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Implementation of the HEART Pathway: Using the Consolidated Framework for Implementation Research

Sabina B. Gesell, PhD¹, Shannon L. Golden, MA², Alexander T. Limkakeng Jr., MD, MHSc, FACEP³, Christine M. Carr, MD, CPE, FACEP⁴, Andrew Matuskowitz, MD⁵, Lane M. Smith, MD, PhD⁶, and Simon A. Mahler, MD, MS⁷

¹Departments of Social Sciences and Health Policy and Implementation Science, Wake Forest School of Medicine, One Medical Center Boulevard, Winston-Salem, NC 27157, sgesell@wakehealth.edu ²Department of Social Sciences and Health Policy, and Qualitative and Patient-Reported Outcomes Developing Shared Resource, Wake Forest Baptist Comprehensive Cancer Center, Wake Forest School of Medicine, One Medical Center Boulevard, Winston-Salem, NC 27157, sgolden@wakehealth.edu ³Division of Emergency Medicine, Duke University Medical Center, 2301 Erwin Road, Durham, NC 27710, alexander.limkakeng@duke.edu ⁴Department of Emergency Medicine and Public Health Sciences, Medical University of South Carolina, 171 Ashley Avenue, Charleston, SC 29403, carrc@musc.edu ⁵Department of Emergency Medicine, Medical University of South Carolina, matuskow@musc.edu ⁶Department of Emergency Medicine, Wake Forest School of Medicine, lmsmith@wakehealth.edu ⁷Departments of

Corresponding author and reprint requests: Sabina Gesell, PhD, Division of Public Health Sciences, Department of Social Sciences and Health Policy, Wake Forest School of Medicine, One Medical Center Boulevard, Winston-Salem, NC 27157, 336-713-8738 – Tel, 336-716-7554 - Fax, sgesell@wakehealth.edu.

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Authors' contributions:

Sabina Gesell led conceptualization and design of the work, collected the data, contributed to data analysis and interpretation, and drafted and critically revised the article for important intellectual content.

Shannon Golden made substantial contributions to the conceptualization and design, led data analysis and interpretation, and made substantial revisions to the article for important intellectual content.

Alexander Limkakeng contributed to the acquisition and interpretation of the data and revised the manuscript for important intellectual content.

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Lane Smith contributed to the acquisition and interpretation of the data and revised the manuscript for important intellectual content.

Simon Mahler made substantial contributions to the conceptualization and design, data analysis and interpretation, and made substantial revisions to the article for important intellectual content.

All authors approve the submitted manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Emergency Medicine, Implementation Science, and Epidemiology and Prevention, Wake Forest School of Medicine, One Medical Center Boulevard, Winston-Salem, NC 27157, smahler@wakehealth.edu

Abstract

Objective—The HEART Pathway is an evidence-based decision tool for identifying emergency department (ED) patients with acute chest pain who are candidates for early discharge, to reduce unhelpful and potentially harmful hospitalizations. Guided by the Consolidated Framework for Implementation Research (CFIR), we sought to identify important barriers and facilitators to implementation of the HEART Pathway.

Study Setting—Data were collected at 4 academic medical centers.

Study Design—We conducted semi-structured interviews with 25 key stakeholders (e.g., health system leaders, ED physicians). We conducted interviews before implementation of the HEART Pathway tool to identify potential barriers and facilitators to successful adoption at other regional academic medical centers. We also conducted post-implementation interviews at one medical center, to understand factors that contributed to successful adoption.

Data Collection—Interviews were recorded and transcribed verbatim. We used a CFIR framework-driven deductive approach for coding and analysis.

Principal Findings—Potential barriers to implementation include time and resource burden, challenges specific to the electronic health record (EHR), sustained communication with and engagement of stakeholders, and patient concerns. Facilitators to implementation include strength of evidence for reduced length of stay and unnecessary testing and iatrogenic complications, ease of use, and supportive provider climate for evidence-based decision tools.

Conclusions—Successful dissemination of the HEART Pathway will require addressing institution-specific barriers, which includes engaging clinical and financial stakeholders. New SMART-FHIR technologies, compatible with many EHR systems, can overcome barriers to health systems with limited information technology resources.

Keywords

risk assessment; emergency department; acute chest pain

Background

Each year, 8 to 10 million patients with chest pain (CP) present to an Emergency Department (ED) in the United States.¹ Over half are hospitalized for serial measures of cardiac biomarkers, stress testing, or angiography, but fewer than 10% are ultimately diagnosed with acute coronary syndrome (ACS)^{2–6}. This pervasive over-triage costs an estimated \$10–13 billion annually^{5,7–10}. Current care patterns for acute CP fail to direct health system resources to patients most likely to benefit from hospitalization and cardiac testing. The Chronic Care Model identifies evidence-based decision-support systems as a way to improve healthcare delivery in chronic conditions such as cardiovascular disease

7–10. Consistent with this model, validated decision-support tools for ACS risk stratification (i.e., the HEART Pathway) have improved the quality and value of care for ED patients with acute CP. The HEART Pathway combines a validated clinical decision aid ^{11–13} with two serial troponin measures, to identify patients with CP who can safely be discharged from the ED without stress testing or angiography (Figure 1). In a single-site randomized controlled trial, use of the HEART Pathway decreased hospitalizations by 20%, stress testing by 12%, and hospital length of stay (median reduction of 12 hours), without increasing adverse events ^{14–16}. The HEART Pathway is integrated into the electronic medical record (EHR) of one of the authors' sites, and used in 90% of eligible patients. The next logical step is to disseminate the HEART Pathway to additional sites. We sought to identify common barriers and facilitators to implementation of the HEART Pathway in 4 academic medical centers in North and South Carolina.

There are nearly 50 theoretical frameworks in the implementation science literature ¹⁷, but these are underused ¹⁸. In response to calls for increased use of theory in implementation research ¹⁹, Damschroder et al integrated the numerous published theories into a single, consolidated framework to guide implementation research ²⁰. Thus, the Consolidated Framework for Implementation Research (CFIR) is a meta-theoretical framework. We selected the CFIR for this study because it was comprehensive, theory-based, and provided standardized terminology and definitions for constructs across the spectrum of implementation research. The CFIR consists of 5 overarching domains: (1) intervention characteristics (e.g., relative advantage, complexity of the decision tool, costs); (2) outer setting (e.g., competitive advantage, patient needs and preferences); (3) inner setting (e.g., implementation climate, compatibility with existing workflow, relative priority); (4) individual characteristics (e.g., knowledge and beliefs about the decision tool, stages of change); and (5) process (e.g., planning rollout, engaging institutional leaders)²¹. Within these domains are 39 constructs to help determine whether an implementation may or may not be successful (Appendix A).

Although the CFIR framework can be applied before, during, or after implementation, to date, only 3 studies have used it in the pre-implementation phase ^{20,22}. Thus, we identified factors that contributed to successful implementation at one academic medical center (post-implementation), and those that may influence implementation at 3 other academic medical centers (pre-implementation). Our findings will be used to (a) refine our implementation strategy (but not adapt the risk stratification tool to local practices), and (b) inform the design and execution of a future multi-site cluster randomized controlled trial.

Methods

Study Design and Setting

We conducted semi-structured interviews with 25 key stakeholders across 4 academic medical centers in North and South Carolina. These sites are members of the Carolinas Collaborative, a learning health system and data sharing network of Clinical Translational Science Awards (CTSA) sites. The Collaborative was developed to enhance the quality of healthcare and accelerate advances in research in institutions in North and South Carolina. Each institution's ED sees approximately 100,000 patients per year.

Sample and Recruitment

We used purposive sampling to identify key stakeholders at each site with influence over implementation of the HEART Pathway. The stakeholders' roles and rationale for inclusion are shown in Table 1. Stakeholders were contacted by email and invited to participate in a 30-minute telephone interview. Of the 30 stakeholders contacted, 2 declined and 3 did not respond (overall response rate 83%). For these 5 individuals, we identified substitutes. Before the interviews, we sent an overview of the HEART pathway algorithm, summary of findings showing advantages over usual care, and copies of relevant publications. We obtained verbal informed consent for all participants.

Ethics Approval and Consent

The Wake Forest University Health Sciences IRB approved this study (IRB00038986). The first author obtained verbal informed consent from study participants prior to initiating any study activities.

Data Collection

At the site where the HEART Pathway was implemented, we interviewed participants post-implementation. Respondents from other sites were asked about their readiness, infrastructure, and expected experience implementing the HEART Pathway. Because participants had different roles across institutions, not everyone was asked the same questions, but the core elements of inquiry were consistent throughout the interviews. All interviews were conducted by the first author. Interviews averaged 22 minutes in length (excluding consenting time), were digitally audio-recorded, and transcribed verbatim.

Measures

The interview guide covered all five CFIR domains. The study team selected CFIR constructs to inform the interview structure after an in-depth interview with the developer of the HEART Pathway post-implementation, a tour of the ED that had fully integrated the tool into care delivery, and observation of the decision tool in the EHR and on a handheld device. These additional steps were taken to enable the study team to better understand the perspectives of the HEART Pathway's end users.

Data Analysis

The CFIR constructs were also used as qualitative coding guidelines. For consistency, one member of the research team (second author) conducted the thematic content analysis, using a deductive (theory- driven) approach²³. Interviews were reviewed, and a codebook was developed using the CFIR framework. When applying codes, any questions about applicability were discussed and resolved with the first author returning to the original transcripts; and consulting the CFIR coding guidelines. Major themes were mapped to the CFIR domains and constructs. Not all CFIR constructs are mutually exclusive; we emphasized internal consistency in the final coding. ATLAS.ti (v.8.0)²⁴ was used to code, organize, and manage the qualitative data. After coding, segments of text were abstracted by code, reviewed, summarized, and synthesized.

Results

Barriers and facilitators, organized by the five CFIR domains, are shown in Table 2. Quotes from some participants are included to support selection of themes. To protect respondent confidentiality, we have grouped all health system leaders and blinded institutional names. Participants are identified after each quote by an identification number constructed from their roles (number) and institutions (letter) as described in Table 1.

Intervention Characteristics

Evidence Strength and Quality—Respondents felt the existing evidence of the HEART Pathway’s effectiveness was compelling, but that a multi-site trial was necessary. A sample response from a health system leader was,

“So, if this were tested in 10,000 patients and clearly added value and reduced costs, I mean it would be embraced relatively quickly by all.” (1D3)

Relative Advantage—Respondents saw the potential reduction in healthcare costs as an advantage over the current standard of care.

“...we have a tremendous problem with space, so decreasing the length of stay will be a huge thing for us and it will allow us to see more patients. Additionally, we do order a lot of reflex, either stress tests or CTs right now, that by using the Heart Pathway will be eliminated.” (2D3)

“Well, as we transition more and more to value, at the end of the day what the Heart Pathway does is provide value to the patient encounter from the patient and the payer perspective.” (2A1)

Complexity—The HEART Pathway was perceived by most respondents as relatively simple conceptually and technically. This sentiment was strongest among the ED physicians – the actual end users:

“... one of the more straightforward workflows that we have.” (2A1)

Cost—Respondents’ concerns about cost focused on time and resources, specifically (1) the time it takes to reach consensus among many stakeholder groups, and (2) the computer expertise and administrative resources needed to integrate the tool in the EHR, educate end users, monitor implementation and provide feed data back to providers in a timely fashion to support the desired behavior change – all of which were deemed essential to successful implementation. A typical response was,

“I think some of the costs are the time it takes and the resources it takes, including people’s time, to get agreement;...the time it takes to educate; the resources it takes to implement it into our EMR (electronic medical record) ; the resources it takes to review when we review cases ...” (2B1)

Outer Setting

Patient Needs—Respondents discussed how decreases in length of stay and admissions could directly benefit patients, and how decreases in unnecessary testing would reduce the rate of false positive results and free up resources for other patients. As one provider said,

“Using this pathway can reduce the amount of time the patient is in the hospital and the ED, and that is important to patients”. (3A)

A health system leader noted,

“A significant portion of our ED visits is related to CP [chest pain] evaluations. If it hastens the throughput there, I think not only does it make us better, potentially, at caring for this specific population, but it enhances our capacity to deal with all of the other folks that need us as well.” (1C1)

The patient advocate discussed patient needs at length, emphasizing patient safety and including the patient in the decision to discharge. To illustrate, she said:

“...most of all I do not want the patient to be short-changed with a new system that isn’t adequate or not tested or researched enough and a patient loses life or time as a result... At least let us, the patient, feel that all of the decisions you are making are based on me with healthy outcome. Not based on the insurance industry, staff time, or how much it is going to cost.” (5E)

The patient advocate also voiced concerns about biases against patients on the basis of gender, race/ethnicity, or culture.

“I just want to have some safeguard that he [biased physician] is not going to utilize this [tool] as a way of not really having to deal with a patient.” (5E)

Both providers and the patient advocate noted that the HEART Pathway does not focus on follow-up with patients after discharge, which can be very important as part of clinical care.

“...ensuring that you order appropriately and the patient knows why you are doing it and how to do it and then somebody following up on those results is going to be key. So, when you say ‘early discharge’ for all of these things, often times there may be some further follow-up that is necessary for the patient.” (2D3)

Peer Pressure—Opinions were mixed about whether the HEART Pathway would afford a competitive advantage over other area medical centers.

“I think early on it will [provide a competitive advantage].... We board a lot of patients; so, we free up inpatient beds for patients that really use them.” (2D2)

“I think the advantage comes just from doing a good job in general clinical care. I don’t know if the HEART Pathway is something we would market... I think what it does is it is important truly for process of care regardless of the competition issue.” (1C3)

Inner Setting

Networks and Communications—Respondents expressed the need for formal and repeated communication to all stakeholder groups involved in implementation.

“[Rollout] should be communicated 10^x, which means we would not only want to see previous publications, the protocol and detail; we would have a series of meetings with the ER CP faculty and our clinical faculty, likely in our division monthly meetings as an announcement followed by another announcement that would be made on multiple occasions... The most important communications will be to get the diagnostic testing done in as timely a fashion as possible and that’s frankly a struggle now in the absence of a protocol.” (1D3)

Culture—Respondents described how decisions were typically made regarding care pathways in the ED and how change happens. Many mentioned the benefit of aligning ED initiatives with institutional priorities to garner cross-departmental and institutional support. Where the HEART Pathway was implemented, it was prioritized because:

“It was addressing a clinical need in an area of inefficiency for the hospital and it got a lot of visibility because of the endorsement of the Dean and our CMO.” (2A2)

Many respondents discussed the benefit of seeking ED physician input and building consensus across stakeholder groups versus pure ‘top-down’ decision-making.

“Generally, [decision-making] is building consensus. There are a few really good examples of top-down decisions that have just wildly failed...the top-down things generally don’t go well with ED docs....” (2D2)

Implementation Climate—Receptivity to future implementation of the HEART Pathway was perceived as generally high. Respondents noted that receptivity required support and buy-in from many levels of the organization, and evidence of the tool’s value (see Evidence Strength). One health system leader stated,

“I would say that part of the challenges here particularly for a complex organization is the number of different stakeholders involved... That being said, I recognize also that is an evidence-based thing and I think having data to support the practices and the value can show what would be great.” (1B1)

Respondents noted that even among ED physicians they expected some variation in receptivity. Several respondents noted there may be support for the tool because their ED physicians were characterized by openness to trying new ways to improve efficiency of care. Others noted that there may be resistance to the tool by ED physicians averse to risk and by older physicians with a longer history and preference for using their own experience as their guide, rather than a protocolized pathway.

Relative Priority—Respondents were asked what level of priority HEART Pathway implementation would be given. Some institutions established governance and workgroups to oversee project prioritization within the EHR, with a sequence of approvals needed before projects are executed. For example, one site used a matrix to score project priorities, while

workgroups were assigned to keep projects moving forward. Respondents noted that clinical and research projects were handled by different governance structures within their institution, and that priority of EHR programming resources to implement the HEART Pathway would differ depending on which committee reviewed it. One respondent stated:

“If this were not connected with research and were just a general activity that the ED was doing, it would need to get in line with the [many]... projects we have running right now inside the information systems group. The thing is that by having dedicated research resources and by this being dedicated research program you know, if this activity has funding we can move it to the front of the line.” (1D2)

However, other respondents felt that high-priority projects were those backed by institutional commitment, which addressed a clinical need, regulatory compliance, or patient safety. Respondents agreed that once a project reached top priority, the time to implementation depended on (a) levels of resources; (personnel), (b) competing priorities; and (c) the extent of coordinated, collaborative support. Once projects were approved, medical centers with multiple sites often implement changes system-wide; this approach to implementing the HEART Pathway would be challenging in terms of resources, standardization, timing, communication, and widespread buy-in.

“I think the issue is resources, because you give people money and that doesn’t do any good at all if your certified builders already have other things to do. Resources don’t automatically appear just because there is funding...raining money down does not solve the problem, because it’s a resource issue.” (1C2)

Readiness for Implementation—Although receptive to the HEART Pathway, respondents generally did not express readiness to implement it. When asked how prepared his ED is to adopt the HEART Pathway, one ED physician responded simply, “*Probably not very.*” (2C2) All three subconstructs of the CFIR readiness for implementation construct were identified as relevant: leadership engagement, available resources, and access to knowledge and information.

Leadership Engagement—“Buy-in” was described as a culmination of leadership engagement, institutional commitment, and a willingness to complete implementation at all levels by allocating necessary resources. Based on his experience with implementation of the HEART Pathway, one respondent noted that “*getting the institutional commitment or political will to allocate time and resources to it in a complex environment*” (1A1) was central to their success.

“I think that it’s boots-on-the-ground buy-in that you have to get. You have to get people to use it.” (2D2)

“I think the key is getting people involved - getting stakeholders involved, and the earlier the better.” (1A3)

“You want people to buy into it, but you also aren’t going to accommodate the whims of each individual practitioner in the application so it’s not going to be a total democracy, right? ...getting buy-in when it’s going to be hundreds of physicians can be challenging...first you have to have all of the leadership agree

and find where the areas of tension are likely to be within the providers and figure out ways in application to address those areas of potential tension.” (2B2)

Available Resources—Respondents were unsure that their institution’s programming support could efficiently implement the HEART Pathway. Although there were conflicting opinions among IT experts about the extent to which the programming could be shared between sites, overall, respondents felt the programming/configuration process would not be complicated given the proper resources in personnel.

“We are all on EPIC, so if we can leverage what has been done at [site that developed pathway], it would help a lot...” (1B4)

“Oh my gosh, no [the code can’t be cut/pasted]. I mean the difference between EPIC at [one site] and EPIC at [another site] and EPIC at [another site] is really pretty amazing.” (1C2)

Access to Knowledge and Information—The site that had created and implemented the HEART Pathway noted that workflow was discussed in teams in the preparation and information-sharing phases of implementation.

“..that’s where a lot of that time and energy was spent - trying to find a way that was not obstructive to the workflow, yet still met the needs of trying to maintain the validity of the intervention.” (2A2)

The other sites also recognized workflow as a viable concern in the implementation process. Respondents noted that successful rollout would require *“taking a look at what the workflow is and how do you embed this to become a natural part of the workflow.”* (1D1)

“The biggest reason I think a policy does not create change is when that policy adds work to the provider. So, if I am being encouraged to do something - two things: It adds an additional work burden, task saturation, to me during my busy ED shift and particularly if that additional work burden does not seem to have a positive effect on patient care, I think that combination of increased work plus not having a big payoff is one of the big barriers.” (2D1)

Characteristics of Individuals

Knowledge and Beliefs about the Intervention—Respondents were positive about the intervention and felt it could standardize patient management, create shorter decision-making times, decrease adverse outcomes, improve provider satisfaction, and reduce admissions.

“I think the upside of this one in particular is actually you get to a disposition decision quicker.”(1D1)

Among respondents, ED physicians had the most knowledge of the principles of the HEART Pathway and were especially enthusiastic about implementing it.

“I would love it [to be used in my ED]. I think it would really strengthen our ability to standardize CP management or ACS management and risk stratification. I am huge proponent of it...” (2D1)

Other Personal Attributes—Despite their own support of the tool, respondents also recognize that others may be resistant or slow to adopt.

“The younger physicians who are more adept at technology may feel more comfortable with pathways. People on the more senior side may have, ‘well that’s not how I do things’, and may be more set in their ways, for lack of a better term.” (1D1)

“I think the challenge initially is actually not getting buy in from cardiology, but it is the risk averse nature or not of the ER staff...” (1D3)

Process

Planning—Several respondents voiced concerns about whether support for the HEART Pathway would be sustained during a lengthy implementation process.

“Once we come up to an agreement that this is what we are going to do and everybody is on the same page, then we need to push the development very quickly because people are going to know you are doing this and you don’t want to lose momentum. If this kind of trickles along people are going to be distracted by shiny objects and move on to something else.” (1C1)

Engaging—Suggestions for engaging internal stakeholders during the planning phase included having internal discussions to determine: (1) what other health systems do, (2) EPIC system configuration, (3) determining what outcomes to collect and how that data will be extracted and shared with providers to monitor implementation success, (4) impact on workflow, and (5) interface with the EHR. Respondents felt it was important to engage *opinion leaders* (individuals with formal or informal influence on attitudes and behaviors of their colleagues regarding implementation); *formally appointed internal implementation leaders*; and *champions* (individuals who dedicate themselves to supporting, marketing, problem-solving, and advancing an implementation through to full adoption). *External change agents* such as policy makers or professional associations were not mentioned as relevant.

“I think another reason things fail, is that leadership all agrees on what they want to do, but there is no champion who is willing to continually work on the group, at least in the acute phase, to ensure that change takes and then to maintain it, then when it feels like it’s hardwired but it’s really not hardwired yet; that can be a challenge.” (2B2)

Overall, respondents agreed that education and training for the HEART Pathway rollout are needed, preferably in an ongoing, focused effort to capture all healthcare providers in the ED, and allowing for staff turnover.

“...the education of it has to be multi-pronged...faculty meeting alone is not going to be enough. Resident conference alone would not be enough. Email alone would not be enough. There is probably going to have to be a module of some sort of PowerPoint or something like that, that everyone has to go through. Then, there’s going to have to be a champion on the back end who is willing to spend the time

and energy to kind of review how people are doing and how it's going and making sure that everyone's beginning to align. That's the only way we will get any standardization.” (2B2)

Reflecting and Evaluating—Respondents expressed a need to monitor adoption and outcomes of the intervention, both for patients and clinicians. Monitoring would include feedback and regular information-sharing with all institutional stakeholder groups. This process would require report generation from IT.

“Was there improvement from an efficiency perspective or something else that may save them time or benefit the patients from a safety perspective that this was a good reason to be able to use this pathway?” (1B2)

Discussion

Despite evidence of the significant quality and value benefits of using the HEART Pathway compared to usual care, to date few hospitals have adopted it. Most hospitals use either no standardized risk stratification tool (relying only on clinician opinion) or use outdated tools not designed for ED use.

Key Facilitators

Our interviews identified several possible facilitators to widespread HEART Pathway dissemination and implementation. At some institutions, there was broad enthusiasm for the tool's ease of use and streamlined workflow. Respondents identified how HEART Pathway implementation could support institutional priorities, including more appropriate inpatient bed capacity, increased efficiency, and standardization. This included faster disposition decisions that reduced ED length of stay. Respondents felt leadership could effectively engage all stakeholders to create change: leaders are best equipped to identify potential barriers and derive solutions that are agreeable to all stakeholders to achieve buy-in throughout the organization.

Key Barriers

Our key informant interviews also identified common barriers to widespread HEART Pathway dissemination and implementation. These included (a) concerns about the time and resources required to implement at their facilities, especially IT resources; (b) prioritization among other projects, and (c) administrative resources needed for full implementation. Respondents stressed the importance of buy-in from key leaders and local champions. Communicating value to the patient (reduced iatrogenic risks and time spent hospitalized) and to providers (decreased work load via increased operational efficiency, increased access and decreased low-value testing) was important.

There were also concerns about getting institutional buy-in from the multiple health system stakeholders to overcome existing workflow inertia. While stakeholders may recognize that care processes are inefficient, that does not inevitably result in agreement on a solution. For example, a large health system in Texas considered HEART Pathway implementation; cardiologists were in favor of HEART Pathway adoption but ED physicians were not.

Ultimately, this disagreement dissuaded health system leadership from HEART Pathway implementation (personal communication).

Our patient advocate had concerns about whether a standardized pathway would be used to justify biased care or could lead to abandoning patients without appropriate follow-up care. A communication strategy should be in place before implementation, to educate both providers and patients on the value of the HEART Pathway. There is evidence that standardized protocols can lead to more equitable care processes²⁵ and can prevent both over testing and avoidance of iatrogenic complications from unnecessary testing. The ability to go home earlier was not mentioned as a benefit from the patient perspective; this may reflect a patient bias toward increased testing, even low-value testing. Patients frequently overestimate the risk of mortality from undiagnosed acute coronary syndrome, which could inform different valuation of stress testing and admission in low-risk chest pain²⁶. Alternatively, our patient advocate's remarks may reflect a concern that the HEART Pathway is something being "done to" a patient, not a management plan created with the patient. To this end, some health systems have combined the HEART Pathway, which does not explicitly use shared decision-making, with a validated shared decision-making tool²⁷.

Potential Solutions to these Barriers

To address technical barriers, our research team has recently developed a SMART-FHIR HEART Pathway application that can be easily downloaded by health systems to their EHR. SMART-FHIR is compatible with many EHR systems, which allows healthcare clinical decision support applications to be implemented more quickly by hospitals using fewer information technology resources. The HEART Pathway CDS application can be downloaded to a health system's EHR, akin to downloading applications to phones. However, SMART-FHIR is a new technology. EPIC and Cerner have only recently deployed their app stores and made them available to hospital systems nationwide. Currently, the HEART Pathway is among only 17 apps validated on the Epic App Orchard (Figure 2), so health systems have yet to meaningfully embrace the EHR app store model. Likewise, our team has yet to implement the HEART Pathway in a health system using the app store model but this is a strategy around limited IT resources

Caveats and Limitations

Our interview sites may not reflect the environment elsewhere. On one hand, academic medical centers have greater IT and other resources than smaller centers, but also more stakeholders and/or clinical sites, requiring more advanced coordination for any implementation process. Significant regional variation in the treatment approach to patients with ACS is evident^{28,29}. Thus, our centers may show variations in their diagnostic approach to chest pain that makes our experience less generalizable. Smaller centers wishing to adopt the HEART Pathway may need to arrange off-hour cardiac testing so that physicians can reasonably meet a new standard of care that suggests admission or cardiac imaging for higher-risk patients. Finally, we did not assess all constructs of the CFIR (although the CFIR developers consider this acceptable). The interview guide was kept succinct to increase the likelihood that busy health system leaders would participate in the study.

Having only one institution with experience with HEART Pathway implementation is a potential limitation of this study. However, we used the CFIR framework both retrospectively, albeit only at one site, and prospectively, at three sites, to inform future implementation efforts. While the prospective recommendations reflect theoretical adoption of a protocol, they come from healthcare system leaders with extensive experience with both successful and failed efforts to change care delivery in academic medical centers. Furthermore, commonalities among their responses provide face validity for which key stakeholders need to be “on board” for a care pathway to be successfully adopted, who the most effective “champion” for an ED based chest pain protocol would be, which key administrative leaders’ support is necessary for successful adoption, and which key barriers must be overcome for successful implementation of the HEART pathway. This prospective approach engaged relevant stakeholders so that they could exert meaningful influence on the design of future implementation efforts in order to maximize success.

Future Research

Future research should examine a broader range of patients (including those who had and had not been treated according to the HEART pathway), patients’ perceptions of personalized versus standardized care and whether they can tell the difference, and what outcomes matter to them when they present to the ED with chest pain. Post-implementation interviews will be critical to assess the predictive value of the baseline assessments to further advance the field of implementation science.

Conclusion

Our assessment, driven by a comprehensive implementation framework, pointed to several strong facilitators to implementing a risk stratification tool for ED patients with acute chest pain and several barriers. The barriers are all determined locally and should be adequately addressed in future efforts to implement the tool in academic medical centers. Our results suggest that successful dissemination of the HEART Pathway will require a well-developed plan to engage health systems. This will require aligning key stakeholders by providing convincing arguments about the value of using the HEART Pathway.

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Appendix A. Consolidated Framework for Implementation Research Constructs

Construct		Short Description
I. INTERVENTION CHARACTERISTICS		
A	Intervention Source	Perception of key stakeholders about whether the intervention is externally or internally developed.
B	Evidence Strength & Quality	Stakeholders' perceptions of the quality and validity of evidence supporting the belief that the intervention will have desired outcomes.
C	Relative Advantage	Stakeholders' perception of the advantage of implementing the intervention versus an alternative solution.
D	Adaptability	The degree to which an intervention can be adapted, tailored, refined, or reinvented to meet local needs.
E	Trialability	The ability to test the intervention on a small scale in the organization, and to be able to reverse course (undo implementation) if warranted.
F	Complexity	Perceived difficulty of implementation, reflected by duration, scope, radicalness, disruptiveness, centrality, and intricacy and number of steps required to implement.
G	Design Quality & Packaging	Perceived excellence in how the intervention is bundled, presented, and assembled.
H	Cost	Costs of the intervention and costs associated with implementing the intervention including investment, supply, and opportunity costs.
II. OUTER SETTING		
A	Patient Needs & Resources	The extent to which patient needs, as well as barriers and facilitators to meet those needs, are accurately known and prioritized by the organization.

Construct		Short Description
B	Cosmopolitanism	The degree to which an organization is networked with other external organizations.
C	Peer Pressure	Mimetic or competitive pressure to implement an intervention; typically because most or other key peer or competing organizations have already implemented or are in a bid for a competitive edge.
D	External Policy & Incentives	A broad construct that includes external strategies to spread interventions, including policy and regulations (governmental or other central entity), external mandates, recommendations and guidelines, pay-for-performance, collaboratives, and public or benchmark reporting.
III. INNER SETTING		
A	Structural Characteristics	The social architecture, age, maturity, and size of an organization.
B	Networks & Communications	The nature and quality of webs of social networks and the nature and quality of formal and informal communications within an organization.
C	Culture	Norms, values, and basic assumptions of a given organization.
D	Implementation Climate	The absorptive capacity for change, shared receptivity of involved individuals to an intervention, and the extent to which use of that intervention will be rewarded, supported, and expected within their organization.
1	Tension for Change	The degree to which stakeholders perceive the current situation as intolerable or needing change.
2	Compatibility	The degree of tangible fit between meaning and values attached to the intervention by involved individuals, how those align with individuals' own norms, values, and perceived risks and needs, and how the intervention fits with existing workflows and systems.
3	Relative Priority	Individuals' shared perception of the importance of the implementation within the organization.
4	Organizational Incentives & Rewards	Extrinsic incentives such as goal-sharing awards, performance reviews, promotions, and raises in salary, and less tangible incentives such as increased stature or respect.
5	Goals and Feedback	The degree to which goals are clearly communicated, acted upon, and fed back to staff, and alignment of that feedback with goals.
6	Learning Climate	A climate in which: a) leaders express their own fallibility and need for team members' assistance and input; b) team members feel that they are essential, valued, and knowledgeable partners in the change process; c) individuals feel psychologically safe to try new methods; and d) there is sufficient time and space for reflective thinking and evaluation.
E	Readiness for Implementation	Tangible and immediate indicators of organizational commitment to its decision to implement an intervention.
1	Leadership Engagement	Commitment, involvement, and accountability of leaders and managers with the implementation.
2	Available Resources	The level of resources dedicated for implementation and on-going operations, including money, training, education, physical space, and time.
3	Access to Knowledge & Information	Ease of access to digestible information and knowledge about the intervention and how to incorporate it into work tasks.
IV. CHARACTERISTICS OF INDIVIDUALS		
A	Knowledge & Beliefs about the Intervention	Individuals' attitudes toward and value placed on the intervention as well as familiarity with facts, truths, and principles related to the intervention.

Construct		Short Description
B	Self-efficacy	Individual belief in their own capabilities to execute courses of action to achieve implementation goals.
C	Individual Stage of Change	Characterization of the phase an individual is in, as he or she progresses toward skilled, enthusiastic, and sustained use of the intervention.
D	Individual Identification with Organization	A broad construct related to how individuals perceive the organization, and their relationship and degree of commitment with that organization.
E	Other Personal Attributes	A broad construct to include other personal traits such as tolerance of ambiguity, intellectual ability, motivation, values, competence, capacity, and learning style.
V. PROCESS		
A	Planning	The degree to which a scheme or method of behavior and tasks for implementing an intervention are developed in advance, and the quality of those schemes or methods.
B	Engaging	Attracting and involving appropriate individuals in the implementation and use of the intervention through a combined strategy of social marketing, education, role modeling, training, and other similar activities.
1	Opinion Leaders	Individuals in an organization who have formal or informal influence on the attitudes and beliefs of their colleagues with respect to implementing the intervention.
2	Formally Appointed Internal Implementation Leaders	Individuals from within the organization who have been formally appointed with responsibility for implementing an intervention as coordinator, project manager, team leader, or other similar role.
3	Champions	"Individuals who dedicate themselves to supporting, marketing, and 'driving through' an [implementation]" [101] (p. 182), overcoming indifference or resistance that the intervention may provoke in an organization.
4	External Change Agents	Individuals who are affiliated with an outside entity who formally influence or facilitate intervention decisions in a desirable direction.
C	Executing	Carrying out or accomplishing the implementation according to plan.
D	Reflecting & Evaluating	Quantitative and qualitative feedback about the progress and quality of implementation accompanied with regular personal and team debriefing about progress and experience.

Figure 1.

The HEART Pathway algorithm. Patients presenting to the Emergency Department for chest pain are evaluated using the HEART Pathway application. The HEART Pathway application assists the provider in deterring a History, Ecg, Age, and Risk factor score (HEAR score). Patients with a HEAR = 0–3 are classified as low risk pending serial troponin measures. Patients with a HEAR score of 4 or more are considered high risk. Patients with an elevated troponin at 0 or 3 hours are considered high risk regardless of HEAR score. Low risk patients with negative serial troponins are identified for possible early discharge from the ED. High risk patients are identified for further evaluation in a hospital based setting, with

most patients receiving stress testing or coronary angiography. Patients with elevated troponins generally require cardiology consultation.

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The screenshot displays the 'HEART Pathway+' app interface. At the top, the title 'HEART Pathway+' is shown with a red heart icon containing a white plus sign. Below the title, the instruction 'Select patient's symptoms:' is centered. A list of six options follows, each with a circular icon to its left. The first four options have green checkmark icons, while the last two have blue minus icons. The options are: 'Middle Or Left Sided', 'Pinpoint/Well Localized', 'Heavy, Pressure, Or Tightness', 'Sharp', 'Worse With Exertion', and 'Next'. The 'Next' option is highlighted with a green background. At the bottom center, there are two small circles, one blue and one grey, indicating the current step in a sequence.

Figure 2.

This is a screen shot from the HEART Pathway app. The app opens in the electronic record environment (i.e., Epic or Cerner) contextually based on the combination of a complaint of chest pain and troponin ordered or based on manual selection by the provider. In this screen shot the provider has selected the patient's symptoms from a drop down list - the provider has indicated that the patient has middle or left sided chest pain, which is pinpoint/well localized, sharp, is not associated with heaviness, tightness, or pressure, and is not worse with exertion. The next button allows the provider to access the subsequent section of the

app to input additional historical and clinical data and ultimately receive a HEAR score and assessment of the patient's risk for adverse cardiac events.

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HEART Pathway stakeholders interviewed

Table 1

Role	Rationale for Inclusion	Academic Medical Center A	Academic Medical Center B	Academic Medical Center C	Academic Medical Center D	Non-Academic Affiliation E	Total
1. Health System Leaders (Chief Medical Officer, ED Chair, Chief Information Officer)	Decision maker for all health system medical care (quality and informatics)	3	4	3	3	-	13
2. ED Physicians	End user of the HEART Pathway	2	2	2	3	-	9
3. ED Nurse	Important ED team member caring for patients with chest pain	1	0	0	0	-	1
4. Health Insurance Payer	Industry that often drives health behaviors due to reimbursement rates/payment structures	-	-	-	-	1	1
5. Patient Advocate	Patient-centered care and patient satisfaction are a high priority for medical center	0	0	0	0	1	1
Total		6	6	5	6	2	25

Table 2

Potential barriers and facilitators to implementation of the HEART Pathway Identified in Stakeholder Interviews

CFIR Domain	Barriers	Facilitators
Intervention Characteristics		Conceptually and technically, the tool is relatively simple
	Absence of data from a large clinical trial	Reliable and sufficient data show that the tool is safe and effective
		Reduced length of stay and reduced unnecessary testing could result in increased institutional savings and value
Outer Setting	Barriers	Facilitators
	Tool does not clearly outline or consider outpatient follow-up	Patients benefit from decreased length of stay and unnecessary testing
		Tool may provide competitive advantage in reducing length of stay, reduced use of observation units, reduced unnecessary stress testing and fewer false-positive results
	Patients may perceive the tool as impersonal if they feel the tool is driving their care	Protocol outlines timeline of diagnostic testing and patient priority
Inner Setting	Barriers	Facilitators
	Top-down decision to implement	Seeking ED physician input and building consensus across all affected stakeholder groups
		Alignment with institutional priorities
		Formal, iterative, repetitive, multipronged communication strategy
		Broad stakeholder receptivity to clinical standardization within the institution as a way to optimize care delivery
	Stakeholder aversion to risk	
	ED physician resistance to using clinical pathways in general or to changing how they have always provided care	
	Inability to prioritize the tool's use, institutionally and within IT units	
	Inadequate number of IT programmers for existing workload.	Funding for IT programmers
		Information- and experience-sharing between institutions, particularly IT
	Lack of resources/personnel to execute the IT-related components successfully	Timing of implementation is aligned with related institutional initiatives (e.g. EHR upgrades)
	Complex system-wide rollout	
	Absence of strong buy-in for new policy	Visible, broad, and sustained engagement by leaders and clinicians; institutional commitment on all levels, including dedicating time and resources (i.e., project manager overseeing implementation, programmers to configure EHR)
	Disruption of workflow	Seamless incorporation into existing workflow and EHR
	Added work for providers	
Individual Characteristics	Barriers	Facilitators

CFIR Domain	Barriers	Facilitators
	Reluctance of some individuals to adopt the tool for any reason	Knowledge/belief that the tool is necessary, safe, beneficial, and effective
Process	Barriers	Facilitators
	Lengthy implementation process and/or slow momentum could reduce levels of interest/support	Internal planning that includes IT involvement
		Individuals who serve as visible champions who push the implementation process through to success
	Involvement from various departments and shifts complicates education/training efforts	Provision of resources to identify, appoint, and support champions and implementation leaders
	Single-pronged training efforts	Comprehensive and repeated education and training at all stages of implementation, in a simple format
		Regular feedback and follow-up on use and effectiveness of the tool, including structured IT/EHR-based reports
		Redundant communication throughout the process to share expectations, progress, and outcomes
		Sustained and focused momentum throughout implementation process to shorten the process and maintain interest/ support

CFIR, Consolidated Framework for Implementation Research; ED, Emergency Department; EHR, electronic health record; IT, information technology.