



Emergency Department Clinician Perceptions of Implementing High-Sensitivity Troponin T Assay in an Academic Hospital Emergency Department

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ABSTRACT

PURPOSE: A newly approved, high-sensitivity troponin T (hsTnT) assay may offer opportunities to more rapidly assess for acute coronary syndrome and identify lower thresholds of myocardial injury. As more emergency departments begin to use the hsTnT assay, anticipating barriers to hsTnT implementation success are critical to realizing potential benefits in rapid, accurate patient assessment.

METHODS: At a tertiary health system emergency department, hsTnT was implemented along with a diagnostic algorithm and a decision tree to aid in utilization. Qualitative interviews with 18 physicians and advance practice providers were conducted 2 months' postimplementation and again 4 to 6 months postimplementation to capture clinician perceptions to hsTnT implementation efforts. Deductive coding was performed using implementation science determinants frameworks to identify emerging themes related to this topic.

RESULTS: Four themes emerged from the interviews: 1) the need for additional clinician education, 2) challenges with care handoffs, 3) lack of buy-in from the hospital community, and 4) key successes.

CONCLUSION: Interviews demonstrated that implementation of hsTnT was associated with several implementation barriers from the perspective of emergency department clinicians. Future implementation efforts should focus on diverse and sustained staff educational efforts, models that address challenges with care handoffs between emergency department clinicians and inpatient clinicians, and operational teams that include inpatient clinicians to facilitate buy-in.

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INTRODUCTION

Background

More than 6 million Americans annually present to the emergency department (ED) with a complaint of chest pain, representing a myriad of conditions from benign musculoskeletal

pain conditions to serious acute coronary syndromes (ACSs).¹ Given the high degree of morbidity and mortality associated with ACS, ED clinicians are challenged to efficiently and safely identify the patients who need rapid and intensive cardiac care.² However, current diagnostic methods (eg, electrocardiogram, serial troponins) to differentiate ACS from other causes are not sufficiently sensitive or rapid.³ Further, chest pain and ACS are the leading causes of ED malpractice claims.⁴ The challenge of accurately identifying patients with ACS, while also balancing the need to safely and rapidly reassure and discharge those without serious conditions, continues to be a problem in many health care systems. Therefore, strategies aimed at appropriately ruling in and ruling out ACS in the ED are of critical importance.⁵

A newly approved, high-sensitivity troponin T (hsTnT) assay may offer opportunities to more rapidly assess for ACS and identify lower thresholds of myocardial injury.⁶ Despite the significant benefits of the hsTnT assay shown in European studies and approval of the assay by the US Food and Drug Administration (FDA) in January 2017, the implementation and adaptation of the assay into the US healthcare systems has been slow and complicated.^{7,8} As with prior changes in laboratory-based evaluation of acute chest pain, implementation barriers may severely limit any realized benefits in more accurate and rapid patient assessment.⁹ Examples may include differing

familiarity or access to the new hsTnT by clinicians in different settings (eg, ED vs hospitalist), inadequate clinical assessment prior to ordering the hsTnT test, and the impact of nonconclusive results from a new test. By learning from early-adopter hospital experience with hsTnT implementation, future centers can anticipate potential barriers and improve their likelihood for realizing the significant benefits of hsTnT testing, including improvements in patient care, reduced clinician-level variation, and shortened ED length of stay.

The primary goal of this study is to understand how clinicians respond to a laboratory test change and what health system actions will promote positive change while limiting unintended consequences. To do this, we conducted semi-structured interviews with key ED clinicians shortly after changing from a troponin I to hsTnT assay.

CLINICAL SIGNIFICANCE

- The high-sensitivity troponin T (hsTnT) assay allows for more rapid assessment of acute coronary syndrome.
- When implementing the hsTnT assay, health systems should address 1) the need for additional clinician education, 2) challenges with care handoffs, and 3) lack of buy-in from the overall hospital community.
- Implementation strategies aimed at addressing key barriers may facilitate successful adoption of the hsTnT assay.

METHODS

hsTnT Diagnostic Algorithm Concept and Development

A Midwestern, tertiary academic medical center with more than 100,000 annual ED visits, implemented the new hsTnT assay and a corresponding chest pain diagnostic algorithm in February 2018. A multidisciplinary team, including

High Sensitivity Troponin T Interpretation

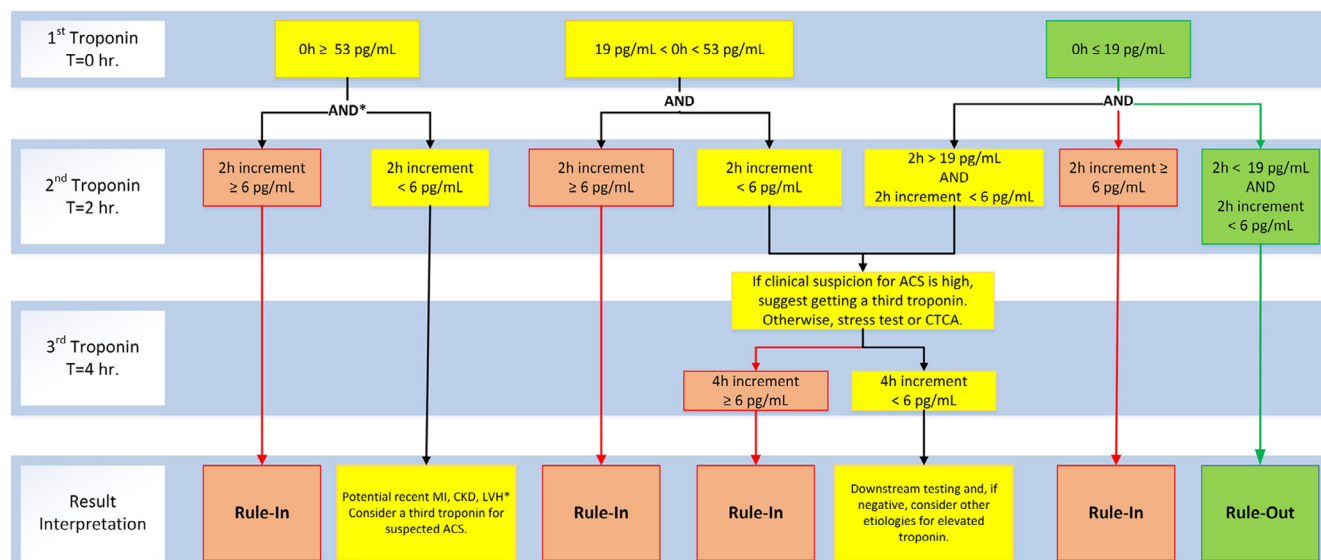


Figure High-sensitivity troponin T interpretation guide. ACS = acute coronary syndrome; CKD = chronic kidney disease; CTCA = computed tomography coronary angiogram; LVH = left ventricular hypertrophy; MI = myocardial infarction.

representatives from the ED, internal medicine, cardiology, and pathology, used a review of the published literature and drew on experience of peer institutions already implementing the hsTnT assay to develop the algorithm for when and how to use the assay together with other diagnostic approaches for patients presenting to the ED with chest pain (Figure and Supplemental Appendix I, available online).^{10,11}

hsTnT Assay and Diagnostic Algorithm Implementation

hsTnT was implemented first in the ED to minimize disruption with other clinical activities in the inpatient and procedural units of the health system. In the ED, the preexisting troponin I assay was no longer available for use. However, all other hospital-based departments continued to use the preexisting troponin I assay without access to the hsTnT assay.

To facilitate implementation, the leadership team led educational efforts across all departments that interfaced with patients with chest pain from the ED, including Internal Medicine faculty and house officers. This included a centrally developed “tip sheet” about the hsTnT algorithm. ED leaders reviewed the hsTnT test characteristics and diagnostic algorithm at faculty meetings and house officer conferences, along with numerous e-mail communications. They also distributed e-mail notifications about the hsTnT test and diagnostic algorithm. Finally, ED operational leaders were available for assistance by page during the implementation.

Design and Subject Recruitment

To evaluate barriers and facilitators that ED clinicians faced in the implementation of the new assay and algorithm, the implementation team partnered with the institution’s Program on Value Enhancement, an embedded research unit.¹² The evaluation focused primarily on the views of ED clinicians (faculty, house officers, and advanced practice practitioners). ED clinicians were recruited using both purposive and convenience sampling strategies.¹³ Three team members (RD, ED, and NA) conducted interviews with clinicians who interacted regularly with the hsTnT assay and diagnostic algorithm at 2 separate time points. Early interviews were conducted 2 months postimplementation (April 2018), followed by later interviews 4-6 months postimplementation (June-August 2018). To examine changes or persistence in perspective within the same clinician, some clinicians were interviewed at both time points. Overall, a convenience sample of 18 interviews were conducted (9 early and 9 late). The 18 interviews consisted of 14 unique participants, including ED physician assistants, house officer physicians, and attending physicians (Table 1).

Interview Setting

The interviews were held at participant-identified locations within the medical center or by telephone. Interviews lasted an average of 25 minutes. A semi-structured interview guide was developed to assess barriers and facilitators to

Table 1 Clinician Types and Participation Dates

Participant Type	Early Postimplementation	Late Postimplementation
Physician	X	X
Assistant		
Physician	X	X
Assistant		
Physician	-	X
Assistant		
House Officer	-	X
House Officer	-	X
House Officer	X	-
House Officer	X	-
Attending	-	X
Attending	-	X
Attending	X	X
Attending	X	X
Attending	X	-
Attending	X	-
Attending	X	-

Total: 14 interview participants, 18 total interviews

X represents interview completion; - represents no interview completion. Early is approximately 2 months postimplementation and late is approximately 4-6 months postimplementation.

the implementation of the hsTnT assay and diagnostic algorithm (See Supplemental Appendix II, available online) based on relevant constructs from 2 implementation science determinants frameworks: the Tailored Implementation for Chronic Diseases (TICD) checklist and the Technology Acceptance Model.^{14,15} These frameworks were chosen to assess clinician perspectives surrounding the broader implementation and interpretation of the hsTnT assay and diagnostic algorithm. Interviews were audio recorded and transcribed verbatim. Verbal consent was obtained by all participants prior to interview participation. Interviews were conducted until no new themes emerged and data saturation was achieved.¹⁶ The project team registered the project with the institution’s review board as a nonregulated, quality improvement study (HUM00145002).

Analysis

Using a group coding process to analyze the transcripts, 3 team members (RD, ED, GB) employed a predominantly deductive framework analysis using the TICD and Technology Acceptance Model to develop an initial codebook.^{17,18} Additional inductive codes were added as necessary for important concepts not captured by the TICD or Technology Acceptance Model (see Supplemental Appendix III, available online). Two coders (RD, ED) then coded interviews separately in batches of 5, reviewing and discussing transcripts and editing the codebook until no new codes were identified. Any additions to the codebook resulted in recoding of all previously coded transcripts. Transcripts were coded using MAXQDA 12 software (VERBI Software GmbH, Berlin, Germany). After iterative coding was completed, inter-rater

Table 2 Themes and Illustrative Quotes

Theme	Quote
Need for Additional Clinician Education	<p>“When you have to acknowledge that . . . many residents are rotating at a [different] site for multiple months, that roll-out on a single day really happens over multiple months as people start to flow back in and adapt to this new process. . . .” House Officer 01, Late Postimplementation</p> <p>“I think the protocol spells out what is indeterminant. I think what’s hard is how you act on that information. Like as a clinician, what does that mean? It requires you to then sort of put the patient into the clinical context more. Was it the right patient to send the troponin on to begin with? Now that I have this information and there’s the indeterminant aspect of it, what do I do about that?” Attending 03 Early Postimplementation</p>
Challenges with Care Handoffs	<p>“[T]hey (the nurses) will come ask the attending on busy days, ‘hey can we order a troponin?’ So, sometimes troponins are ordered before you even talk to the patient and you are like, ‘gosh, I would never have ordered that and it is totally going to affect what I do.’” Physician Assistant 02, Early Postimplementation</p> <p>“There are some barriers when trying to admit patients. If you want to admit someone for a chest pain rule-in then you get, ‘can you order the troponin I? I do not know what to do with these new ones.’” Physician Assistant 02, Late Postimplementation</p> <p>“I have started getting [troponin Is] now on the patients I know [inpatient is] going to ask for it on. Technically, we are not supposed to be sending those anymore now that we have switched, but . . .” Attending 07, Early Postimplementation</p>
Lack of Buy-In from the Hospital Community	<p>“There are a lot of people who you do [hsTnT] on and by the letter of the law they have ruled in. However, you do not believe it, so you do a troponin I and the troponin I is negative and it further invalidates the use of the [hsTnT].” Attending 06, Early Postimplementation</p>
Key Successes	<p>“I think the order set, where it orders the 0- and 2-hour together is really helpful, otherwise the 2 hour one never gets ordered.” Physician Assistant 02, Late Postimplementation</p>

agreement of 80% or higher was found for all transcripts. Finally, team members (RD, ED, GB) reviewed coded transcripts to develop themes to answer the main research questions. Research team members assessed for thematic change between the 2 interview time points (2 months and 4-6 months postimplementation) by comparing responses from the same interviewee across time points.

RESULTS

Four primary themes emerged regarding the hsTnT assay and diagnostic algorithm implementation. These were 1) the need for additional clinician education, 2) challenges with care handoffs, 3) lack of buy-in from the hospital community, and 4) key successes (Table 2).

Theme 1: Need for Additional Clinician Education

As noted, educational efforts were conducted for specific departments (eg, ED, internal medicine) and clinicians to help tailor to the specific capacity in which different clinicians interact with the hsTnT assay and diagnostic algorithm. Yet, interviewed clinicians noted that variations in work schedules and learning styles sometimes made it difficult for information to be effectively assimilated.

Clinicians suggested many ways in which it may be helpful to approach pathway education, such as broaching the topic at multiple conferences, conducting case reviews, and sending e-mails with clarifications. Clinicians stressed that education needs to be continuous, allowing them the opportunity to stay up to date and address concerns as they arise.

Additionally, clinicians emphasized that 1 of the biggest areas of confusion was test interpretation. Although clinicians

felt that they could reasonably determine when results were indeterminant, they stressed wanting more clarification surrounding how to approach acting on these values in practice.

Theme 2: Challenges With Care Handoffs

In the process of patient care in the ED, there are many handoffs that occur: nurse triage to ED clinician, clinician-clinician handoff between ED work shifts, clinician-clinician handoff for inpatient admission, ED consultation with cardiology, etc. With each, care delivery in 1 setting impacts clinicians in the next setting. For example, nurses in triage often obtain troponin tests in an effort to expedite patient evaluation and flow.¹⁹ This could occur based on limited clinical information and before a physician or physician assistant has taken a thorough history. Given the greater sensitivity of the hsTnT assay compared to the traditional troponin assay, a positive or indeterminant result occurs more often.²⁰ This increased sensitivity presented a challenge for clinicians in our study because the ambiguous results of the tests then had to be addressed.

Another critical patient handoff occurs with admission to the inpatient service. ED clinicians, who have been instructed to only use the new hsTnT test, must hand off patients with suspected ACS to the internal medicine clinicians, who only have access to the troponin I test. Access to different troponin tests in the different settings presented as an important barrier for the ED clinicians, especially when inpatient clinicians are not as familiar with the hsTnT test result.

Further, as part of the diagnostic algorithm guidelines, ED clinicians were strongly encouraged to no longer order the troponin I assay. Yet, ED clinicians stated feeling conflicted; either they needed to follow the pathway

recommendations and take additional steps to have their patient admitted, or they could ignore the guideline and ultimately order the troponin I assay.

Theme 3: Lack of Buy-In From the Hospital Community

Perspectives surrounding the validity of a recommendation and individual expectations of the diagnostic algorithm's outcomes impact the likelihood of adherence. Despite the validity of the hsTnT assay demonstrated in the literature, the assay's increased sensitivity frequently results in discrepant results between hsTnT and troponin I tests, leading clinicians to question the validity of the hsTnT assay.

Theme 4: Key Successes

In addition to some of the barriers identified in this study, there were also notable successes. The ordering of the prior troponin I test saw variation in clinician ordering, including when sequential troponin labs were drawn. One concern of implementation leadership was around both successful ordering and accurate drawing of this assay. To aid in assay ordering, implementation leadership included prespecified orders with specific draw times in the electronic medical record order set. Although not explicitly probed during the interviews, many clinicians expressed that this functionality greatly aided in the success of this ordering change.

DISCUSSION

The introduction of a hsTnT assay and diagnostic algorithm was intended to improve the management of patients presenting to the ED with chest pain. Indeed, our ongoing quantitative evaluation showed that this intervention streamlined management of patients presenting with chest pain and a decreased overall ED length of stay.²¹ However, as is expected when any new test or clinical pathway is implemented, we identified specific implementation barriers from the perspective of ED clinicians. These include the need for additional clinician education, challenges with care handoffs, and lack of buy-in from the hospital community. Specific facilitators to the success of this implementation were also identified. The decision to create a combined order set for the initial and follow-up hsTnT assay increased convenience of assay ordering and improved the accuracy of the hsTnT in terms of the time sequence.

On a broader level, any learning health system aims to examine the care it provides and identify areas for improvement, yet, this study highlights how implementation is a lengthy and iterative process that involves active and multifaceted implementation strategies.²² Unfortunately, published descriptions of implementation strategies are often both conceptually unclear and do not include sufficient guidance for successful replication.²³ To translate our finding into actionable next steps for both our and other health care organizations, we decided to consult the Expert Recommendation for

Implementing Change project. The Expert Recommendation for Implementing Change project is an evidence-based list of implementation interventions aimed at bridging care gaps.²⁴ We have identified specific implementation strategies that were used throughout our hsTnT and diagnostic algorithm implementation along with additional strategies that may help further address the broader interpretation of the barriers identified in this study (Table 3).

Robust educational efforts are always necessary when any new process is being implemented. Clinicians in our study highlighted the importance of considering both the when and how of these efforts, in addition to the content that needs to be included. More specifically, pathway education should be dynamic and ongoing (ie, occurring in a variety of methods over a sustained amount of time). This approach to pathway education allows more clinicians to be reached and for learning to occur in multiple formats, helping to promote clinician confidence and expand clinician skill set. Future education and implementation efforts should focus on the management of patients with an "indeterminant" hsTnT result to aid ED clinicians with this complex clinical situation. Effective educational interventions include making training dynamic, conducting ongoing training, reminding clinicians, conducting educational meetings and outreach visits, and developing and distributing educational materials. In direct response to this barrier, our clinician educational materials were revised and focused more on clinical scenarios, common questions, and management recommendations for patients with indeterminate hsTnT test results.

Challenges that arose in relation to pathway handoffs highlight the reciprocal nature of health care: The actions of 1 clinician influence the practice styles and decisions of other clinicians. The interpretation of the hsTnT was problematic, whether due to lack of trust in the assay, unfamiliarity with the assay, or lack of clarity around applying the assay in everyday practice. Additionally, ordering the assay in triage without a thorough assessment of the clinical scenario (and therefore without complete assessment of pretest probability) exacerbated this barrier. A key lesson learned is that introducing a new pathway or algorithm into preexisting clinical workflow can lead to unforeseen consequences. Experts in the implementation of hsTnT have highlighted, due to this relationship, the importance of strategic clinician education around indiscriminate hsTnT ordering and modifications to clinical workflow.²⁵

Additionally, in hindsight, it is possible that the selective rollout of the hsTnT only to the ED contributed to the difficulties with inpatient care handoffs. It is not known if implementing the hsTnT test to the entire health system concurrently would have avoided some of the inpatient handoff barriers or presented new challenges. To address overall issues with clinician handoffs, the additional implementation approaches could include modeling and stimulating change prior to implementation and using stakeholder input so that barriers related to patient transfers may be noticed and addressed earlier.

Table 3 Summary of Overall Themes and Barrier Descriptions With Potential Implementation Strategies

Theme	Barrier Description	Potential Implementation Strategy and Description
Need for Additional Clinician Education	One-time, single-format educational efforts are not enough to adequately prepare clinicians for changes in practice because of inconsistent clinician attendance at meetings, rotating clinician schedules, and changes in protocol that occur over time.	<ol style="list-style-type: none"> 1. Make training dynamic <ul style="list-style-type: none"> - Vary the information delivery methods to cater to different learning styles and work contexts, and shape the training in the innovation to be interactive. 2. Conduct ongoing training <ul style="list-style-type: none"> - Plan for and conduct training in the clinical innovation in an ongoing way. 3. Remind clinicians <ul style="list-style-type: none"> - Develop reminder systems designed to help clinicians to recall information or prompt them to use the clinical innovation. 4. Develop and distribute educational materials <ul style="list-style-type: none"> - Develop and format manuals, tool kits, and other supporting materials in ways that make it easier for stakeholders to learn about the innovation and for clinicians to learn how to deliver the clinical innovation. - Distribute education materials in person, by mail, or electronically. 5. Conduct educational meetings and outreach visits <ul style="list-style-type: none"> - Hold meetings targeted toward different stakeholder groups to teach them about clinical innovation - Have a trained person meet with the clinicians in their practice setting to educate clinicians about the clinical innovation with the intent of changing the clinician's practice.
Challenges With Care Handoffs	Seamless transition of patients between clinician types or departments may be hindered by variable practice styles and availability of necessary resources.	<ol style="list-style-type: none"> 1. Model and simulate change <ul style="list-style-type: none"> - Model or stimulate change that will be implemented prior to implementation. 2. Use advisory board and work groups <ul style="list-style-type: none"> - Create and engage a formal group of multiple kinds of stakeholders to provide input and advice on implementation efforts and to elicit recommendations for improvements. 3. Promote adaptability <ul style="list-style-type: none"> - Identify the ways a clinical innovation can be tailored to meet local needs and clarify which elements of the innovation must be maintained to preserve fidelity.
Lack of Buy-In From the Hospital Community	The extent to which the clinicians agree with the recommendations, expect the recommendation to lead to a certain outcome, or "trust" the results of the tests impact their willingness to adhere to the pathway.	<ol style="list-style-type: none"> 1. Build a coalition <ul style="list-style-type: none"> - Recruit and cultivate relationships with partners in the implementation effort. 2. Identify and prepare champions in each role <ul style="list-style-type: none"> - Identify and prepare individuals who dedicate themselves to supporting, marketing, and driving through an implementation and overcoming indifference or resistance that the intervention may provoke in an organization. 3. Inform local opinion leaders <ul style="list-style-type: none"> - Inform clinicians identified by colleagues as opinion leaders or "educationally influential" about the clinical innovation in the hopes that they will influence colleagues to adopt it. 4. Audit and provide feedback <ul style="list-style-type: none"> - Collect and summarize clinical performance data over a specified time period and give it to clinicians and administrators to monitor, evaluate, and modify clinician behavior.

Our study highlights that education efforts alone are not enough for successful implementation. Research demonstrates that guideline adoption also requires changes in the attitudes and behaviors of health professionals.²⁶ Even though the hsTnT assay is well validated in the literature and reference studies were provided, negative expectations held by the

clinicians and questions of hsTnT assay validity negatively influenced pathway adherence. Literature has shown that physician attitudes toward the use of research in clinical practice can be strongly shaped by organizational culture (ie, the shared assumptions, beliefs, values, and norms among the organization members).²⁷ To address issues of buy-in from the hospital

community at large, we engaged leaders from all relevant disciplines in the implementation team and conducted educational efforts with all clinicians who care for patients. This is in line with established implementation strategies around building a coalition, identifying champions, and informing local opinion leaders. Moving forward, however, another implementation strategy to employ includes providing audit and feedback. More specifically, audit and feedback tools, particularly in relation to pathway outcomes such as reductions in ED length-of-stay, improved patient outcomes, or decreased clinician burden, may help to motivate algorithm adherence and appropriate hsTnT ordering by highlighting the direct added value of the implementation.

Important limitations must be acknowledged. This study was conducted in a singular Midwest academic medical center. Therefore, this analysis may not be applicable to all types of health systems in all locations. Additionally, interviews were conducted only with clinicians from the ED. Perspectives from nursing staff, clinicians outside the ED, the implementation team, and patients were not included in this analysis. Nonetheless, this study has a number of strengths, including the in-depth interviews with a variety of ED clinicians at 2 different time points following implementation. It also used validated implementation science determinants frameworks to guide the interviews and qualitative analyses.

CONCLUSIONS

In conclusion, this study identified key barriers experienced by ED clinicians to implementing a hsTnT assay and diagnostic algorithm in the ED. These include 1) need for additional education, 2) challenges with care handoffs, and 3) lack of buy-in from the hospital community. Health systems looking to implement a hsTnT assay and similar diagnostic algorithm may benefit from assessing these potential barriers and employing specific strategies prior to, during, and after implementation.

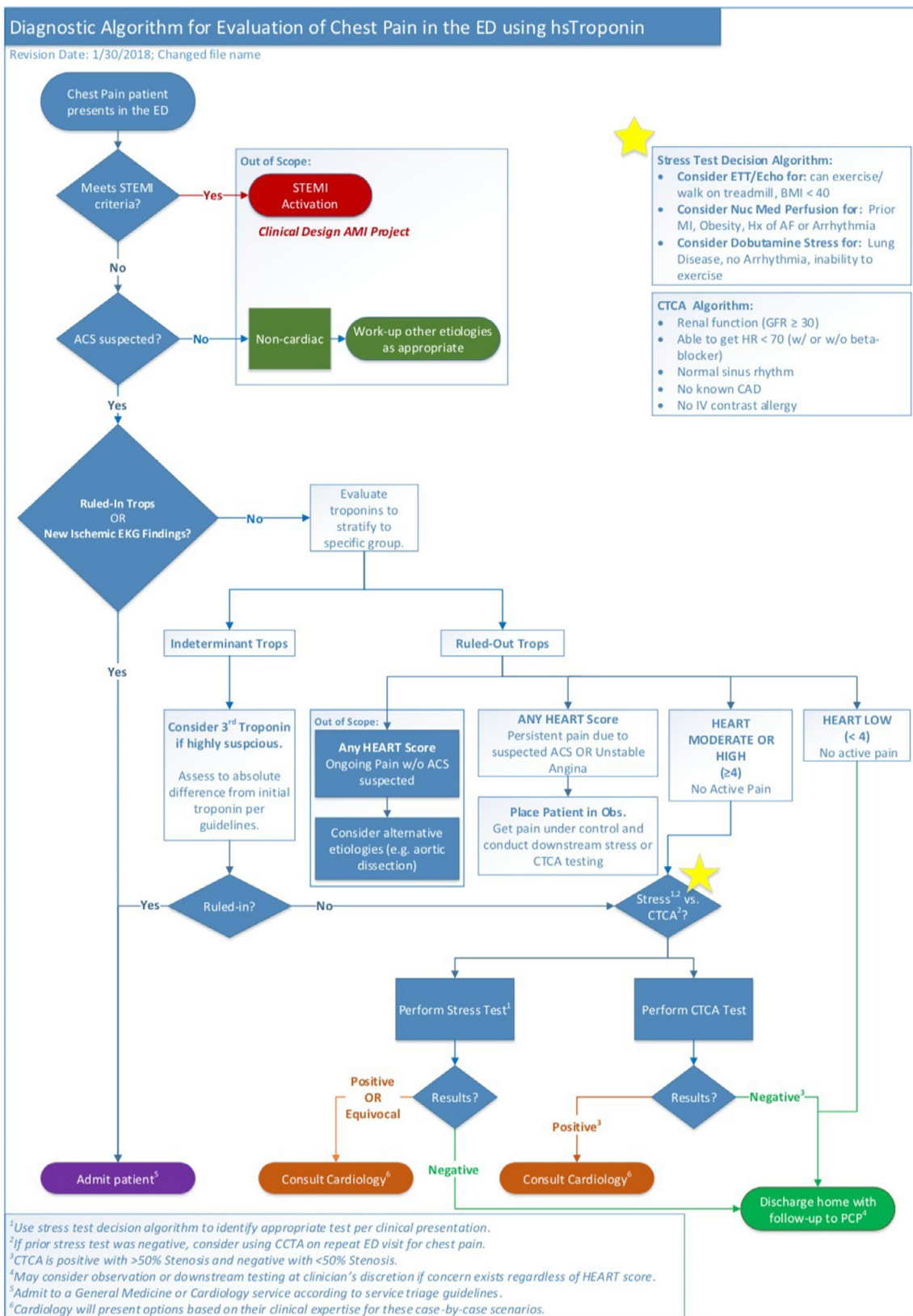
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Supplemental Appendix I – hsTnT Assay Diagnostic Algorithm



ACS = acute coronary syndrome; AF = atrial fibrillation; CAD = computer-aided design; CTCA = computed tomography coronary angiogram; ED = emergency department; EKG/ECG = electrocardiogram; ETT = exercise tolerance testing; GFR = glomerular filtration rate; Hx = history; HR = heart rate; IV = intravenous; MI = myocardial infarction; PCP = primary care physician; STEMI = ST-elevation myocardial infarction.

Supplemental Appendix II – Interview Guide

Introduction: Hi, my name is _____. I am working with [redacted], part of the hospital’s Quality Department, to conduct quality improvement within [redacted]. One project we are currently working on is the Chest Pain Pathway. I am hoping to speak with you about your experience with both the Chest Pain Pathway, [hsTnT], and some of the technology-based solutions that have been developed to aid in its usage. Our hope is to use the interviews to improve certain aspects of the pathway, as well as to inform future roll-out processes.

Before we get started, I wanted to ask if it would be okay for me to record this interview for note-taking purposes? Recording the responses allows me to be more engaged

during the interview, and you would not be identified in any way.

Also, I want to let you know that we are interested in your comfort in this interview and I want to be respectful of your time, so please feel free to skip any questions or end the interview at any time. The previous interviews having been taking about 30 minutes on average.

The hsTnT diagnostic algorithm (decisional tree) was originally referenced to as the “Chest Pain Pathway” by implementation leadership. This language was not used as part of the official language in the emergency department, however, which is why it is referred to throughout this paper as the hsTnT diagnostic algorithm. The language in our interview guide highlights that of implementation leadership.

For the first part of this interview, I am going to be asking you questions about the Chest Pain Pathway overall, meaning the algorithm and steps you were asked to follow with patients who enter the ED with chest pain.

What has been your experience with patients presenting with chest pain in the ED?
 How does the Chest Pain pathway...
 fit with your routine?
 impact productivity?
 What is your opinion about the clarity of the pathway?
 In what settings/contexts are you less clear of what is being asked of you?
 How do you access guidelines related to the pathway?
 What factors impact your ability to follow the pathway?
 Day of the week, Time of day, Availability of Tests

How has the path looked different before and after the new pathway?
 What has your experience been with trying to get patients admitted?
 What has been your experience with consulting cardiology?
 What are some of the challenges that still remain even 6 months later?
 How might things look or change in another 6 months? What might be a little slow to change?
 What suggestions would you give to the hospital to consider or do differently when rolling out future processes?
 What sort of education did you receive prior to the roll-out and what education is still necessary? Whose responsibility is it to provide? In what format?

For this part of this interview, I am going to be asking you questions about [hsTnT].

Tell me about your experience with [hsTnT].
 When would you or other clinicians order [hsTnT] if a patient does not have chest pain or suspected ACS?

Tell me about your experience with indeterminants.
 What do you say to patients when they have indeterminant values?

For the final part of this interview, I am going to be asking you questions that focus on the [EMR] tool that was developed to assist in following the Chest Pain Pathway.

Tell me about your experience using [the EMR] with the Chest Pain Pathway.
 How often do you and other clinicians use the Chest Pain Pathway tool in [the EMR] for patients presenting with chest pain?
 How useful are the [EMR]-based solutions in helping you to follow the pathway?
 How does using the tools and resources developed in [the EMR] help or hinder your ability to follow the pathway?
 What parts of the system are difficult to navigate?
 What factors impact your likelihood of using the tools developed in [the EMR] to follow the pathway?
 Day of the week, Time of the day, Availability
 People you are working with

If you don’t use the pathway routinely, what would need to happen for you to do so? (Looking for facilitators, not lack of barriers)
 How could the pathway be designed to increase usage?

*Final thoughts or comments? Anything we haven’t touched upon? Please feel free to email me if anything else comes up.
 EMR = electronic medical record.*

Supplemental Appendix III - Codebook

Code	Original Definition	Working Definition	TICD Domain	TICD Construct
Referral Processes	Process for transferring patients and communication between different levels of care, between health and social services, and between the targeted health care professionals and targeted patients.	Process for transferring patients and communication between different departments or levels of care (including consults), in addition to communication between ED clinicians and targeted patients (including perspective of other clinician's ordering patterns).	Professional Interactions	N/A
Communication and Influence	The extent to which the targeted health care professionals' adherence is influenced by professional opinions and communication.	The extent to which the ED clinicians' adherence to hsTnT guideline (posted algorithm) recommendations is influenced by colleagues or other influential people (within their department, ie, not consults).	Professional Interactions	N/A
Self-Efficacy	The targeted health care professionals' self-perceived competence or confidence in their abilities.	The ED clinicians' self-perceived competence or confidence (or lack thereof) in their abilities in terms of adhering to the hsTnT guidelines; commenting when competence/confidence is needed to perform the recommendation.	Individual Health Professional Factors	Cognitions
Information System	The extent to which the information system facilitates or hinders adherence.	How does the information system (EMR, posting/location of algorithm, etc.) facilitate or hinder adherence to the hsTnT guideline (posted algorithm) recommendations?	Incentives and Resources	N/A
Clarity	The clearness of the target population, the settings in which the recommendation is to be used and the recommended action.	The clearness (or lack thereof) of the hsTnT guideline (posted algorithm) recommendations (when to order, what to do with results, what results mean, etc.).	Guideline Factors	Recommendation
Expected Outcome	The extent to which the targeted health care professionals believe that adherence with the recommendation will lead to desired outcomes.	Extent to which clinicians believe behavior will lead to expected outcome; comments surrounding expectations of what will happen (ie, if ₂ then).	Individual Health Professional Factors	Cognitions
System-Level Variability	N/A	Variability in overarching system factors, such as patient volume (unpredictable) and day of the week variability (predictable).	N/A	N/A
Clinician-Level Variability	N/A	Variability in specific clinician practice patterns and behavior within the ED.	N/A	N/A
Compatibility	The extent to which the recommended behavior fits with current practices.	The state in which the hsTnT guideline (posted algorithm) recommended behavior and clinician practice are able to exist/occur together without problems or conflict.	Guideline Factors	Recommended Behavior

(Continued)				
Code	Original Definition	Working Definition	TICD Domain	TICD Construct
Availability of Necessary Resources	The extent to which the resources that are needed to adhere are available.	The extent to which resources (financial, people, facilities, equipment, and supplies) needed to adhere to the hsTnT guideline (posted algorithm) recommendations are available.	Incentives and Resources	N/A
Knowledge About Own Practice	The extent to which the targeted health care professionals are aware of their own practice in relationship to the recommended practice.	The extent to which the ED clinicians are aware of their own hsTnT (or Troponin I) practice in relationship to the recommended hsTnT guidelines → knowledge about <i>own compliance</i> .	Individual Health Professional Factors	Knowledge and Skills
Patient Complexity	N/A	Comments surrounding complexity of patients (including variability in the types of patients) and how that effects pathway adherence.	N/A	N/A
Domain Knowledge	The extent to which the targeted health care professionals have preexisting knowledge or expertise about the targeted health condition.	The extent to which the ED clinicians have preexisting knowledge about myocardial infarction or other relevant health conditions related to the hsTnT guideline (posted algorithm) recommendations; in addition to preexisting knowledge surrounding hsTnT, HEART scores, etc.).	Individual Health Professional Factors	Knowledge and Skills
Change Over Time (General)	N/A	Comments about general changes the clinicians have noticed over time about the pathway and test implementation.	N/A	N/A
Change Over Time: Resolved	N/A	Problems that resolve over time (self-resolve over time or addressed and resolved).	N/A	N/A
Change Over Time: Continued Problems	N/A	Continued problems (ignored, still persisting despite being addressed).	N/A	N/A
Awareness and Familiarity With Recommendation	The extent to which the targeted health care professionals are aware of and familiar with the recommendation.	The extent to which the ED clinicians are familiar with the hsTnT guideline (posted algorithm) recommendations.	Individual Health Professional Factors	Knowledge and Skills
Quality of Evidence Supporting the Recommendation	How confident we are in the estimates of effects?	Extent to which clinicians believe hsTnT is reliable.	Guideline Factors	Recommendation
Agreement With the Recommendation	The extent to which the targeted health care professionals agree with the recommendation.	Extent to which clinicians believe the hsTnT recommendations and pathway recommendations are "good" for the clinicians, patients, and hospital system.	Individual Health Professional Factors	Cognitions
Education Received	N/A	Education received by clinicians prior to the pathway rollout; how was information presented to them? What information was presented to them? Etc. (past-oriented).	N/A	N/A

(Continued)

Code	Original Definition	Working Definition	TICD Domain	TICD Construct
Accessibility of Recommendation	How accessible the guideline or recommendation is?	How clinicians access guidelines surrounding hsTnT and Chest Pain Pathway (including ease of access)?	Guideline Factors	Recommendation
Feasibility (and Effort)	The extent to which the recommended clinical intervention is practical.	The extent to which the hsTnT guideline (posted algorithm) recommendations are easily or conveniently performed (amount of effort it takes to perform recommendation).	Guideline Factors	Recommended Clinical Intervention
Change Over Time: Evolution in Practice	N/A	What evolution in practice patterns are predicted (future-oriented)?	N/A	N/A
Continuing-Education System	The extent to which the continuing-education system facilitates or hinders adherence.	What topics/concepts do the targeted health care professionals prefer or suggest continuing-education efforts to focus on? (future-oriented).	Incentives and Resources	N/A
Patient Preferences and Patient Needs (Combined Code)	Real or perceived needs and demands of the patient; patients' values in relationship to professional values or those in the recommendation.	Specific patient decisions or access that effect pathway adherence or change treatment plans due to patient preference.	Patient Factors	N/A
Learning Style	The preferred way in which the targeted health care professionals learn.	In what ways do the targeted health care professionals prefer or suggest continuing-education efforts to be conducted?	Individual Health Professional Factors	Cognitions

ED = emergency department; EMR = electronic medical record; hsTnT = high-sensitivity troponin T; TICD = Tailored Implementation for Chronic Diseases.