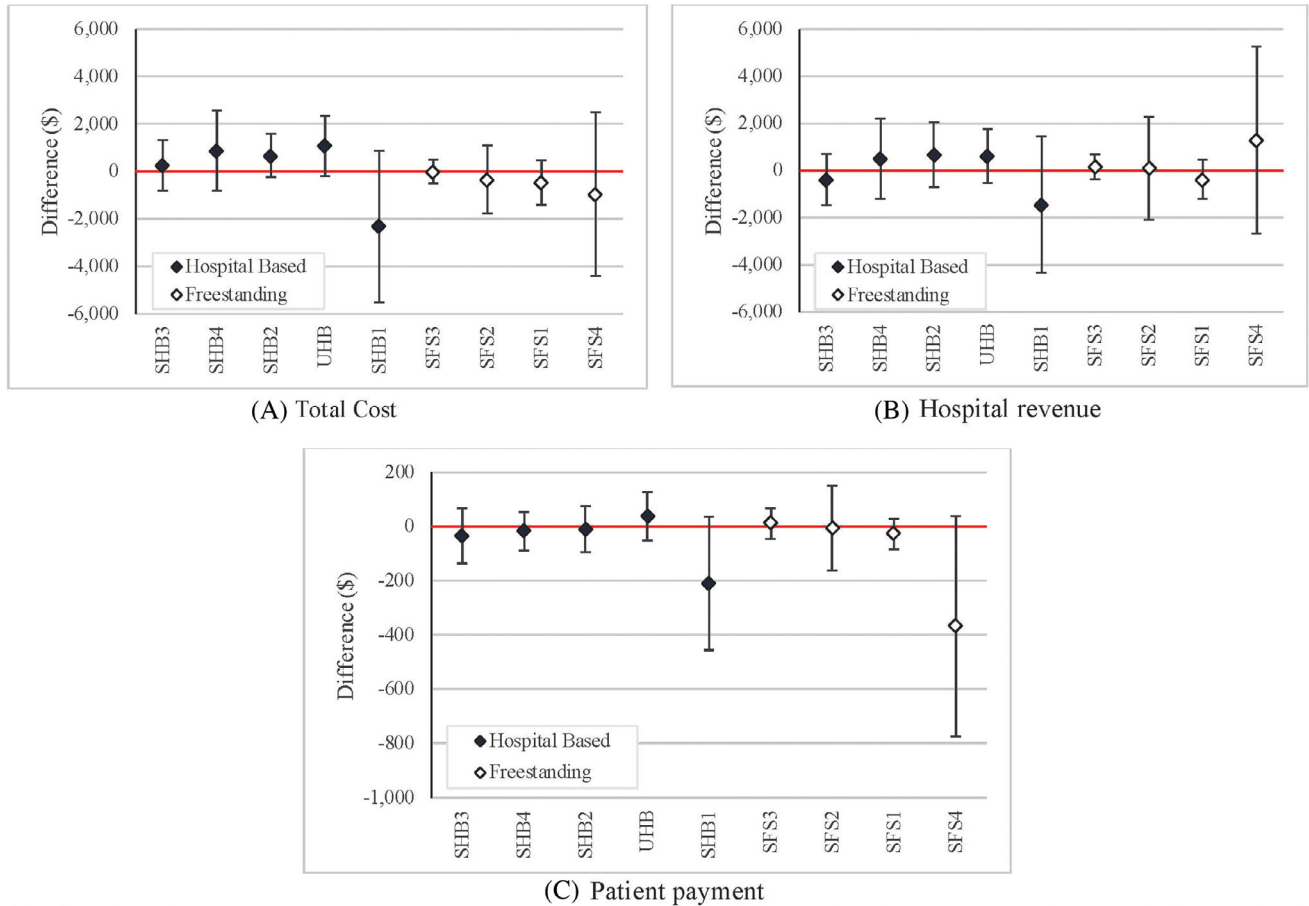
FIGURE 1 Adjusted differences in (A) total cost, (B) hospital revenue, and (C) patient payment by site in United States dollars. Negative values reflect a reduced length of stay in the accelerated protocol compared with the standard care cohort. In each panel, each point represents estimates for outcome in a sample restricted to one department. Each estimate adjusts for demographic characteristics and payer, month, and patient zip code fixed effects. The brackets around the point estimate represent the 95% confidence interval. SFS, suburban free-standing; SHB, suburban hospital based; UHB, urban hospital based.
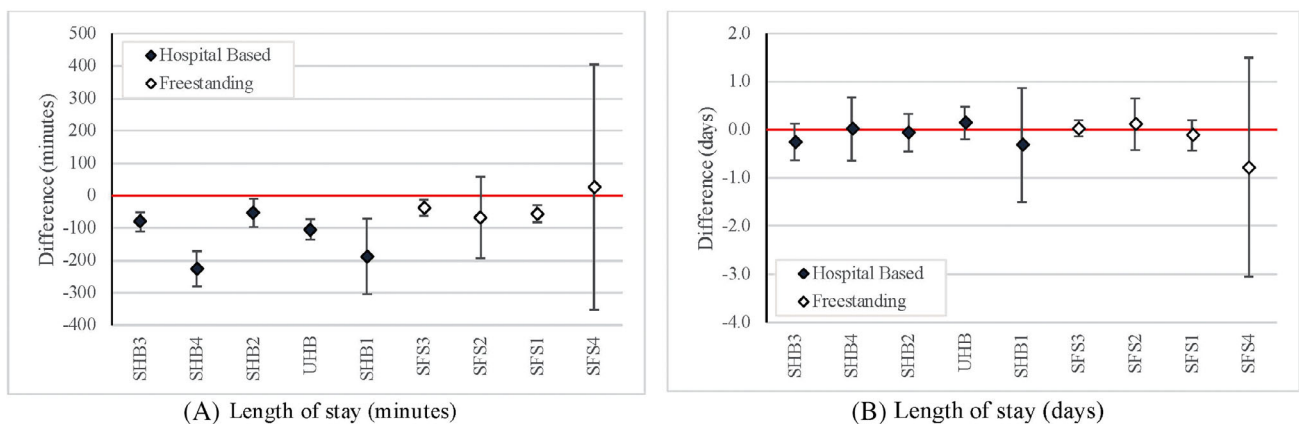
FIGURE 2 Adjusted differences in length of stay by site. Length of hospital stays in minutes, including same day discharges and stays longer than 24 h in panel (A); length of hospital stays in days, where same day discharges are categorized as 0 days, in panel (B). Negative values reflect a reduced length of stay in the accelerated protocol compared with the standard care cohort. In each panel, each point represents estimates for each emergency department in the trial. Each estimate adjusts for demographic characteristics and payer, month, and patient zip code. The brackets around the point estimate represent the 95% confidence interval. SFS, suburban free-standing; SHB, suburban hospital based; UHB, urban hospital based.

analysis also focused on patients with cTn levels below the 99th percentile (18 ng/L), and the costs for patients with higher cTn values were not assessed.

As the timing of the trial was during the COVID-19 pandemic, numerous patients within the trial had MI evaluated as part of symptoms related to COVID-19. It is also possible that unmeasured factors related to the pandemic may limit the generalizability of study results under usual ED operating conditions. We also suspect that temporal trends related to the pandemic had an unmeasured, negative impact on ED length of stay and economics factors. Finally, although we capture costs accrued to the hospital system, patient, and payer, we cannot evaluate time-costs saved from shorter length of stay accruing to patient and benefits from faster turnaround of facilities to the hospital system. Therefore, our estimates constitute a lower bound on potential total cost savings of care with an AP.

Finally, the analysis conducted here focuses on costs and revenues accrued by the hospital system from implementing an AP, as well as the patient length of stay. This study does not evaluate the general impact or clinical efficacy of AP relative to SC; such analysis has been conducted elsewhere.

5 | DISCUSSION

The RACE-IT trial was a real-world implementation study of an AP rule-out protocol with hs-cTnI in the United States. The EDs in which the implementation occurred comprised a broad mix of community and academic medical centers, including multiple free-standing EDs. The primary economic finding was that there were no statistically significant differences in the overall costs associated with implementation of the AP using the hs-cTnI. There was no significant difference in total costs, hospital revenues, or patient costs.

These findings differ from previous literature assessing the impact of hs-cTn protocols outside of the United States healthcare system.[7] While not seen overall, there were differences in length of stay for the subgroup of patients seen at free-standing EDs. Reductions in length of stay were also realized in a recent pragmatic trial in the United Kingdom.[8] This United Kingdom trial did not measure economic factors.

What is the economic meaning of these findings? Although we anticipated that the AP might provide financial savings to the patient and the payer, we found that this was not the case across the board. These findings are still noteworthy. Implementation of a test with higher sensitivity could lead to increased cardiac testing and overall costs within a United States healthcare system. This concern is particularly noteworthy for patients with indeterminate hs-cTn levels between the limit of detection and the 99th percentile (4–18 ng/L). Prior to implementation of hs-cTn protocols, such patients had "negative" cTn testing and may not have undergone additional testing. With reporting of these indeterminate hs-cTn values, there is the potential for additional costs. Our results provide reassurance that implementation of an AP using hs-cTnI can be largely cost neutral.

Each of these three measures of costs we analyzed is imperfect in their own way, but each provides a perspective that is important for our evaluation. Total costs, the closest measurement of resource use intensity, is an estimate developed upon imprecise measurements of the fraction of professional, facility, and equipment use. As such, it may differ substantially between hospitals within the same system. Total payments received from the patient and insurance do not capture uncompensated care. Furthermore, total payments differ by payer, hospital, state, and region for the same procedure, and, therefore, may not reflect underlying resource utilization intensity or costs.[11] The patient payment captures the share of cost they bear, which offers an important insight into the financial burden of care imposed on patients; however, it is an incomplete picture of resource utilization.

While our study provides overall evidence of a cost-neutral effect in a pragmatic trial, future work could benefit from evaluating subgroups and physician behaviors associated with observation placement and cardiac testing. Much of the costs associated with the evaluation of suspected acute MI occur in the observation unit and factoring proper use of this resource into future analyses would be beneficial.

In conclusion, in this large pragmatic trial assessing the impact of a rapid acute MI rule-out protocol using hs-cTnI across an integrated health system, there was no significant difference in economic costs or ED length of stay.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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