10 Minute Tracing: A Literature Review to Improving Acquisition Times of ECGs in Emergency Departments

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Abstract

Introduction: ST-elevation myocardial infarction is a type of acute coronary syndrome (ACS) that requires immediate diagnosis using an electrocardiogram (ECG) and timely reperfusion with primary percutaneous coronary intervention or fibrinolysis. This expedited diagnosis is crucial in saving cardiac tissue, reducing mortality, and preventing future complications. The 2019 Canadian Cardiovascular Society guidelines present a strong recommendation for an ECG to be acquired and interpreted within 10 minutes from first medical contact (1). Currently this recommendation is not adequately met.

Objectives: This literature review investigates the strengths and limitations of several strategies that attempt to reduce the door-to-electrocardiogram (D2E) time in Emergency Departments (EDs). Furthermore, this literature review also investigates which of these strategies are the most effective in improving the acquisition time of ECGs for patients that present with symptoms concerning for ACS.

Methods: A literary search using key terms was performed using two databases; Medline and Embase, from 2014-2024 encompassing articles relevant to interventions for improving D2E times within EDs. This search yielded nine articles that met the inclusion criteria.

Results: Statistically significant interventions to reduce D2E time include obtaining an immediate ECG for patients with ACS symptoms, having a dedicated ECG machine and technician for triage, triage staff education and optimization, using team members beyond triage nurses to initiate an ECG, and having regular interdisciplinary meetings and team communication.

Discussion and Conclusion: While no single ideal strategy to improving D2E times exists, this review concludes four main steps to achieving optimal D2E times: A process to identify patients who require an ECG, having proper infrastructure in EDs to accommodate a dedicated ECG at triage, initiating specific protocols to empower other staff members to identify those with symptoms concerning for ACS, and maintaining ongoing education and communication with the interdisciplinary team. This type of quality improvement work should be individually tailored to each unique ED to get the best yet currently realistic D2E times that are also sustainable for the future.

Contents

1. Introduction

1.1 Background

Cardiac-related presentations are among the leading reasons that adult patients require the use of a hospital's emergency department (ED), with chest pain being the second most common complaint among EDs within Canada (2). Cardiovascular disease (CVD) remains the leading cause of death and disability throughout the world, with 20.5 million deaths recorded in 2021 (3,4). One type of CVD that presents itself in symptoms such as chest pain is acute coronary syndrome (ACS), which is when perfusion to the myocardial tissue is compromised. One subset of this condition is an ST-elevation myocardial infarction (STEMI). A STEMI is when the coronary artery is completely occluded, or in other words, no blood flow can get through, resulting in transmural ischemia and the eventual death of myocardial tissue (3). This led to the saying "time is muscle", due to the prompt identification of patients with this condition being crucial in saving cardiac tissue (5). The typical pathophysiology of a STEMI results in the rupture of a plaque and creation of a thrombus inside the coronary artery (3). The STEMI pathophysiology is represented visually in Figure 1.1 (6).

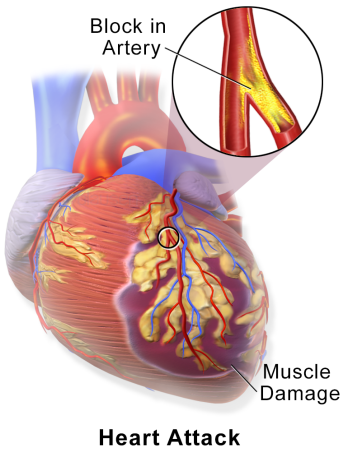

Figure 1.1: A STEMI Pathophysiology (6)

Common risk factors for a STEMI include diabetes, history of tobacco use, sedentary lifestyle, hypertension, dyslipidemia, and obesity. A STEMI is diagnosed with a heart tracing called an electrocardiogram (ECG) (3). This ECG is the key diagnostic tool that is used for patients who present with cardiac features to potentially identify those with a STEMI (7). To more effectively manage the symptom of chest pain, the 2019 Canadian Cardiovascular Society (CCS) guidelines present a strong recommendation for an ECG to be acquired and interpreted within 10 minutes as measured from first medical contact (FMC) (registration time) (1). Registration is when a specific indication for patients presenting to an ED is identified and entered into the system by a clerk (8). The door to ECG (D2E) time is the interval from when a patient is registered to ECG acquisition. The prompt recognition of symptoms and subsequent ECG diagnostic test can lead to timely diagnosis of STEMI patients. A timely diagnosis is the precursor to expedited treatment with the gold standard method of primary percutaneous coronary intervention (PCI) (5). PCI is an invasive treat-

ment which uses a stent or balloon at the area of narrowing or occlusion in the coronary artery to improve the perfusion of myocardial tissue (9). The PCI procedure is represented visually in Figure 1.2 (10). Furthermore, as per the CCS guidelines, intervention with PCI should be performed within 90 minutes of FMC at PCI capable facilities (1). For STEMI patients, primary PCI is the favoured intervention for re-perfusing the cardiac muscle tissue if performed within guideline recommended timelines (11). The door to balloon (D2B) time is a time interval from when a patient gets registered to when they get PCI treatment.

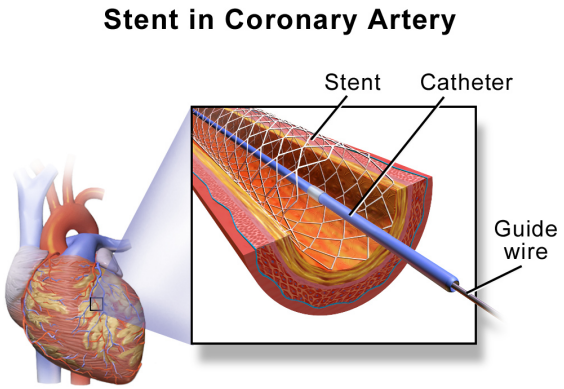

Figure 1.2: A graphic of primary percutaneous coronary intervention (PCI) (10)

Fundamentally, the best outcomes for STEMI patients are achieved with a low D2E time, leading to an expedited diagnosis and treatment with coronary revascularization through PCI. One study showed that every time the D2E time is increased by one minute, an overall 1.24-minute delay in receiving PCI treatment is caused (12), showing that D2E time is a critical factor to expediting PCI treatment.

When a STEMI is not diagnosed promptly, it increases the risk of mortality and of future

complications (13). One study observed that a one-hour delay in D2B time increased the one-year mortality risk by 64% (11). A 2.46 times higher in-hospital mortality risk when the D2E time exceeded the recommended ten-minute time frame was shown in another study (14). Furthermore, a STEMI that is not diagnosed promptly can also lead to increased risk of heart failure (13). With this complication, one study found a difference of a 2.5% increased risk of left ventricular ejection fraction (LVEF) dysfunction when an ECG was performed in greater than 10 minutes. LVEF dysfunction leads to a diagnosis of heart failure. This occurs due to the loss of myocardial tissue, which results in remodelling of the myocardium, scarring and dilation of the ventricles, and ultimately changes the amount of blood that is ejected every time the heart contracts (15).

While it is clear from the literature improving the D2E time can improve outcomes, the target is rarely achieved. A large study comprising of over 7000 patients within Canadian and United States (US) hospitals, demonstrated only one third of patients presenting with cardiac features received an ECG faster than the target time of 10 minutes (16). Another study from the US also showed that only 37.9% of patients presenting with cardiac features received their ECG in under 10 minutes (8). This lack in expediency is not unique to North America with an Irish study reporting 28.8% of patients meeting the target D2E time (17). These studies demonstrate significant room for improvement to meet this recommendation.

1.2 Research Problem and Objectives

There is a crucial need for improving D2E time to improve patient outcome in ACS, particularly in STEMI. (13). Research indicates that a significant number of patients do not receive an ECG within 10 minutes of FMC. This is a critical issue because any delay in obtaining an ECG can lead to increased risk for cardiac muscle cell death, leading to future complications such as heart failure or death (13, 15).

The purpose of this study is to conduct a literature review that investigates the strengths and limitations of different strategies that aim to improve acquisition time of ECGs in EDs from FMC and to then identify the most effective strategies that can be utilized within EDs.

The strategies found in the literature review can serve as a reference and be implemented by other EDs in hospitals across Canada and perhaps globally. This study can also prove relevant to physician assistants who are working within EDs by helping them select some of these strategies to optimize the process of getting ECGs more promptly.

1.3 Research Questions

There are two core research questions that will be answered in this literature review:

1. Among patients presenting to the ED with symptoms concerning for ACS, what are the strengths and limitations of different strategies aimed at achieving an ECG within

ten minutes from FMC?

2. Among patients presenting to the ED with symptoms concerning for ACS, what strategies are the most effective in achieving an ECG within the recommended time of ten minutes and how do they compare to current processes in improving clinical outcomes?

2. Methods

2.1 Inclusion and Exclusion Criteria

The inclusion criteria consisted of articles that were published in English and had unrestricted access to full-text articles through the University of Manitoba's library system. To maintain modern relevance, studies needed to be published from 2014 to 2024 inclusive. Furthermore, the research needed to cover interventions focused on improving D2E times within an ED, with pre-intervention and post-intervention D2E times being reported. Finally, this search did not include any geographic considerations regarding selected EDs.

The exclusion criteria consisted of incomplete articles, conference proceedings, and articles that were not published in English. Any study which focused on pre-hospital interventions such as ECG acquisition at an alternate facility or before arriving at the ED was also omitted.

2.2 Search Strategy and Study Selection

A search of the literature was performed using two OVID databases, Medline and Embase. The time frame of the search was from 2014 to 2024. Full search strategies are provided in Appendix A. The search strategies yielded 188 articles identified in the Medline database and 104 articles identified in the Embase database, for a total of 292 articles. After identi-

fying and removing duplicate articles, 231 articles were screened by both title and abstract. This yielded 22 articles that were assessed for eligibility by reading the full-text articles. Additionally, a snowball sampling technique was conducted of the articles' references for any relevant research. However, this did not yield any additional results beyond the search presented. After reviewing these full text articles, some articles were excluded due to lack of specific intervention, unreported pre and post D2E times, pre-hospital interventions implemented, and lack of relevance to the research question. This triage resulted in nine articles that were included in the literature review. Figure 2.1 showcases a PRISMA flow diagram outlining the more detailed search strategy (18).

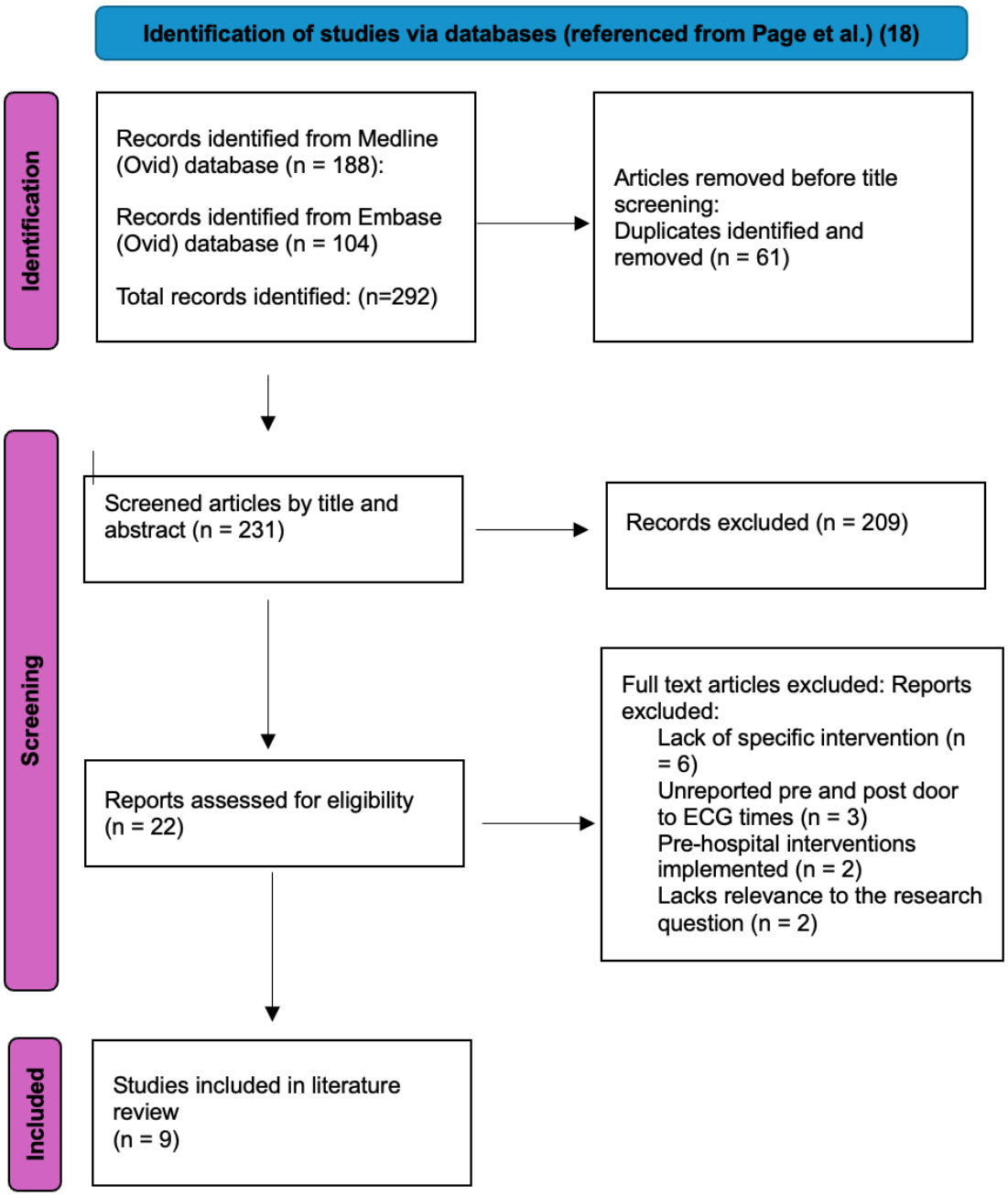

Figure 2.1: A PRISMA Flow Diagram Outlining Search Strategy (18)

3. Results

The search of the literature yielded nine articles that met the inclusion/exclusion criteria and were relevant to the research questions. The studies' sample sizes ranged from 117 to 11518 patients. Setting included Columbia, USA, Taiwan, Saudi Arabia, and India. The years of the studies ranged from 2015-2022. The duration of the studies spanned 3 months up to 29 months. Of the articles included in the literature review, eight out of nine articles achieved a goal D2E time of less than 10 minutes. All p-values were reported to be statistically significant*.

This review found five common, recurring themes: Performing an immediate ECG for patients with ACS symptoms, having a dedicated ECG machine and technician for triage, triage staff education and optimization, using other team members to initiate an ECG, and having regular interdisciplinary meetings and team communication. Each of the five themes are further described, with Appendix B summarizing the results of the literature review including year published, the study setting (country, ED type, sample size), timeline of the study, interventions implemented, median D2E time, sustainability of the intervention, and the p-value.

*Using a p-value of <0.05 to be statistically significant

3.1 Immediate ECG for Patients with ACS Symptoms

The most common theme found was a protocol to perform an immediate ECG if patients presented with symptoms consistent with ACS. One such protocol was implemented at triage for when a patient presented with a chief complaint of chest pain, shortness of breath, or other anginal equivalent, they would bypass the regular triage process, and an ECG would immediately be acquired (19). A similar concept presented was the evaluation of any present ischemic cardiac symptoms or other unusual symptoms such as dyspnea, or if the patient had increased cardiovascular risk factors, including increased age or diabetes. If any such factors were present, an ED physician would take a history and order an ECG if appropriate (13). Multiple studies also implemented chest pain protocols where the patient would bypass the regular triage process and get an immediate ECG if presenting with symptoms consistent with ACS (20, 21, 22). Finally, one study implemented a new protocol where patients presenting with chest pain got an immediate ECG. This protocol was complemented with a scoring tool called the ASAP score to help identify high-risk patients presenting with other symptoms. If these patients had a score equal to or higher than three points, an ECG would be performed immediately. Table 3.1 shows a table of the full ASAP risk score (23).

Risk Factors		**Score**
Age & **S**ex	Male $>$ 50 years old	1
	Female $>$ 60 years old	1
Atypical Presentation	Altered consciousness	1
	Generalized weakness	1
	Abdominal pain or nausea/vomiting	1
Past History	Hypertension	1
	Diabetes mellitus	1
	Prior coronary artery disease	1
Maximum Score		**7**

Table 3.1: ASAP Risk Score Assessment (23)

3.2 Dedicated ECG Machine and Technician for Triage

The second most common theme was the placement of a dedicated ECG machine and technician in the triage area. One study demonstrated that introducing a machine within the triage space and assigning ECG acquisition to the assistant nurse stationed there reduced the median D2E time from 16 minutes to 5 minutes (24). Positioning a dedicated ECG technician and machine directly in triage also produced a 9 minute improvement in D2E time (19). Additional studies described keeping an assistant nurse, ECG technician, or dedicated nurse in triage to perform ECGs as needed (19, 20, 24). One centre ensured that every shift included a nurse equipped with an ECG machine to prioritise chest pain patients (20). Finally, providing ECG technicians with a dedicated phone for immediate response to orders was reported to streamline the process (21, 25).

3.3 Triage Staff Education and Optimization

Another prevalent theme was triage staff education and optimization. This includes training triage nurses to perform the ECG when ECG technicians do not arrive promptly, with specialized training for performing the ECG quickly and efficiently. One study showed a D2E improvement time of 2.2 minutes with the largest sample size of 11518 (26). Triage nurses can also help prepare the patient for the ECG before the ECG technician arrived at triage (21). Nursing staff in general can also improve EDs with ECG training (20). Finally, interventions to decrease staff turnover at triage, and the formation of a new triage team that consisted of doctors, nurses, health attendants, and security guards were discussed (22).

3.4 Using Other Team Members to Initiate an ECG

Using other team members, specifically registration clerks to initiate an ECG was another intervention that was shown to be successful. One new and effective protocol was to have the registration clerk investigate the patient's chief complaint. If the chief complaint was a symptom for ACS, they would immediately walk the patient by the nurse directly to the ECG booth. They would also give these patients a "laminated red heart symbol" to act as a visual cue so their ECG would be prioritized. After the ECG, they would return to get a full triage assessment. This improved D2E times by 10 minutes (25). Similarly, there was also

discussion on having the primary triage nurse working alongside the registration clerk to help identify ACS symptoms (26). Besides registration clerks, security guards and health attendants could also help by searching the waiting room and bring any patients with chest pain to be triaged immediately (22).

3.5 Regular Interdisciplinary Meetings and Team Communication

The final main theme was having regular interdisciplinary meetings and team communication. For example, this was done in two studies with monthly team meetings where staff could be informed about new protocols and bring up any concerns or issues (13, 22). Communication was also enhanced with posters about the quality improvement (QI) project being posted throughout the department, enabling staff to share success stories about specific patient encounters (22). Technology also contributed to better communication with the creation of a "WhatsApp" group which let the interdisciplinary team review daily, identify potential causes of delay, and ultimately improve outcomes (20). Finally, having support from leadership and senior management was shown to be important (22, 26). This departmental buy-in was imperative to the success of these interventions and contributed to the long-term sustainability of new protocols (22).

4. Discussion

4.1 Review of Themes

4.1.1 Immediate ECG for Patients with ACS Symptoms

The most prevalent theme was getting an immediate ECG for patients that presented with ACS symptoms. Throughout these studies, the new protocols created a streamlined process that specifically targets patients presenting with ACS features to get an ECG done faster with improved efficiency, in turn leading to expedited diagnoses. A notable method was the discussion of a "red patient corridor" which is a specific route for patients with priority medical concerns (22). A similar theme was implemented by labelling critical patients with a red warning tag (13) or by providing a laminated heart symbol to act as a visual cue for other staff members such as healthcare aids and registration staff (25). Common among all these implementations is the imperative that the patients do not follow the typical triage process and are instead prioritized to have an ECG done immediately. To this end, a unique scoring system called the ASAP score identified high risk patients as an alternate take on this theme, giving a notable improvement in median D2E time of 24 minutes (23).

Ane ECG is a non-invasive, important diagnostic tool providing information about heart rate, rhythm, and heart function. As an additional benefit, this examination is extremely cost effective, estimated at approximately 5 US dollars per procedure (21), which is a near

trivial amount of money when compared to the cost of other things within the healthcare system. Most of the studies showed nurses to be the initiators of ECGs, however one study instead the ED physician obtained the patient history and ordered an ECG when appropriate. This process was an outlier in the studies reviewed and was specifically implemented to decrease the workload of nursing staff and reduce the need to have a specific space for the ECG machine. This article also reported its methods to be cost effective as the ECG was only performed if deemed appropriate through history taking by the ED physician. However, this article only showed a one-minute D2E time improvement (13). Given the very low cost of the ECG examinations, coupled with most of the other articles reviewed reporting greater improvements from performing the ECG directly at triage, this method was deemed to be less effective than other protocols for reducing D2E times. The key elements of this theme are a protocol-based approach to ECG acquisition that is focused on identifying high-risk patients and identifying nurses as being well positioned to identify these patients and visible cues to identify high risk patients which can improve D2E times.

4.1.2 Dedicated ECG Machine and Technician for Triage

Another prevalent theme was the benefit of having a dedicated ECG machine and technician for triage, resulting in great improvements in D2E times. This permanent availability guaranteed promptness in obtaining the ECG test when it was needed (24). This also reduced any transit time of walking the patient to another area of the department or providing

transport to the ECG area (21). Furthermore, having a dedicated ECG technician or other staff member trained to perform the ECG directly within the triage area could create a sense of urgency given that they are watching the interaction happen and are aware of the situation, also clearing up any potential confusion as to who should be performing the ECG on the patient (19). Finally, ECG technicians were also given individual phones to prioritize performing triage ECGs and ensured that no pages were missed (21, 25). In summary, this theme involves having an optimal location for the ECG machine directly within triage leading to expedited efficiency and prioritization. However, for this implementation to be successful, it would also be important to consider whether the ED has the proper infrastructure to accommodate an ECG within the triage area.

4.1.3 Triage Staff Education and Optimization

The next important theme was triage staff education and optimization. This included training of other members of the healthcare team to set up and perform the ECG. This ensures the patient is ready for the ECG when the technician arrives and reduces delays by having multiple options of staff available to perform the test (21, 26). Also worth noting is a reduction in staff turnover (22). This would improve efficiency, teamwork, and communication by always working with more experienced co-workers. In summary, the key element of this theme is staff retention and continued education for maintaining knowledge of ACS and performing ECGs.

4.1.4 Using Other Team Members To Initiate an ECG

Another theme was using other team members to initiate an ECG, primarily the registration clerk. One such example was initiating a new triage protocol where the registration clerk would ascertain the chief complaint and if it fit into the ACS criteria, they would initiate an ECG. The important distinguishing feature was that the registration clerk was not carrying out an assessment of the patient but just following a specific protocol and workflow (25). It was important that the registration clerks were empowered and supported through this process feeling that they played an important role in improving patient outcomes. Another important part of this process was that the registration clerk would walk the patient by the triage nurse on the way to the ECG booth. This would allow the nurse to perform a quick look and primary survey to identify any deteriorating or unstable patients (25). Another idea was the implementation of signage throughout the department to help patients verbalize if they are experiencing symptoms of ACS (26). This idea was coupled with the nurse triaging alongside the registration clerk, which helped with the immediate initiation of an ECG. Finally, having staff such as security guards within the waiting room trained in basic life support, with a specific role to identify patients with chest pain and bring them to be triaged immediately was also studied (22). This ensured that patients were triaged in the correct order of acuity especially in busy EDs that have a high patient load. In summary, this theme covered empowering other staff members to identify patients with ACS symptoms and prioritizing them within the department.

4.1.5 Regular Interdisciplinary Meetings and Team Communication

The final main theme that was explored was having regular interdisciplinary meetings and team communication. These meetings would ensure that the emergency team was fully informed and engaged with any new protocols and provided opportunities to bring up new concerns that arose. Communication was also done through QI posters throughout the department showing the impressive improvements in D2E times, motivating staff members involved in the project and improving morale (22). In addition, having support from management showed encouragement and appreciation for front-line healthcare workers which ultimately could help with the sustainability of these interventions (22, 26). Furthermore, having a "WhatsApp" group has proven to be an excellent communication method in QI projects by providing a daily case review and the opportunity for learning from each individual outcome to improve things in the future (20). The key point of this theme was to stress the importance of team communications, with several ideas on implementation.

In this section, five themes were identified separately, however throughout the articles reviewed these themes were used in combination to achieve reduction in D2E times.

4.2 Analysis of the Data

The most common theme that was implemented in 6/9 articles was obtaining an immediate ECG for patients that presented with symptoms concerning for ACS. The second most

common theme was having a dedicated ECG machine and technician for triage, which was studied in 5/9 of the articles. The largest reduction in median D2E time was a difference in time of 24 minutes and was studying a new protocol initiated which included an immediate ECG for patients presenting with chest pain and utilizing the ASAP score to identify high-risk patients. The sustainability of this intervention was not discussed (23). The second highest improvement of median D2E time was 14 minutes, which had a multi-intervention approach including a fast-track protocol and regular team meetings (22). The article that had the greatest number of themes was tied between (20) and (22) which both had four out of five of the main themes identified in these studies. A full table of which articles discussed each theme is provided in Appendix C.

One surprising observation was that three of the articles had a pre intervention time of less than 10 minutes (13, 21, 26). Since the 2019 CCS guidelines recommend for an ECG to be acquired and interpreted within 10 minutes as measured from FMC (registration time), these studies are already below the recommended guideline times. This raises the question of why these EDs would invest resources to try to improve this time. The resources and money related to healthcare are limited, and it therefore seems strange as to why they would dedicate time and effort into a process that already meets recommended times. In Appendix D, the table lists themes for each article, which explicitly differentiates between articles that had pre-intervention median D2E times greater and less than ten minutes.

Another finding that is worth noting is that most of the reviewed articles do not report

whether the interventions implemented that improved D2E times were sustained beyond the time of the study. This makes it challenging to assess whether these interventions are effective for the long-term, or whether the D2E times will regress to pre-intervention times following the study. One article did track the data for four months after the study and saw that the results were sustainable. This article had extensive interventions regarding team meetings, posters for the QI project to communicate positive results, sharing stories of success, and support from leadership and senior management (22). This could show that with good team communication, strong positive morale, and when staff feel heard, results can be sustainable after QI projects are completed.

4.3 Is There a Single Isolated Intervention to Improving D2E Times?

Overall, the articles analysed demonstrated some very similar themes. The results have shown that many interventions are effective, leading to statistically reductions in D2E times. In most studies however, there were multiple interventions that were implemented simultaneously. On top of that, studies were also conducted in many different settings. Finally, many studies had similar interventions to other studies with varied D2E times and improvements. The combination and variability of these factors made it difficult to recommend one specific intervention that will be successful, since individual interventions could

not be isolated.

Therefore, this review concludes that regardless of the ED site, implementing multiple strategies simultaneously would be the most beneficial to improving D2E times. This includes four steps: A process to identify patients who require an ECG, having the proper infrastructure in the ED to accommodate a dedicated ECG at triage, initiating specific protocols to empower other staff members to identify those with symptoms concerning of ACS, and maintaining ongoing education and communication with the interdisciplinary team. With these key concepts in mind, each individual ED needs to develop their own specific standardized approach with their team that focuses on strong team building and communication. One approach is drawing a complete map of where patients went depending on their entrance compliant (22). Patient flow charts help determine delays or gaps in the process, identify and empower the FMC to recognize ACS symptoms, and ensure there is both space and staff are available to perform an ECG. For any of these interventions to be successful and sustainable in the future there always needs to be ongoing monitoring of D2E times and feedback given to staff members. In conclusion, these strategies have shown a positive impact on faster revascularization times, leading to a reduction of complications, and an optimization of healthcare system costs.

5. Limitations and Conflicts of Interest

No conflicts of interest are to be disclosed. However, there are some limitations to discuss that may have influenced the findings presented. First, the literature search was not exhaustive and therefore there may have been studies that were missed amongst the review of the literature results or were excluded in the initial search results. Another limitation was that conference abstracts were omitted as insufficient details on the research and interventions were included. However, the limited data claimed excellent results which could have been valuable in pointing to additional useful strategies. Moreover, one study did not report a p-value or sample size making it difficult to know whether the interventions were effective. However, the study did report a significant improvement in D2E time and therefore was included (22). Also, the included studies were located in limited geographic areas, with no studies originating specifically in Canada, potentially limiting generalization of results and local applicability. Despite these limitations, this literature review attempts to ensure that the available data was presented in a way that limited any bias.

6. Future Direction

This study focuses on improving D2E time from FMC until when the patient gets an ECG. This could be broadened in scope by studying how to improve the time from when symptom onset of chest pain at home occurs until the patient arrives at the ED. In addition, one study showed that unusual symptoms including syncope, weakness, gastrointestinal symptoms, and shortness of breath have accounted for a large portion of patients who have experienced increased D2E times (21). Certain populations, such as the elderly and diabetic also experience delayed symptom to door times (27). Therefore, it is imperative to further study how to avoid missing patients with unusual symptoms during the screening process in assessing for symptoms concerning for ACS.

7. Conclusion

In conclusion, this type of QI work must be a multi-intervention process that is individualized to each ED to achieve optimal, yet sustainable D2E times. The four main steps to achieving this include: A process to identify patients who require an ECG, having the proper infrastructure in the ED to accommodate a dedicated ECG at triage, initiating specific protocols to empower other staff members to identify those with symptoms concerning for ACS, and maintaining ongoing education and communication with the interdisciplinary team. Improving D2E times will help meet the CCS guideline of under 10 minutes. This, in turn, positively affects patient care by enabling faster revascularization through PCI, reducing mortality, and preventing unnecessary complications, making it a goal that should continue to be actively pursued.

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A. Literature Search Strategy for Medline and Embase Databases

A search of the literature was performed using two OVID databases, Medline and Embase. The key search terms were: “acute coronary syndrome” or “STEMI”, “electrocardiogram”, “door-to-ECG”, and “emergency department”. For the Medline database, the following MeSH terms were used: “Acute Coronary Syndrome”, “St Elevation Myocardial Infarction”, “Electrocardiography”, and “Time Factors”. For the Embase database, the following Emtree terms were used: “Acute Coronary Syndrome”, “ST segment elevation Myocardial infarction”, “electrocardiography”, and “Time Factor”. The full detailed search results are outlined below for Medline (Ovid) database and Embase (Ovid) database.

A.1 Search Results from Medline (Ovid) database

1. (“acute coronary syndrome” or “STEMI” or “ST elevation myocardial infarction” or “STEMI diagnosis” or “acute coronary syndrome diagnosis” or “ST-segment elevation myocardial infarction” or “chest pain” or “acute coronary syndromes”).ti,ab,kw. 102400

2. Acute Coronary Syndrome/di or St Elevation Myocardial Infarction/di 8691

3. 1 or 2 103233

4. (ECG or EKG or electrocardiogr*).ti,ab,kw. 163377

5. Electrocardiography/ 206096

6. 4 or 5 277249

7. ("door-to-ECG" or "door to ECG wait time" or "door to electrocardiogram" or "door-to-ECG" or "door-to-EKG" or "time to ECG diagnosis" or "door-to-electrocardiogram time" or D2ECG or D2E or D2EKG or "door-to-ECG time" or "door to electrocardiography time" or "door to electrocardiography times" or "triage to ECG time" or "early ECG" or "time to ECG diagnosis").ti,ab,kw. 158

8. Time Factors/ 1247111

9. 7 or 8 1247208

10. ("triage" or "cardiac triage" or "emergency department" or "emergency departments" or "screening criteria" or "STEMI screening" or "cardiac triage strategy" or "emergency room" or "emergency service").ti,ab,kw. 191752

11. 3 and 6 and 9 and 10 476

12. limit 11 to (yr="2014 - 2024" and english) 188

A.2 Search Results from Embase (Ovid) database

1. (“acute coronary syndrome” or “STEMI” or “ST elevation myocardial infarction” or “STEMI diagnosis” or “acute coronary syndrome diagnosis” or “ST-segment elevation myocardial infarction” or “chest pain” or “acute coronary syndromes”).ti,ab,kw. 188635

2. Acute Coronary Syndrome/di or ST segment elevation Myocardial Infarction/di 9743

3. 1 or 2 190993

4. (ECG or EKG or electrocardiogr*).ti,ab,kw. 240337

5. Electrocardiography/ 171588

6. 4 or 5 326945

7. (“door-to-ECG” or “door to ECG wait time” or “door to electrocardiogram” or “door-to-ECG” or “door-to-EKG” or “time to ECG diagnosis” or “door-to-electrocardiogram time” or D2ECG or D2E or D2EKG or “door-to-ECG time” or “door to electrocardiography time” or “door to electrocardiography times” or “triage to ECG time” or “early ECG” or “time to ECG diagnosis”).ti,ab,kw. 302

8. Time Factor/ 50348

9. 7 or 8 50645

10. ("triage" or "cardiac triage" or "emergency department" or "emergency departments" or "screening criteria" or "STEMI screening" or "cardiac triage strategy" or "emergency room" or "emergency service").ti,ab,kw. 301375

11. 3 and 6 and 9 and 10 158

12. limit 11 to (english and yr="2014 - 2024") 104

B. Results Summary

Study	Study setting	Timeline of the study	Interventions	Median door-to-ECG time (minutes)	Sustainability of the intervention	p-value
Sprockel, 2015	Country: Columbia ED type: Tertiary Sample size: 373	3 months	1. Dedicated ECG machine directly at triage 2. Directly assigning the task of performing ECGs to an assistant nurse within triage area	**Pre: 16** **Post: 5** **Difference: 11**	Not discussed	<0.001
Coyne, 2015	Country: USA ED type: Urban Sample size: 232	26 months	1. Dedicated ECG technician and ECG machine directly at triage 2. Implementing cardiac triage protocol to bypass the regular triage process and get an immediate ECG	**Pre: 23** **Post: 14** **Difference: 9**	Following the research period, D2E times "continued to improve", however only "anecdotally"	<0.01
Su, 2021	Country: Taiwan ED type: Tertiary Sample size: 117	12 months	1. Implementing cardiac triage protocol to evaluate if ischemic symptoms exist, label relevant patients with red warning tags, and get immediate ED physician assessment 2. Monthly staff meetings to address concerns	**Pre: 5** **Post: 4** **Difference: 1**	Not discussed	0.02

Table with adapted design from Chhabra et al. (2019) (2).

Maliszewski, 2020	Country: USA ED type: Urban Sample size: 1950	26 months	1. New triage protocol where registration clerks initiate ECGs instead of at triage, patients are given a red heart symbol to act as a visual cue 2. ECG technicians are given a dedicated phone to immediately respond to ECG orders	**<u>Mean:</u> Pre: 17 Post: 7 Difference: 10**	Not discussed	<0.001
Keats, 2017	Country: Saudi Arabia ED type: Multiple centers Sample size: 11518	29 months	1. Primary triage nurse triaging with registration clerk, if the nurse is away the registration clerk can ring a bell to call the nurse back if a patient has ACS symptoms 2. Maintaining a large number of nurses in triage that are female 3. Training triage nurses to perform ECGs if an ECG technician does not arrive promptly 4. Training of ECG technicians to perform ECGs quickly and optimize settings on the ECG machine	**Pre: 6.6 Post: 4.4 Difference: 2.2**	Not discussed	<0.001

			5. Making certain that ECG equipment is well maintained 6. Maintaining a team based multi-disciplinary approach to discuss concerns/issues			
Wang, 2022	Country: Taiwan ED type: Urban Sample size: 154	12 months	1. Implementing protocol that if a patient presents with chest pain, then an immediate ECG is done. For other symptoms a scoring tool called the ASAP score is used to determine if an ECG should be performed	**Pre: 30** **Post: 6** **Difference: 24**	Not discussed	<0.001
Alhejily, 2021	Country: Saudi Arabia ED type: Urban Sample size: 457	6 months	1. New chest pain pathway protocol allowing for a structured approach 2. Creating a new "WhatsApp" group to allow the team to analyze and review daily cases 3. Dedicated nurse with an ECG machine every shift	**<u>Mean:</u>** **Pre: 12** **Post: 7** **Difference: 5**	Not discussed	0.0001

			4. ECG training for nursing staff within the ED			
Lee, 2019	Country: Taiwan ED type: Urban Sample size: 214	4 months	1. New protocol for initiating an ECG immediately if patients present with certain symptoms 2. Dedicated ECG machine directly next to triage area 3. ECG technician was given a dedicated phone to respond immediately 4. Triage nurse to help prepare the patient for ECG before the ECG technician arrived at triage	**Pre: 4** **Post: 5** **Difference: -1***	Not discussed	0.005
Gopinath, 2022	Country: India ED type: Tertiary Sample size: not reported	12 months	1. Team meetings to discuss new protocol, share success stories, and discuss concerns 2. New fast-track protocol where patients with chest pain bypass the initial triage process, get an immediate ECG, and are transferred to the treatment area	**Pre: 20** **Post: 6** **Difference: 14**	Data was collected for 4 months after interventions, and D2E time stayed stable throughout. Data was not collected after this period due to	Not reported

		3. Protocol change for security guards and health attendants to be trained to search the waiting room to identify patients with chest pain 4. Decreasing staff turnover at triage, and forming a new triage team			
				the COVID 19 pandemic	

*While this study showed an increase in median time, it came with a decrease in variability which had a positive and statistically significant impact on the <10 minutes target time. The results showed a statistically significant increase in rate of meeting the target time from 79.8% to 93.3%, which resulted in a statistically significant p-value of 0.005.

C. Table Representing Main Themes

Theme	Study	Intervention	Median door-to-ECG time (minutes)	p-value
Dedicated ECG machine and technician for triage	Sprockel, 2015	1. Dedicated ECG machine directly at triage 2. Directly assigning the task of performing the ECG to assistant nurse within triage area	Pre: 16 Post: 5 Difference: 11	<0.001
	Coyne, 2015	1. Dedicated ECG technician and ECG machine directly at triage	Pre: 23 Post: 14 Difference: 9	<0.01
	Maliszewski, 2020	1. ECG technicians are given a dedicated phone to immediately respond to ECG orders	Mean: Pre: 17 Post: 7 Difference: 10	<0.001
	Alhejily, 2021	1. Dedicated nurse with an ECG machine every shift	Mean: Pre: 12 Post: 7 Difference: 5	0.0001
	Lee, 2019	1. Dedicated ECG machine directly next to triage area 2. ECG technicians are given a dedicated phone to respond immediately	Pre: 4 Post: 5 Difference: -1*	0.005
Triage staff education and optimization	Keats, 2017	1. Training triage nurses to perform the ECG if the ECG technician does not arrive promptly 2. Training of the ECG technician to perform ECG quickly and optimize settings on ECG machine	Pre: 6.6 Post: 4.4 Difference: 2.2	<0.001
	Alhejily, 2021	1. ECG training for nursing staff within the ED	Mean: Pre: 12 Post: 7 Difference: 5	0.0001

Lee, 2019	1. Triage nurse helping prepare the patient for ECG before the ECG technician arrived at triage	Pre: 4 Post: 5 Difference: -1*	0.005	
Gopinath, 2022	1. Decreasing staff turnover at triage, and forming a new triage team	Pre: 20 Post: 6 Difference: 14	Not reported	
Immediate ECG for patients with cardiac features	Coyne, 2015	1. Implementing cardiac triage protocol to bypass the regular triage process and get an immediate ECG	Pre: 23 Post: 14 Difference: 9	<0.01
Su, 2021	1. Implementing cardiac triage protocol to evaluate if ischemic symptoms, label with red warning tag, and get immediate ED physician assessment	Pre: 5 Post: 4 Difference: 1	0.02	
Wang, 2022	1. New protocol that if a patient presented with chest pain, then an immediate ECG was done. However, if they have non-chest pain symptoms then a scoring tool called the ASAP score was used to determine if an ECG would be performed	Pre: 30 Post: 6 Difference: 24	<0.001	
Alhejily, 2021	1. New chest pain pathway protocol allowing for a structured approach	<u>Mean:</u> Pre: 12 Post: 7 Difference: 5	0.0001	
Lee, 2019	1. New protocol for initiating an ECG immediately if patients presented with certain symptoms	Pre: 4 Post: 5 Difference: -1*	0.005	
Gopinath, 2022	1. New fast-track protocol where patients with chest pain bypass the initial triage process, get an immediate ECG, and are transferred to the treatment area	Pre: 20 Post: 6 Difference: 14	Not reported	

Using other team members to initiate an ECG	Maliszewski, 2020	1. New triage protocol where registration clerks initiate ECG based on chief complaint, instead of at triage	Mean: Pre: 17 Post: 7 Difference: 10	<0.001
	Keats, 2017	1. Primary triage nurse triaging with registration clerk, and if the nurse is away the registration clerk can ring a bell to call the nurse back if a patient has ACS symptoms	Pre: 6.6 Post: 4.4 Difference: 2.2	<0.001
	Gopinath, 2022	1. Protocol change that security guards and health attendants are trained to search the waiting room to identify patients with chest pain	Pre: 20 Post: 6 Difference: 14	Not reported
Regular interdisciplinary meetings and team communication	Su, 2021	1. Monthly staff meetings to address concerns	Pre: 5 Post: 4 Difference: 1	0.02
	Keats, 2017	1. Maintaining a team based multi-disciplinary approach to discuss concerns and issues	Pre: 6.6 Post: 4.4 Difference: 2.2	<0.001
	Alhejily, 2021	1. A new "WhatsApp" group is established to allow the team to analyze and review daily cases	Mean: Pre: 12 Post: 7 Difference: 5	0.0001
	Gopinath, 2022	1. Team meetings to discuss new protocol, share success stories, and discuss concerns	Pre: 20 Post: 6 Difference: 14	Not reported
Other	Keats, 2017	1. Maintaining a large number of nurses in triage that are female 2. Making certain that ECG equipment is well maintained	Pre: 6.6 Post: 4.4 Difference: 2.2	<0.001

*While this study showed an increase in median time, it came with a decrease in variability which had a positive and statistically significant impact on the <10 minutes target time. The results showed a statistically significant increase in rate of meeting the target time from 79.8% to 93.3%, which resulted in a statistically significant p-value of 0.005.

D. Comparison of Articles with Different Pre-Intervention D2E Times

D2E pre-intervention times of more than 10 minutes		
Article	Themes included	Median D2E time improvement (minutes)
Sprockel, 2015	- Dedicated ECG machine and technician for triage	Pre: 16 Post: 5 **Difference: 11**
Coyne, 2015	- Dedicated ECG machine and technician for triage - Immediate ECG for patients with cardiac features	Pre: 23 Post: 14 **Difference: 9**
Maliszewski, 2020	- Dedicated ECG machine and technician for triage - Using other team members to initiate an ECG	Mean: Pre: 17 Post: 7 **Difference: 10**
Wang, 2022	- Immediate ECG for patients with cardiac features	Pre: 30 Post: 6 **Difference: 24**
Alhejily, 2021	- Dedicated ECG machine and technician for triage - Triage staff education and optimization - Immediate ECG for patients with cardiac features - Regular interdisciplinary meetings and team communication	Mean: Pre: 12 Post: 7 **Difference: 5**
Gopinath, 2022	- Triage staff education and optimization - Immediate ECG for patients with cardiac features - Using other team members to initiate an ECG - Regular interdisciplinary meetings and team communication	Pre: 20 Post: 6 **Difference: 14**

D2E pre-intervention times of less than 10 minutes		
Article	Themes included	Median D2E time improvement (minutes)
Su, 2021	- Immediate ECG for patients with cardiac features - Regular interdisciplinary meetings and team communication	Pre: 5 Post: 4 **Difference: 1**
Keats, 2017	- Triage staff education and optimization - Using other team members to initiate an ECG - Regular interdisciplinary meetings and team communication	Pre: 6.6 Post: 4.4 **Difference: 2.2**
Lee, 2019	- Dedicated ECG machine and technician for triage - Triage staff education and optimization - Immediate ECG for patients with cardiac features	Pre: 4 Post: 5 **Difference: -1**

E. Connection with the ACS Network and Local Data

E.1 Connection with the ACS Network

On a personal note, I was previously a registered nurse for six years working at St. Boniface General Hospital with a strong interest in cardiac care of patients. I worked on cardiac surgery, cardiology wards, and in emergency departments. During this time, I increased my knowledge of acute coronary syndrome, ECG interpretation, and treatment with percutaneous coronary intervention. Prior to starting to work on my capstone project, I contacted the ACS network whose mandate is to improve outcomes of patients with acute coronary syndrome (ACS) in Manitoba (28). I specifically discussed my strong interest in cardiac care of patients with two members of the executive team, Dr. Lorraine Avery and Dr. John Ducas. At the time, they were currently doing a project with local emergency departments (EDs) in Manitoba (28). They were specifically looking at interventions to reduce the door-to-ECG (D2E) time within these emergency rooms (ER) (28). The ACS network wanted some ideas of how to further improve the quality improvement (QI) work that they were doing, as some sites were unfortunately not meeting the target time (28). Therefore, I was able to create this literature review to assist in the ACS networks research goals.

E.2 Local Data

With regards to some local work being done within EDs in Manitoba, the ACS network has been making some huge improvements to D2E time. Within one local acute care facility, the registration to ECG median times have improved dramatically from 31.5 minutes to 6 minutes over a timeline of 12 months. These times were monitored for an additional 17 months after, and the times remained the same (28). This shows great sustainability of these interventions in the long-term. The full set of results from this local ER can be found in Appendix F.

The intervention that has resulted in the biggest change to the data has been empowering the FMC to initiate ordering the ECG. Within this local ER, the registration clerk was the FMC to recognize relevant ACS symptoms and make the decision to get the ECG (28). This fits with the data studied in this literature review, where a similar process was described (25).

The project that is being done is called "TMT" which stands for Ten Minute Tracing. Appendix G shows the TMT poster that is used at the registration desk for the registration clerk to determine whether to initiate an ECG based on the entrance complaint and age of the patient presenting. Another important element that the ACS Network has identified through the TMT project has been staff engagement. This engagement includes regular staff meetings to discuss the process and how it can be improved. This fosters teamwork

and communication from an interdisciplinary perspective. It includes all members of the healthcare team including registered nurses, healthcare aides, physician assistants, registration clerks, managers, cardiology technologists, physicians, and other members of the allied healthcare team (28). This also fits with a similar process studied in the literature review (13, 22).

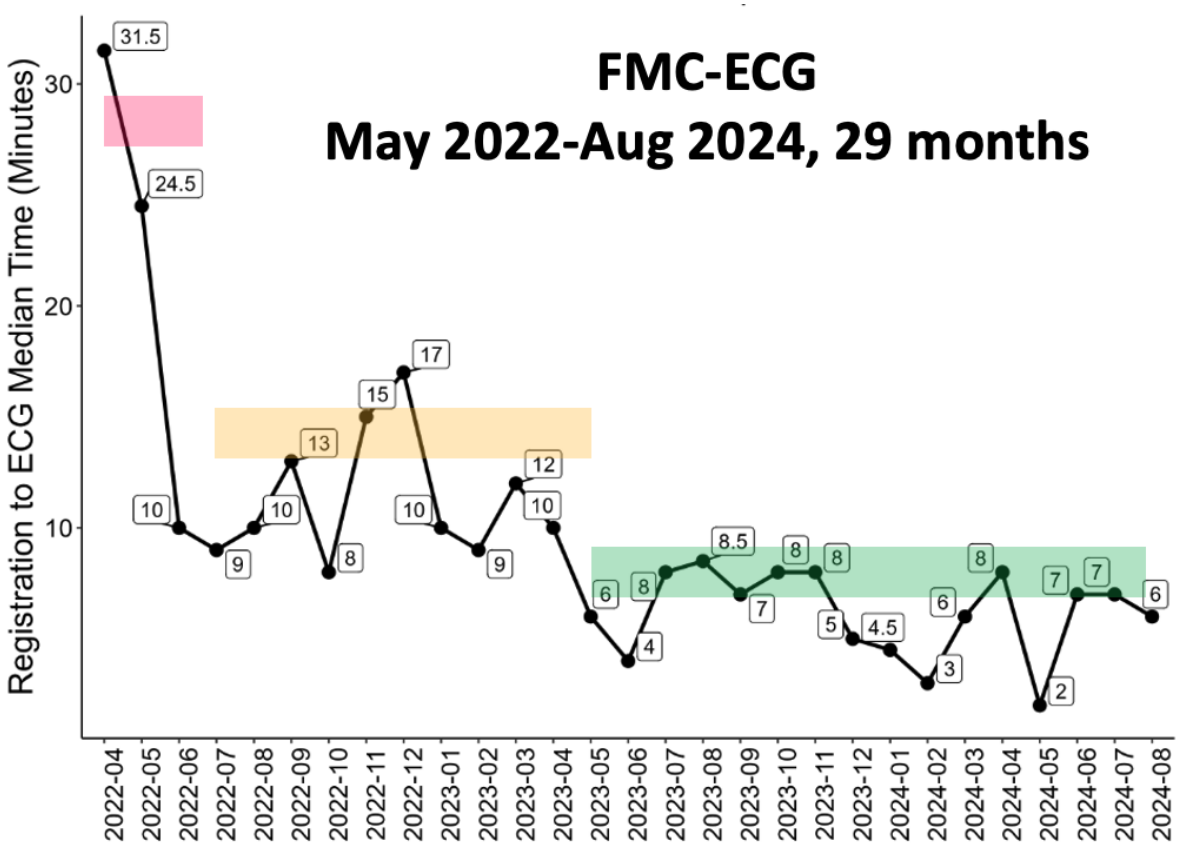
Throughout this QI project, a poster was used within staff meetings to explain the project. This was also used to identify any gaps and specific areas of improvement along the path from FMC to ECG completion (28). It describes different steps specific to this process that can be used when trying to determine process and protocol changes.

The first step is "recognize", which is identifying who the first person is that the patient talks to when entering the department and who asks the patient their initial entrance complaint. The second step is "empowered" which is determining who identifies which patients need an ECG, and who would call for this ECG to be done. The third step is "available" which is determining whether there is a cardiology technologist available to perform the ECG and discussing how they are best contacted. The fourth step is "accessible" which is having a dedicated room for ECGs to be performed and discussing who brings them there and helps them undress. Finally, the last step is "interpreted" which is determining who reviews and determines the interpretation of the ECG (28). For further information on this process, appendix H has the full poster.

Overall, within this local QI project, the interventions that were done and the substantial

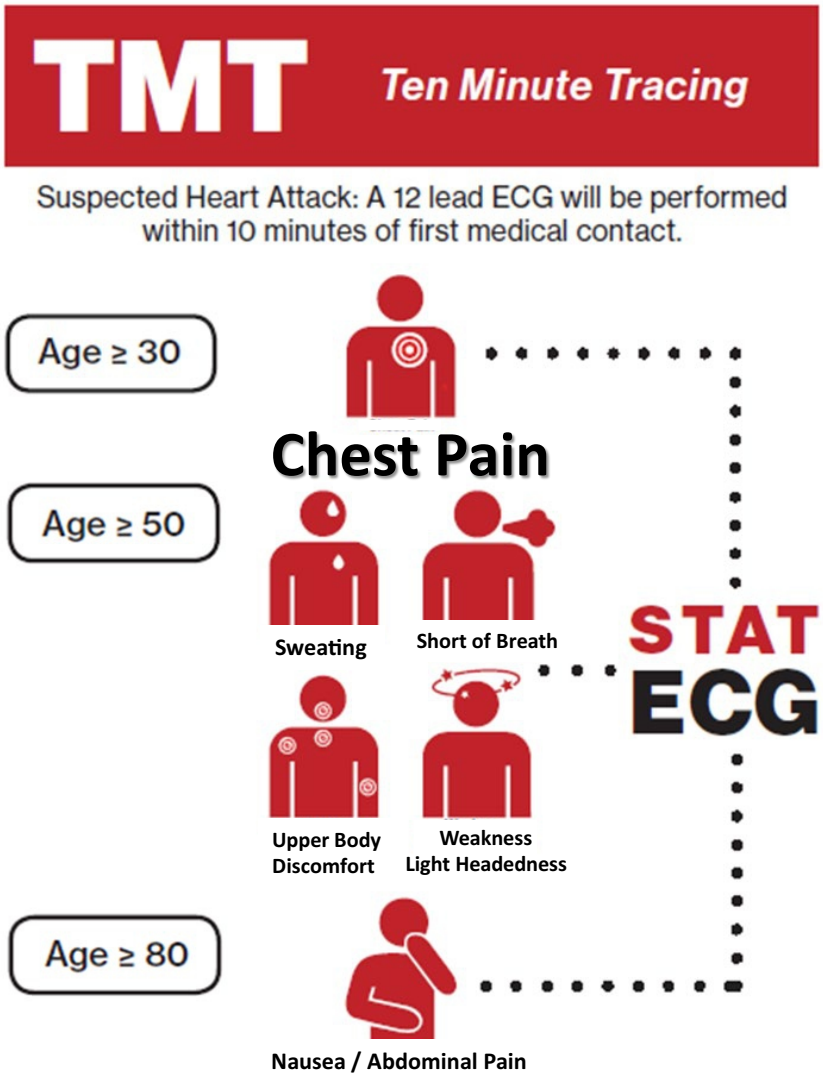
reduction in D2E time that resulted align with the literature review completed and the main themes discussed. The local EDs included in the ACS QI project can therefore confidently use the data from the studies in this review and ultimately have a positive impact on patient care.

F. Local Acute Care Facility Registration to ECG Median Time Data*



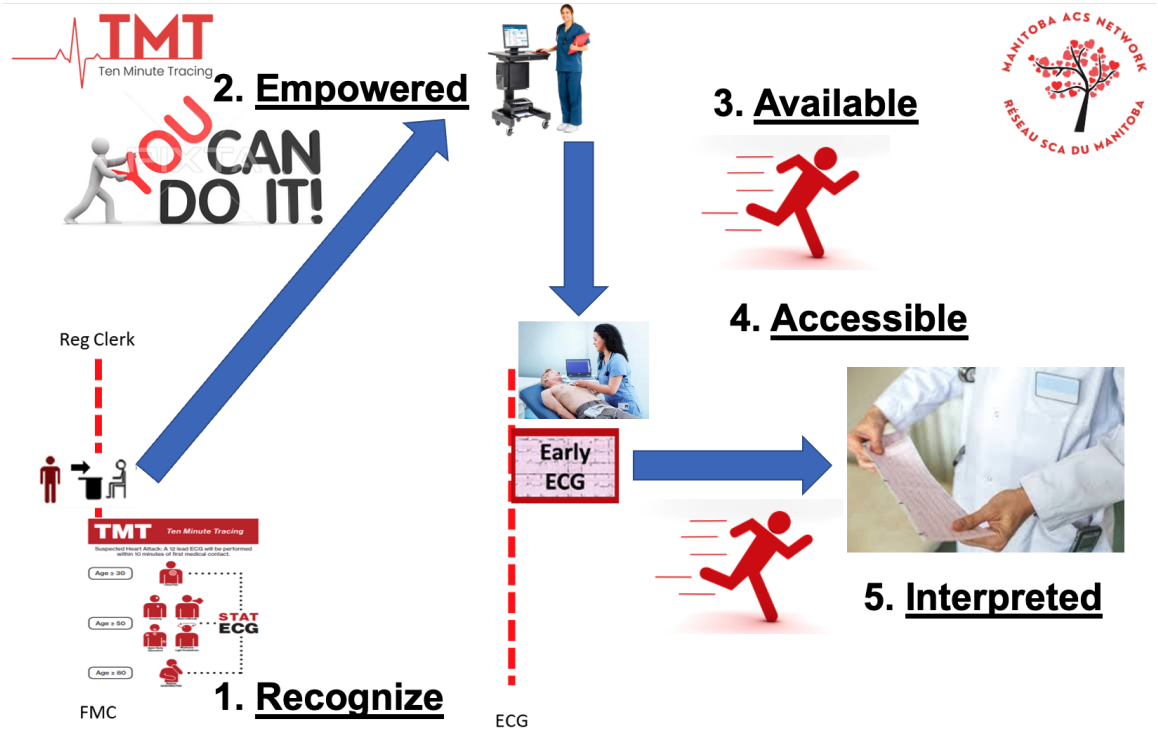
*Used with permission from the ACS network (Dr. Lorraine Avery and Dr. John Ducas). The data was not modified in any way.

G. TMT Poster*



*Used with permission from the ACS network (Dr. Lorraine Avery and Dr. John Ducas). The TMT poster was not modified in any way.

H. TMT Graphic to Improve First Medical Contact to ECG Time*



*Used with permission from the ACS network (Dr. Lorraine Avery and Dr. John Ducas). The TMT Graphic was not modified in any way.