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Flattening the other curve: Reducing emergency department STEMI delays during the COVID-19 pandemic

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1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had a major impact on ST-Elevation Myocardial Infarction (STEMI) patients. The virus itself can produce direct cardiac complications—including heart failure, myocarditis, arrhythmias and acute coronary syndrome [1,2]. In addition, the pandemic has also had an indirect impact on STEMI patients, so-called “collateral damage” [3]. A systematic review [4] and global survey [5] both found a significant decrease in STEMI patients during the early pandemic.

At the same time, patients who do present to hospital and are diagnosed with STEMI have experienced delayed reperfusion [6-8]. Some studies have found pre-hospital delays, from patients or medical transportation [9-12] Others have found hospital delays, with the main metric being door-to-balloon (DTB) time. While not all centres have reported increased DTB time during the pandemic [13,14] DTB delays have been the dominant trend. A registry of European countries [15], analysis of hospitals across the US [16] and China [17], a Canadian provincial study [18] and a global meta-analysis [19] all found that STEMI cases decreased while delays to reperfusion increased.

However, none of these studies have examined STEMI reperfusion delays within the emergency department (ED). As such, ED
contributions to delays are largely unknown. Overall metrics like DTB time obscure the contribution of EDs because they combine triage and diagnosis with transportation to the cath lab and the PCI procedure itself. Studies from the emergency medicine literature have reported significantly lower overall patient visits and admissions during the pandemic [20-26] as well as lower volumes of patients with cardiac emergencies. [27-33]. But these studies have not examined delays in processes of care of STEMI patients within the ED.

Historically, EDs have been reorganized to achieve low door-to-ECG (DTE) times [34], and emergency physicians have been trained to diagnose STEMI by ECG and directly activate the cath lab [35]. But it’s unknown how the pandemic has impacted these crucial contributions to STEMI reperfusion. We sought to measure STEMI delays and related quality benchmarks in the ED over the different phases of the pandemic, including differentiating between the nursing triage processes and the physician diagnostic processes.

2. Methods

2.1. Study design, setting and population

This study was a multi-centre, retrospective chart review. It was part of an ongoing quality improvement initiative to monitor and improve the quality of care of ED patients with suspected acute coronary occlusion, which received Research Ethics Board exemption.

We collected data from two urban, academic medical centres in Toronto, Ontario, Canada that collectively receive 220 patients with Code STEMI per year, including 80 activated from the ED. The EDs collectively see 115,000 patients a year (pre-pandemic volumes) and are staffed by 80 emergency physicians, in addition to residents and students. Emergency physicians can directly activate a Code STEMI or request a STAT cardiology consult for equivocal cases. All Code STEMI patients undergo coronary angiography, which received Research Ethics Board exemption.

Both sites have received COVID patients throughout the pandemic. In January 2020, our hospitals began to screen for travel from Wuhan and test for COVID. In February, COVID testing expanded to those with respiratory symptoms and any travel history and in March, travel history was removed as a testing requirement given presumed local community transmission. A major change happened at the end of March and early April, coinciding with the first wave: on March 23, 2020, the hospitals instituted universal masking. On April 3, 2020 they instituted extended PPE use; (3) post-first wave, July–November 2020: end of first wave and lockdown measures, and ongoing use of PPE; (4) second wave: December 2020–February 2021: second wave and accompanying lockdown. These were compared with the baseline pre-pandemic phase of January–December 2019.

We calculated median DTE and ETA times for each phase, and we compared them using Wilcoxon rank-sum tests. We calculated the percentage of ECGs with DTE times ≤10 min and the percentage of ECGs with ETA times ≤10 min, and again compared each phase using chi-square tests. We also present descriptive statistics of patients and their presenting and outcome characteristics, as well as volume-based measures of ED visits, COVID swabs and COVID cases.

We used Statistical Process Control ([SPC] or Shewhart) Xbar-R charts [36] to assess for special cause variation and delineate process changes through QI Macros® (Version 2019.06, KnowWare International Inc., Denver, CO, USA) for Microsoft® Excel® (Microsoft Corporation, Redmond, WA, USA, Version 16.48). Center line calculation was completed using formulae [37] with control limit rules recommended by the Institute for Healthcare Improvement [38].

3. Results

The cath lab received 230 Code STEMI patients in the 12 months prior to the pandemic, and 231 Code STEMI patients in the 14 months of the pandemic period to the end of the second wave. Fig. 1 displays the number of patients included, based on the inclusion and exclusion criteria. Final analysis included 80 Code STEMI patients from the ED pre-pandemic, 64 of which had culprit lesions; and 71 Code STEMI patients from the ED during the pandemic, 52 of which had culprit lesions. None of these patients received thrombolytics prior to angiography.

We reviewed the charts of those patients with culprit lesions to determine the age, sex, cardiac risk factors, arrival by ambulance, chief complaint, and whether the first ED ECG was labelled as "STEMI" or not. We measured door-to-ECG (DTE) time from the triage time to the time printed on the first ED ECG, and ECG-to-Activation (ETA) time from the time printed on the first ED ECG to the time the cath lab was activated based on hospital log call database.

2.3. Data analysis

Based on the local timeline and pandemic response outlined above, we analyzed four pandemic phases, approximated to monthly intervals: (1) pre-first wave: January–March 2020, during which there was increasing testing and cases in the region but no changes to process of care in our EDs; (2) first wave: April–June 2020, rising case counts in the region, first lockdown and changes to ED processes of care including universal masking and extended PPE use; (3) post-first wave, July–November 2020: end of first wave and lockdown measures, and ongoing use of PPE; (4) second wave: December 2020–February 2021: second wave and accompanying lockdown. These were compared with the baseline pre-pandemic phase of January–December 2019.

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Table 1 demonstrates the characteristics of ED Code STEMI patients with culprit lesions during the study period. Baseline characteristics pre-pandemic included a median age of 63.5 with approximately 80% men, and over 40% of patients arrived by ambulance. Chief complaints included approximately 70% with chest pain, 20% with angina equivalent and 10% with cardiac arrest, and only half of first ED ECGs were labelled “STEMI”. During the pandemic, there was no change in age, cardiac risk factors, arrival by ambulance, chief complaint, or computer interpretation of “STEMI” on the first ED ECG. There were proportionately fewer men during the pandemic compared to before the pandemic.

Fig. 2 demonstrates the ED volumes, COVID-19 tests and COVID-19 cases over the course of the pandemic. In the pre-first wave COVID-19 tests and cases began, but there was no change in ED volumes (99.5% baseline, $p = 0.91$). In the first wave COVID-19 testing nearly quadrupled (461 to 1688 tests per month, $p = 0.04$) and ED volumes fell from 99.5% to 60.8% of baseline ($p < 0.01$). In the post-first wave phase ED volumes partially normalized (60.8 to 77.2% of baseline, $p = 0.02$) while COVID testing and cases were sustained. In the second wave, COVID-19 cases tripled (53 to 170 per month, $p = 0.02$) and ED volumes declined again (from 77.2 to 67.5% of baseline, $p = 0.04$).

Table 2 demonstrates ED STEMI quality metrics over the course of the pandemic. In the pre-first wave phase there was no change in any quality metric, but in the first wave there was a significant delay in all metrics: median DTE time tripled (10.0 to 29.5 min, $p = 0.02$), median ETA time doubled (8.0 to 17.0 min, $p = 0.04$), and there was a decline in

| Table 1 | Characteristics of ED Code STEMI patients with culprit lesions. | Baseline ($n = 64$) | Pandemic ($n = 52$) | $p$-value |
|---------|---------------------------------------------------------------|---------------------|---------------------|-----------|
| Demographics | | | | |
| Median age (years) | 63.5 | 63.5 | 1.0 |
| Men | 51 (79.7%) | 34 (65.4%) | 0.01 |
| Cardiac risk factors | | | |
| Diabetes | 22 (34.4%) | 12 (23.1%) | 0.08 |
| Hypertension | 33 (51.6%) | 29 (55.8%) | 0.54 |
| Dyslipidemia | 22 (34.4%) | 24 (46.2%) | 0.07 |
| Coronary artery disease | 22 (34.4%) | 14 (26.9%) | 0.06 |
| Smoking | 14 (21.9%) | 12 (23.1%) | 0.83 |
| Arrival by ambulance | 27 (42.2%) | 26 (50.0%) | 0.25 |
| Chief complaint | | | |
| Chest pain | 43 (67.2%) | 39 (75.0%) | 0.23 |
| Angina equivalent | 14 (21.9%) | 11 (21.1%) | 0.90 |
| Cardiac arrest | 7 (10.9%) | 2 (3.8%) | 0.10 |
| ECG labelled “STEMI” by automated interpretation | 32 (50.0%) | 27 (51.9%) | 0.66 |

STEMI, ST-Segment Elevation Myocardial Infarction; ED, emergency department.
the percentage of both DTE $\leq 10$ min (54.7% to 12.5%, $p = 0.02$) and ETA $\leq 10$ min (57.8% to 12.5%, $p = 0.01$). In the post-first wave phase all metrics returned to baseline, and there was no significant change during the second wave. There was significant overlap in ETA interquartile range between the first-wave and post-first wave, but this resolved in the second wave with an interquartile range back to baseline. These findings are also demonstrated in the SPC charts (Figs. 3 and 4). DTE and ETA time process changes (centre line) shows the increase in the first wave and the return to baseline level by the second wave. Fig. 3 shows two points meeting special cause variation rules (red dots) for August 2019 and April 2020, meaning potentially having external cause beyond random effects. The former point coincided with significant random variation beyond the baseline and was thought to be part of this random variation cycle. The latter point, however, coincided with the first wave after a period of sustained lower values. It is likely attributed to COVID-19 effects, and it was short lived. Fig. 4 shows three points meeting special cause variation for January to March 2020 (red points and line), but they were not associated with any specific intervention or significant event that we could identify.

### 4. Discussion

The ED has a crucial role to play in the triage and diagnosis of STEMI patients, and these time-sensitive processes are more challenging when significant disruptions to usual workflows are at play, such as when a pandemic develops. We found the COVID-19 pandemic was associated with STEMI reperfusion delays despite a drop in ED volumes. In addition we highlighted the ED contribution to these delays and charted their evolution over the course of the first two waves of the pandemic. By measuring both DTE and ETA times during different phases of the pandemic, we uncovered how the pandemic negatively impacted both triage and diagnosis of STEMI patients during the first wave, but also that nurses and physicians adapted to maintain STEMI quality of care despite a worse second wave of COVID-19.

DTE time has been widely studied and DTE time $\leq 10$ min is considered a key quality metric for triage nurses [34]. We previously demonstrated that the ETA time is another important quality metric, specific to emergency physicians [40], and that it can help guide quality improvement initiatives to reduce diagnostic time for acute coronary

### Table 2
ED STEMI quality benchmarks during the different phases of the pandemic.

|                      | Baseline (2019) | Pre-first wave (Jan - Mar 2020) | First wave (Apr - June 2020) | Post-first wave (July - Nov 2020) | Second wave (Dec 2020 - Feb 2021) |
|----------------------|----------------|---------------------------------|------------------------------|----------------------------------|----------------------------------|
| n                    | 64             | 10                              | 8                            | 22                               | 12                               |
| Median DTE time in minutes (IQR) | 10.0 (6.0–19.0) | 6.5 (3.5–9.8)                  | 29.5 (14.75–39.5)             | 5.5 (4.0–16.0)                   | 8.0 (0–28.3)                     |
| p = 0.08             |                |                                 | $p = 0.02$                    | $p = 0.01$                       | $p = 0.10$                       |
| Percentage DTE $\leq 10$ min | 54.7           | 80.0                            | 54.5                          | 66.7                             |                                  |
| Median ETA time in minutes (IQR) | 8.0 (4.8–30.3) | 7.5 (3.25–25.5)                 | 17.0 (12.8–51.8)              | 14.5 (5.25–50.0)                 | 13.0 (2.5–32.5)                  |
| p = 0.11             |                |                                 | $p = 0.02$                    | $p = 0.99$                       | (p = 0.40)                       |
| Percentage ETA $\leq 10$ min | 57.8           | 70.0                            | 12.5%                         | 40.1%                            | 41.7%                            |
| p = 0.44             |                |                                 | $p = 0.04$                    | $p = 0.24$                       | $p = 0.49$                       |

ED, emergency department; STEMI, ST-segment Elevation Myocardial Infarction; DTE, door-to-ECG; ETA, ECG-to-Activation; IQR, Interquartile range. All $p$-values compared to baseline values.
occlusion [41]. Together, DTE and ETA times form the Door-to-Activation (DTA) time, which is a key driver of DTB time: achieving a DTA time of $\leq 20$ min has been associated with a DTB time of $\leq 90$ min, a widely accepted measure of STEMI quality [42]. Since DTA includes both DTE and ETA times, and since DTE time $\leq 10$ min is already a widely recognized goal, we propose that ETA time $\leq 10$ min be regarded as a complementary and necessary quality metric.

Neither DTE nor ETA times were affected by the pre-first wave of the pandemic. When COVID-19 prevalence was low and testing for COVID-19 was restricted to travelers with fevers, the pandemic did not affect the overall process of care in the ED including triage and diagnosis of STEMI patients. But during the first wave when COVID-19 prevalence increased and testing thresholds dropped, there was a quadrupling of COVID-19 testing and new protocols requiring expanded PPE for all patients. Despite a 40% drop in ED volumes, the first wave of the pandemic impacted the process of care of all patients, and negatively affected STEMI patients: median DTE time tripled (along with a special cause variation), median ETA time doubled and both percentage of DTE time $\leq 10$ min and percentage ETA time $\leq 10$ min fell by three quarters. These delays may also have been related to clinical factors including a focus on identifying COVID-19 patients at the expense of STEMI patients in the first wave of a new pandemic, potential symptom overlap between COVID-19 and STEMI [18], or diagnostic uncertainty given the possibility of COVID myocarditis [44,45]. These delays may also reflect workflow factors including the time to adapt to new PPE protocols, and the psychological impact of a COVID outbreak among ED staff.

But despite ongoing COVID-19 testing and universal PPE, both DTE and ETA metrics normalized after the first wave—though the overlap in ETA interquartile range suggests this metric took longer to normalize. Then, despite a tripling of COVID-19 cases during the second wave, no metric significantly changed. This suggests nurses and physicians were able to adapt to the pandemic in order to safely and effectively triage and diagnose STEMI patients. As there were no formal process changes implemented to improve the triage and diagnosis of STEMI patients during the pandemic, the normalization of quality metrics likely represents multifactorial adaptation to the pandemic—including clinical comfort with COVID and a return of attention to non-COVID emergencies, greater workflow efficiency with PPE, and a recovery from the initial psychological impact of the new pandemic.

DTE and ETA times can help monitor the impact of future waves of the pandemic on STEMI delays, and can help nurses and physicians assess STEMI quality of care and identify targets for quality improvement beyond the pandemic.

4.1. Study limitations

This was a retrospective chart review of patients with Code STEMI who were taken to the cath lab emergently and survived. This could have excluded STEMI patients who were managed non-emergently because of diagnostic dilemmas or late presentations during the pandemic, or who died before angiography as a result of diagnostic delay. It is possible that some of these patients received thrombolytics and died before angiography, but no Code STEMI patients in the pre-pandemic or pandemic period who underwent angiography had received thrombolytics in the ED. As with other studies, these factors could contribute to the widespread observation of reduced STEMI patients during the pandemic.

As there were no formal process changes, it is difficult to pinpoint what led to an improvement in metrics over the course of the pandemic. But the multifactorial impact of the pandemic introduces many confounding variables that would challenge any conclusion related to a specific intervention. However, we have generated a number of hypotheses—including clinical, workflow and psychological factors—that might account for the initial worsening and subsequent improvement in quality metrics, and which could be further investigated.

The numbers of patients was relatively small, in part because of the pandemic itself, which could limit the generalizability of our specific data. Replicating this study in other centres would be helpful to determine if these results were observed elsewhere, and future studies using larger cohorts from multiple centres could help with generalizability in addition to identifying more subtle changes that we could not identify with our available cohort of patients. But the methods of tracking STEMI quality metrics specific to the ED are widely generalizable: DTE and DTE $\leq 10$ min are already widely used, and there are no barriers to monitoring ETA and ETAs10 min as complementary quality metrics.

5. Conclusions

Despite a fall in ED volumes, the first wave of COVID-19 was associated with a significant rise in DTE and ETA times, and significant fall in the proportion of patients with DTE $\leq 10$ min and ETA $\leq 10$ min. But these quality metrics returned to baseline after the first wave and...
were not impacted by the second wave. This demonstrates how the pandemic affected both triage and diagnosis of STEMI patients, how ED providers adapted to their new environment, and how monitoring both DTE and ETA times can help with quality improvement efforts.

**Author contributions**

JTTM contributed conceptualization, data curation, data analysis, methodology, writing-original draft and writing- review & editing. AKT contributed data curation, methodology, and writing- review & editing. LBC contributed to data curation, methodology, visualization, writing – original draft, and writing – review & editing.

**Declaration of Competing Interest**

All authors report no conflict of interest.

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