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

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ABSTRACT

Background: The COVID-19 pandemic has been associated with ST-Elevation Myocardial Infarction (STEMI) reperfusion delays despite reduced emergency department (ED) volumes. However, little is known about ED contributions to these delays. We sought to measure STEMI delays and ED quality benchmarks over the course of the first two waves of the pandemic.
Study: This study was a multi-centre, retrospective chart review from two urban, academic medical centres. We obtained ED volumes, COVID-19 tests and COVID-19 cases from the hospital databases and ED Code STEMIs with culprit lesions from the cath lab. We measured door-to-ECG (DTE) time and ECG-to-Activation (ETA) time during the phases of the pandemic in our jurisdiction: pre-first wave (Jan-Mar 2020), first wave (Apr-June 2020), post-first wave (July-Nov 2020), and second wave (Dec 2020 to Feb 2021). We calculated median DTE and ETA times and compared them to the 2019 baseline using Wilcox rank-sum test. We calculated the percentages of DTE ≤10 min and of ETA ≤10 min and compared them to baseline using chi-square test. We also utilized Statistical Process Control (SPC) Xbar-R charts to assess for special cause variation.
Results: COVID-19 cases began during the pre-wave phase, but there was no change in ED volumes or STEMI quality metrics. During the first wave ED volumes fell by 40%, DTE tripled (10.0 to 29.5 min, $p = 0.016$), ETA doubled (8.5 to 17.0 min, $p = 0.04$), and percentages for both DTE ≤10 min and ETA ≤10 min fell by three-quarters (each from more than 50%, to both 12.5%, both $p < 0.05$). After the first wave all STEMI quality benchmarks returned to baseline and did not significantly change during the second wave. A brief period of special cause variation was noted for DTE during the first wave.
Conclusions: Both DTE and ETA metrics worsened during the first wave of the pandemic, revealing how it negatively impacted the triage and diagnosis of STEMI patients. But these normalized after the first wave and were unaffected by the second wave, indicating that nurses and physicians adapted to the pandemic to maintain STEMI quality of care. DTE and ETA metrics can help EDs identify delays to reperfusion during the pandemic and beyond.

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

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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 percutaneous coronary intervention (PCI) and it is very rare at our hospitals to use thrombolytics. In these cases (eg cardiac arrest without return of spontaneous circulation, and a high suspicion for acute coronary occlusion) patients are transferred to the cath lab for PCI after thrombolytics.

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 personal protective equipment (PPE) including gowns and gloves. This coincided with the start of a city-wide lockdown on March 23, 2020, which continued until June 24, 2020. The first wave included a COVID outbreak among emergency department staff at one of the hospitals, declared on May 13, requiring all staff to undergo weekly COVID testing for a month. In response to the second wave, another city-wide lockdown was implemented from November 23, 2020 to March 8, 2021. Throughout the pandemic there was no change in EMS protocols for pre-hospital ECG acquisition and notification, and no change in ED protocols to manage STEMI patients with thrombolytics instead of PCI.

2.2. Measures

From our hospital databases, we obtained the monthly numbers of ED visits, COVID swabs sent from the ED, and positive COVID swabs sent from the ED. From our cath lab we obtained the list of all Code STEMI patients who underwent emergent angiography from January 2019 to February 2021. We examined those activated from the ED, which were dichotomized as with or without culprit lesion by the interventional cardiologist.

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 by the automated computer analysis 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.

We calculated median DTE and ETA times for each phase, and we compared them using Wilcox 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.

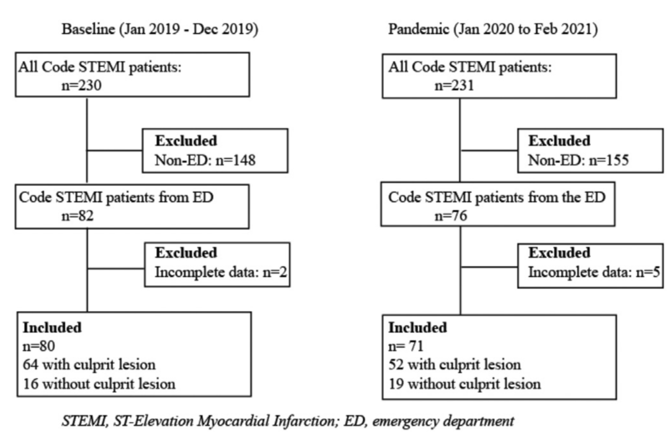

Fig. 1. Flow diagram of included and excluded patients.
STEMI, ST-Elevation Myocardial Infarction; ED, emergency department.

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.

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

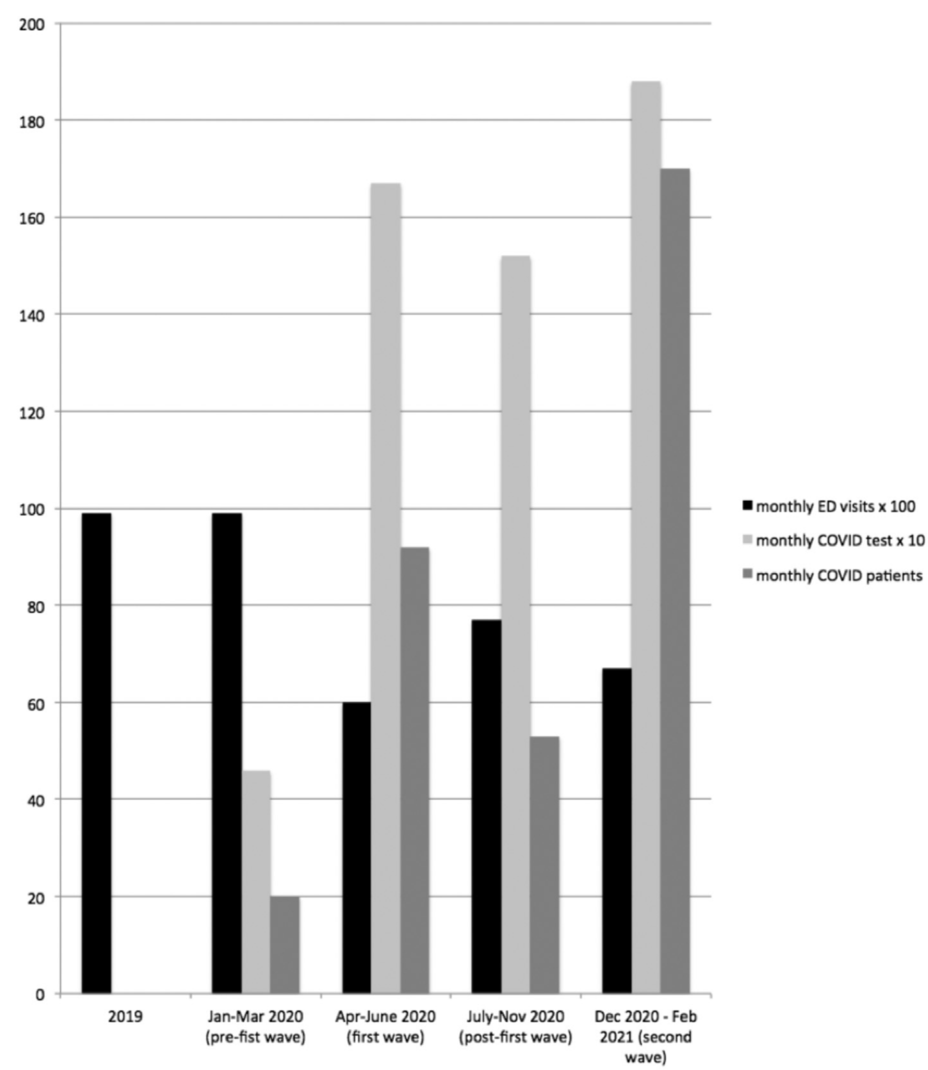

Fig. 2. ED volumes, COVID-19 tests and COVID-19 patients.

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)
	$n = 64$	$n = 10$	$n = 8$	$n = 22$	$n = 12$
Median DTE time in minutes (IQR)	10.0 (6.0–19.0)	6.5 (3.5–9.8) $p = 0.08$	29.5 (14.75–39.5) $p = 0.02$	5.5 (4.0–16.0) $p = 0.11$	8.0 (0–28.3) $p = 0.10$
Percentage DTE ≤10 min	54.7	80.0 $p = 0.11$	12.5 $p = 0.02$	54.5 ($p = 0.99$)	66.7 ($p = 0.40$)
Median ETA time in minutes (IQR)	8.0 (4.8–30.3)	7.5 (3.25–25.5) $p = 0.23$	17.0 (12.8–51.8) $p = 0.04$	14.5 (5.25–50.0) $p = 0.24$	13.0 (2.5–32.5) $p = 0.49$
Percentage ETA ≤10 min	57.8	70.0 $p = 0.44$	12.5% $p = 0.01$	40.1% $p = 0.11$	41.7% $p = 0.26$

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.

the percentage of both DTE ≤10 min (54.7% to 12.5%, p = 0.02) and ETA ≤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 ≤ 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

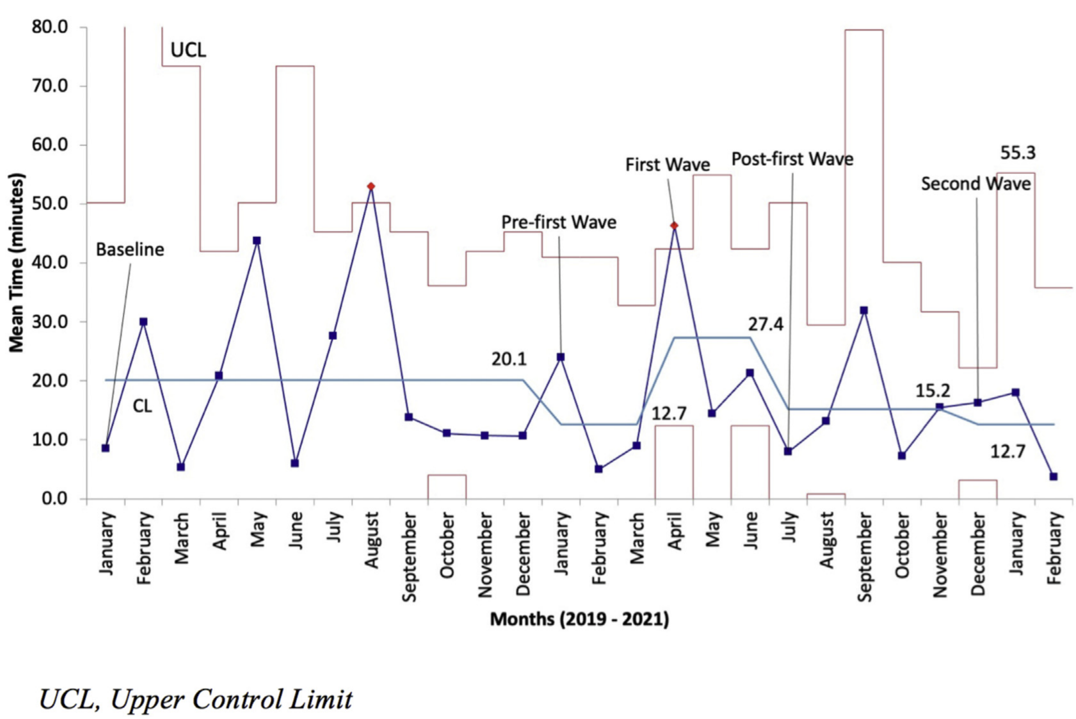

Fig. 3. Door-to-ECG time during the COVID-19 pandemic, Xbar-R statistical process control chart.
UCL, Upper Control Limit.

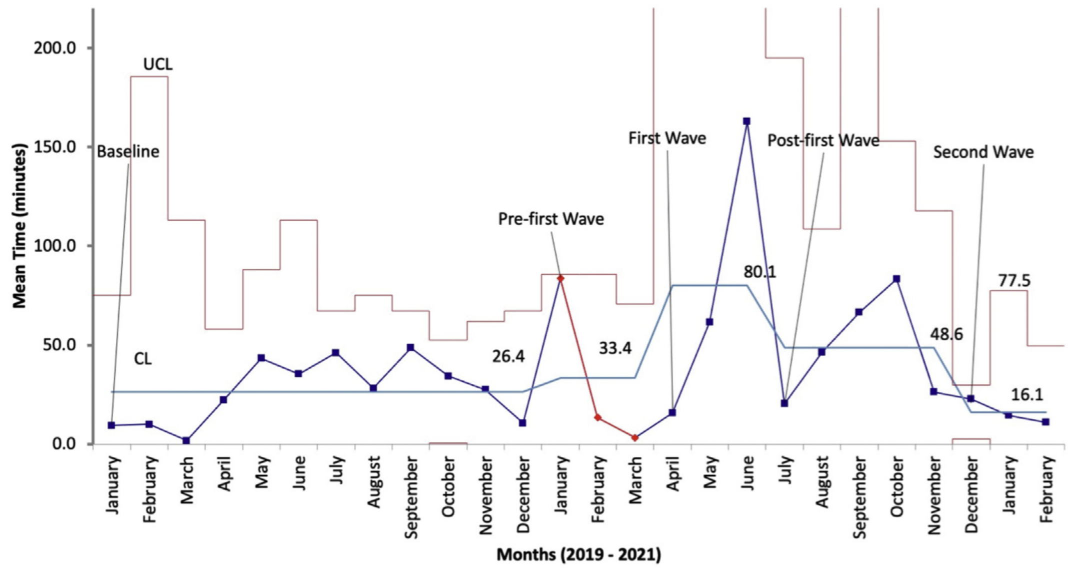

Fig. 4. ECG-to-Activation time during the COVID-19 pandemic, Xbar-R statistical process control chart.
UCL, Upper Control Limit.

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 ≤20 min has been associated with a DTB time of ≤90 min, a widely accepted measure of STEMI quality [42]. Since DTA includes both DTE and ETA times, and since DTE time ≤ 10 min is already a widely recognized goal, we propose that ETA time ≤ 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 ≤ 10 min and percentage ETA time ≤ 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 to 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 ≤10 min are already widely used, and there are no barriers to monitoring ETA and ETA≤10 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 ≤10 min and ETA ≤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.

Credit authorship contribution statement

Jesse TT McLaren: conceptualization, methodology, investigation, writing - original draft, writing - review & editing; **Ahmed K Taher**: formal analysis, writing - review & editing; **Lucas B Chartier**: visualization, writing original draft, writing - review & editing

Declaration of Competing Interest

All authors report no conflict of interest.

References

[1] Driggin E, Madhavan MV, Bikdeli B, Chuich T, Laracy J, Biondi-Zoccai G, et al. Cardiovascular considerations for patients, health care workers, and health systems during the COVID-19 pandemic. J Am Coll Cardiol. 2020 May 12;75(18):2352–71.
[2] Boukhris M, Hillani A, Moroni F, Annabi MS, Addad F, Ribeiro MH, et al. Cardiovascular implications of the COVID-19 pandemic: a global perspective. Can J Cardiol. 2020 Jul;36(7):1068–80.
[3] Huynh K. Reduced hospital admissions for ACS—more collateral damage from COVID-19. Nat Rev Cardiol. 2020 Aug;17(8):453.
[4] Kiss P, Carcel C, Hockham C, Peters SAE. The impact of the COVID-19 pandemic on the care and management of patients with acute cardiovascular disease: a systematic review. Eur Heart J Qual Care Clin Outcomes. 2021 Jan 25;7(1):18–27.
[5] Pessoa-Amorim G, Camm CF, Gajendragadkar P, de Maria GL, Arsa C, Laroche C, et al. Admission of patients with STEMI since the outbreak of the COVID-19 pandemic: a survey by the European Society of Cardiology. Eur Heart J Qual Care Clin Outcomes. 2020 Jul 1;6(3):210–6.
[6] Popovic B, Varlot J, Metzdort PE, Jeulin H, Goehringer F, Camenzind E. Changes in characteristics and management among patients with ST-elevation myocardial infarction due to COVID-19 infection. Catheter Cardiovasc Interv. 2021 Feb 15;97(3):E319–26.
[7] Rosa De, Spaccarotella C, Basso C, Calabro MP, Curcio A, Filardi PP, et al. Reduction of hospitalizations for myocardial infarction in Italy in the COVID-19 era. Eur Heart J. 2020 Jun 7;41(22):2083–8.
[8] Rattka M, Dreyhaupt J, Winsauer C, Stuhler L, Maumhardt M, Thiessen K, et al. Effect of COVID-19 pandemic on mortality of patients with STEMI: a systematic review and meta-analysis. Heart. 2021;107:482–7 heartjnl-2020-318360.
[9] Toner L, Koshy AN, Hamilton GW, Clark D, Farouque O, Yudi MB. Acute coronary syndromes undergoing percutaneous coronary intervention in the COVID-19 era: comparable case volumes but delayed symptom onset to hospital presentation. Eur Heart J Qual Care Clin Outcomes. 2020 Jul 1;6(3):225–6.
[10] Tam CCF, Cheung KS, Lam S, Wong A, Yung A, Sze M, et al. Impact of coronavirus disease 2019 (COVID-19) outbreak on ST-segment elevation myocardial infarction care in Hong Kong, China. Circ Cardiovasc Qual Outcomes. 2020 Apr;13(4):e006631.
[11] Hammad TA, Parikh M, Tashtish N, Lowry CM, Gorbey D, Corouzandeh F, et al. Impact of COVID-19 pandemic on ST-elevation myocardial infarction in a non-COVID-19 epicentre. Catheter Cardiovasc Interv. 2021 Feb 1;97(2):208–14.
[12] Little CD, Kotecha T, Candilio L, Jabbour RJ, Collins GB, Shmed A, et al. COVID-19 pandemic and STEMI: pathway activation and outcomes from the pan-London heart attack group. Open Heart. 2020 Oct;7(2):3001432.
[13] Reinstadler SJ, Reindl M, Lechner I, Holzknecht M, Tiller C, Roithinger FX, et al. Effect of the COVID-19 pandemic on treatment delays in patients with ST-segment elevation myocardial infarction. J Clin Med. 2020 Jul;9(7):2183.
[14] Abdelaziz HK, Abdelrahman A, Nabi A, Debski M, Mentias A, Choudhury T, et al. Impact of COVID-19 pandemic on patients with ST-segment elevation myocardial infarction: insights from a British cardiac center. Am Heart J. 2020 Aug;226:45–8.
[15] De Luca G, Verdoia M, Cercek M, Jensen LO, Vavlukis M, Calmac L, et al. Impact of COVID-19 pandemic on mechanical reperfusion for patients with STEMI. J Am Coll Cardiol. 2020;76:2321–30.
[16] Garcia S, Stanberry L, Schmidt C, Sharkey S, Megaly M, Albaghadadi MS, et al. Impact of COVID-19 pandemic on STEMI care: an expanded analysis from the United States. Catheter Cardiovasc Interv. 2020 Aug 7. https://doi.org/10.1002/ccd.29154.
[17] Xiang D, Xiang X, Zhang W, Yi S, Zhang J, Gu X, et al. Management and outcomes of patients with STEMI during the COVID-19 pandemic in China. J Am Coll Cardiol. 2020 Sep 15;76(11):1318–24.
[18] Natarajan MK, Wijeysundera HC, Oakes G, Cantor WJ, Miner SES, Wilsford M, et al. Early observations during the COVID-19 pandemic in cardiac catheterization procedures for ST-elevation myocardial infarction across Ontario. CJC Open. 2020 Nov;2(6):678–83.
[19] Chew NWS, Ow ZGW, Teo VXY, Hang RRY, Ng CH, Lee C-H, et al. The global impact of the COVID-19 pandemic on STEMI care: a systematic review and meta-analysis. Can J Cardiol. 2021 Apr;20.
[20] Hartnett KP, Kite-Powell A, DeVies J, Coletta MA, Boehmer TK, Adjemian J, et al. Impact of the COVID-19 pandemic on emergency department visits – United States, January 1, 2019 – May 30, 2020. MMWR Morb Mortal Wkly Rep. 2020;69:699–704.
[21] Westgard BC, Morgan MW, Vazquez-Benitez G, Erickson LO, Zwank MD. An analysis of changes in emergency department visits after a state of declaration during the time of COVID-19. Ann Emerg Med. 2020 Nov;76(5):595–601.
[22] Nourazari S, Davis S, Granovsky R, Austin R, Straff DJ, Joseph JW, et al. Decreased hospital admissions through emergency departments during the COVID-19 pandemic. Am J Emerg Med. 2021 Apr;42:203–10.
[23] Isik G, Cevik Y. Impact of COVID-19 pandemic on visits of an urban emergency department. Am J Emerg Med. 2021 Jan 14;42:78–82.
[24] Morello F, Bima P, Ferreri E, Chiarlo M, Balzaretti P, Tirabassi G, et al. After the first wave and beyond lockdown: long-lasting changes in emergency department visit number, characteristics, diagnoses and hospital admissions. Intern Emerg Med. 2021 Mar;8:1–8.
[25] Lee DD, Jung H, Lou W, Rauchwerger D, Chartier LB, Masood S, et al. The impact of COVID-19 on a large, Canadian community emergency department. West J Emerg Med. 2021 May;5.
[26] Boserup B, McKenney M, Elkbuli A. The impact of the COVID-19 pandemic on emergency department visits and patient safety in the United States. Am J Emerg Med. 2020 Sep;38(9):1732–6.
[27] Kim HS, Cruz DS, Conrardy M, Gandhi KR, Seltzer JA, Loftus TM, et al. Emergency department visits for serious diagnoses during the COVID-19 pandemic. Acad Emerg Med. 2020 Sep;27(9):910–3.
[28] Walker LE, Heaton HA, Monroe RJ, Reichard RR, Kendall M, Mullan AF, et al. Impact of the SARS-CoV-2 pandemic on emergency department presentations in an integrated health system. Mayo Clin Proc. 2020 Nov;95(11):2395–407.
[29] Choudhary R, Gautam D, Mathur R, Choudhary D. Management of cardiovascular emergencies during the COVID-19 pandemic. Emerg Med J. 2020 Dec;37(12):778–80.
[30] Lange SJ, Ritchey MD, Goodman AB, Dias T, Twentyman E, Fuld J, et al. Potential indirect effects of the COVID-19 pandemic on the use of emergency departments for acute life-threatening conditions – United States, January –may 2020. MMWR Morb Mortal Wkly Rep. 2020 Jun 26;69(25):795–800.
[31] Montagnon R, Rouffilange L, Agard G, Benner P, Cazes N, Renard A. Impact of the COVID-19 pandemic on emergency department use: focus on patients requiring urgent revascularization. J Emerg Med. 2021 Feb;60(2):229–36.
[32] Fu X-Y, Shen X-F, Cheng Y-R, Zhou M-Y, Ye L, Feng Z-H, et al. Effect of COVID-19 outbreak on the treatment of patients with acute ST-segment elevation myocardial infarction. Am J Emerg Med. 2020 Sep;17:S0735–6757(20) [30833-0].
[33] Pines JM, Zocchi MS, Black BS, Celedon P, Carlson JN, Moghtaderi A. The effect of the COVID-19 pandemic on emergency department visits for serious cardiovascular conditions. Am J Emerg Med. 2021 Sep;47:42–51.
[34] Chhabra S, Eagles D, Kwok ESH, Perry JJ. Interventions to reduce emergency department door-to-electrocardiogram times: a systematic review. CJEM. 2019;21(5):607–17.
[35] Kontos MC, Kurz MC, Roberts CS, Joyner SE, Kreisa L, Ornato JP, et al. Emergency physician-initiated cath lab activation reduces door to balloon times in ST-segment elevation myocardial infarction patients. Am J Emerg Med. 2011 Oct;29(8):868–74.
[36] Fretheim A, Tomic O. Statistical process control and interrupted time series: a golden opportunity for impact evaluation in quality improvement. BMJ Qual Saf. 2015 Dec 1;24(12):748–52.
[37] Xbar Chart Formulas. QI Macros. Accessed May 10, 2021 https://www.qimacros.com/control-chart-formulas/x-bar-r-chart-formula/; 2020.
[38] Control chart rules are used to perform stability analysis. QI Macros. Accessed online May 10 2021 https://www.qimacros.com/control-chart/stability-analysis-control-chart-rules/; 2019.
[40] McLaren JTT, Kapoor M, Yi SL, Chartier LB. Using ECG-to-activation time to assess emergency physicians' diagnostic time for acute coronary occlusion. J Emerg Med. 2021 Jan;60(1):25–34.
[41] McLaren JTT, Taher AK, Kapoor M, Yi SL, Chartier LB. Sharing and teaching ECGs to minimize infarction (STEMI): reducing diagnostic delay for acute coronary occlusion in the emergency department. Am J Emerg Med. 2021 Mar 25;48:18–32.
[42] McCabe JM, Armstrong EJ, Hoffmayer K, Brave PD, MacGregor JS, Hsue P. Impact of door-to-activation time on door-to-balloon time in primary percutaneous intervention for ST-segment elevation myocardial infarctions: a report from the activate-SF registry. Circ Cardiovasc Qual Outcomes. 2012 Sep 1;5(5):672–9.
[44] Roffi M, Guagliumi G, Ibanez B. The obstacle course of reperfusion for ST-segment elevation myocardial infarction in the COVID-19 pandemic. Circulation. 2020 Jun 16;141(24):1951–3.
[45] Mahmud E, Dauerman HL, Welt RGP, Messenger JC, Rao S, Grines C, et al. Management of acute myocardial infarction during the COVID-19 pandemic: a position statement from the Society for Cardiovascular Angiography and Interventions (SCAI), the American College of Cardiology (ACC), and the American College of Emergency Physicians (ACEP). J Am Coll Cariol. 2020 Sep 15;76(11):1375–84.