COVID-19 lockdown impact on quality of treatment and outcomes of STEMI and Stroke patients in a large tertiary medical center: an observational study

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Abstract

Background: The COVID-19 pandemic affected healthcare systems worldwide, leading to fewer admissions and raising concerns about quality-of-care. The objective of the study was to investigate the early effects of the COVID-19 pandemic on quality-of-care among stroke and ST-elevation myocardial infarction (STEMI) patients, focusing on clinical outcomes and direct treatment costs.

Methods: This retrospective, observational study was based on the 10-week period that included the first wave of the COVID-19 pandemic in Israel (2/15/2020–4/30/2020). Emergency department (ED) admissions for stroke and STEMI were compared to parallel periods in 2017–2019, focusing on demographics, risk and severity scores, and the effect of clinical outcomes on hospitalization costs.

Results: The 634 stroke and 186 STEMI cases comprised 16% and 19% fewer admissions, respectively, compared to 2019. No significant changes were detected in demographics, most disease management parameters, readmission and mortality outcomes. Mean door-to-balloon time increased insignificantly by 33%, lowering the health quality indicator (HQI) for treatment in <90 minutes from 94.7% in 2017–2019 to 83% in 2020 ($p=0.022$). Among suspected stroke patients, 97.2% underwent imaging, with 28% longer median time from admission ($p=0.05$). Consequently, only 24.3% met the HQI of imaging in <29 minutes, compared to 45.5% in 2017–2019 ($p<0.01$). Increased length of stay and more intensive care unit admissions were the leading causes of 6.5% increased mean cost of STEMI patients' initial hospitalization, which totalled $29,300 in the COVID-19 period ($p=0.008$).

Conclusion: The initial pandemic period caused a decline in HQI linked to diagnostic and treatment protocols, without changes in outcomes, but with increased hospital costs. Medical information and awareness of life-threatening conditions among patients and caregivers should be increased to enable proper diagnosis and management.

Keywords: COVID-19, health quality indicators (HQI), clinical outcomes, cerebro-vascular accident (CVA), stroke, acute ST-elevation myocardial infarction (STEMI)

Introduction

The COVID-19 pandemic caused by the SARS-CoV-2 virus affected healthcare systems worldwide. Recent research showed that the pandemic's effect on emergency departments (ED), included a 12-50% decrease in the arrival of STEMI and stroke cases due to healthcare avoidance.[1,2]

Israel initiated pandemic coping strategies in early March 2020, with restrictions on air travel and gatherings that gradually led to a complete lockdown, rescinded at the end of April 2020. This caused changes in health service consumption, including ED referrals and admissions.[3]

Many countries have invested considerable efforts to improve the performance of their healthcare systems, while curbing excessive expenditures. These efforts are reflected in a variety of organizational, professional, and administrative activities known collectively as "quality improvement in medicine". Some of the most notable steps are quality measurement programs, which assess key aspects of medical treatment to evaluate and improve effectiveness.[4]

The impact of the COVID-19 pandemic on healthcare systems has been studied extensively. Several studies reported changes in disease severity and effects on medical quality, as demonstrated by health quality indicators (HQI). Some examined primary care[5,6] and oncology[7] but most focused on ED admissions.[1,8,9] However, no study focused on HQI and economic effects of the pandemic on emergency care.

Conventional treatment for ST elevation myocardial infarction (STEMI) includes urgent percutaneous coronary intervention (PCI) within 90 minutes of arrival to the hospital which has been shown to reduce 30-day and one-year morbidity and mortality.[10]

Treatment of acute cerebral events begins with diagnosis via CT/MRI. Rapid diagnosis is critical, as brain injury becomes irreversible over time. The American Stroke Association

(ASA) recommends the test be performed within 20 minutes from patient arrival[11] and within 29 minutes according to the Israel Ministry of Health (MOH) HQI program[12].

AHA/ASA recommendations for ischemic stroke include rapid thrombolytic therapy via intravenous recombinant tissue plasminogen activator (IV-rt-PA). [11] Maximum effectiveness of treatment is obtained up to 3 hours from the onset of symptoms, but moderate efficacy is found 3-4.5 hours after.[13]

The current study aimed to better understand the early effects of the COVID-19 pandemic on the emergency services of a large tertiary medical centre in Israel, focusing on patients seeking or avoiding acute medical care for stroke and STEMI. Disease severity, clinical outcomes and changes in HQI and direct treatment costs in the three years preceding the pandemic were compared to those during the first wave.
Results may assist policymakers and healthcare organizations in addressing issues that potentially harm public health, as shown by HQI and clinical outcomes.

Methods

Study design

This retrospective, observational cohort study included all patients who visited the ED of a 1,900-bed, university-affiliated, tertiary referral medical centre in Israel, from February 15 to April 30, in 2017–2020, who were diagnosed with STEMI or stroke according to the Israeli Ministry of Health criteria for quality measurement programs.[12] The study period was defined as February 15–April 30, 2020 while the control period was the same dates for the three previous years (2017–2019). This timeframe was based on the initial COVID-19 preparations on February 15, 2020. The first confirmed case on February 20, 2021, marked the onset of the first wave, which ended when the lockdown was lifted and ambulatory services were restored on April 30. During that period, medical staff gradually moved to 12-hour shifts while coping with staff shortages due to quarantine and other tasks, such as an additional respiratory ED and COVID-19 screening. Staff shortages, reaching up to 15% in some professions, also caused delays or unavailability of services, including imaging, operating rooms and catheterization labs.

Data were obtained using the MDClone big data platform (MDClone, Beer-Sheva, Israel),[14] a validated data extraction and processing platform used for research and decision-making in medical centres. MDClone allows extraction of desired cohorts and their characteristics, including demographics; clinical, social and financial data; and related events during the patient's care path. We collected patient information regarding comorbidities, imaging and laboratory tests, and administrative and demographic data during a patient's initial hospitalization and up to 30 days post-discharge.

Outcome measures

The primary outcomes of interest for STEMI patients were whether the HQI were accomplished within 90 minutes from arrival in the ED to PCI. PCR examinations were done in the ER, after which patients were transported to the catheterization laboratory regardless of their COVID-19 status. For stroke, primary outcomes were IV-rt-PA thrombolysis administered within 4.5 hours or brain catheterization within 24 hours from symptom onset, for patients arriving at the ED up to 3.5 hours since the first sign of stroke symptoms. All patients with cerebro-vascular accident (CVA) or transient ischemic attack (TIA) should have had a CT or MRI within 29 minutes of ED arrival.

Secondary outcomes were in-hospital mortality, out-of-hospital mortality, readmission within 30 days post-discharge and ED readmission within 7 days.

To assess event severity and mortality risk for STEMI,[15] the TIMI and GRACE 2.0[16] indices were calculated, together with the TIMI Grade Flow, which is based on blood flow in the coronary arteries during catheterization. The severity of the cerebral event was assessed by comparing the National Institutes of Health Stroke Scale (NIHSS) and Modified Ranking Scale (MRS) indices at admission and discharge, when available. These represent disability or dependence in daily activities following stroke.[17]

Hospitalization costs were based on length of stay (LOS), department type and imaging exams during the initial hospitalization and 30 days post-discharge. The interventional procedures PCI, IV-rt-PA and brain catheterization were priced using the relevant DRG (diagnosis-related group) code, which include hospitalization costs, regardless of LOS.

These were calculated according to the MOH, April 2020 price list (in New Israeli Shekels) and was converted to USD using a 3.5 conversion rate.

Statistical Methods

STEMI and stroke data were compared for February 15–April 30 in 2017–2020, first by year and then by comparing 2020 with the other 3 years combined. Categorical variables were compared using Chi-squared or Fisher's exact test (when the numbers were small). Continuous variables were checked for normality. Normal variables were compared using ANOVA (analysis of variance); non-normal variables were analysed using the Kruskal-Wallis Rank Sum Test. Stroke patients were also stratified by the treatment they received (IV-rt-PA or brain catheterization) and by the interval until they received it. The p-values in each table were adjusted for multiple comparisons (using the false discovery rate method).

Statistical analyses were conducted using R-3.4.1 (R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/).

Results

Patients and demographics

A total of 186 patients with a clinical diagnosis of STEMI and 634 with stroke was admitted during the same periods of the 4-year study. Baseline characteristics are summarized in Table 1 (STEMI) and Table 2 (stroke).

In 2020, total ED, stroke and STEMI admissions were 20%, 19% and 16% lower, respectively, compared to the parallel period in 2019. No significant changes were found when comparing 2020 admissions to the average of 2017–2019.

Similarly, no differences were found in key characteristics of stroke patients (Table 2). Although, some non-significant differences between 2020 and 2019 were noticed in age and gender distributions.

Clinical and background characteristics

Contrary to the TIMI risk score, which showed an increased medium-group risk (p=0.04), the GRACE 2.0 risk score and the KILLIP score showed no increased risk based on patient background diseases and laboratory tests at admission. This correlates with the consistency in the known medical history, vital signs and laboratory findings for STEMI patients during the study (Table 1).

Stroke patients showed no differences in clinical admission parameters and event severity (Table 2). The percentage of patients in the high-severity group (14+) of admission NIHSS increased, while medium-severity group (6-13) patients decreased. These changes were not significant.

Outcomes

Even though STEMI patient characteristics showed no differences over the study periods, except for the change in risk scores, the HQI of door-to-balloon (DTB) <90 minutes decreased from an average of 94.7% to 83% in 2020 (p=0.022; Table 3); a 33% increase. When divided according to patient journey stages, mean interval from hospital admission to ED release was not affected, while the mean interval from ED release to procedure start increased 63% (p=0.037). Additionally, catheter laboratory procedure time increased by 7% in the COVID-19 period compared to 2019, as opposed to a decrease in the trend noticed in previous years. No changes were found in LOS, mortality and readmission.

More than 50% of stroke patients did not have a clear symptom start time and thus, no symptom-to-hospital time. Although non-significant, a smaller proportion of patients arrived in the recommended period of <3.5 hours, which led to a 28% increase (p=0.027) in symptom start to IV-rt-PA time (Table 4).

A non-significant decrease in patients who underwent IV-rt-PA and an increase in brain catheterizations were noticed, with no changes over time between treatment type. Significant changes were found only in the >3.5-hour group, with 72.2% undergoing brain catheterization in 2020 versus 40% in the previous years (p=0.025).

No change was found among suspected stroke arrivals, as 97.2% underwent imaging in 2020.

Median admission-to-image time was 28% longer in 2020 (p=0.05), resulting in only 24.3% (p<0.001) of suspected and 37.5% (p=0.029) of confirmed stroke-patients meeting the HQI of imaging in <29 minutes, compared to 45.5% and 53.9%, respectively, in the previous years.

LOS decrease was non-significant, but when focusing on symptom-to-arrival times, total LOS decreased 30% in the <3.5-hour group (p=0.05), while the >3.5-hour group had a 65% increase (p=0.04). Event impact showed no change based on MRS and NIHSS scores, together with ED and hospital readmissions and mortality rates.

Costs

Increases in STEMI patients' (Figure 1) total and ICU LOS led to a 7% increase in expenditures during the initial admission and 30-day follow-up, from an average of $27.4K to $29.3K in 2020 (p=0.008). Excluding PCI, expenditures increased by 15%, from $9.2K to $10.6K in 2020 (p=0.02).

Stroke patients had a non-significant 9% cost increase, from $11.2K to $12.1K in 2020. However, deduction of costly IV-rt-PA procedures led to a 10% decrease from $6.2K to $5.6K in 2020.

Further analysis of stroke patients (Figure 1) based on symptom-to-hospital arrival time, showed a 70–78% increase in expenditures in the >3.5 hours' group. When thromboembolic procedures were considered, costs grew to $41.2K (p=0.008). When they were excluded, the mean cost was $13.5K per patient (p=0.04).

Discussion

Principal findings

This study evaluated the effects of the COVID-19 pandemic on ED-related HQIs, outcomes and costs between 2020 and the previous three years. We found moderate declines in total STEMI (19%) and stroke (16%) ED visits, and in total ED visits (20%) in 2020 compared to 2019.

The HQI of PCI within 90 minutes for STEMI declined 13.8%. The mean DTB from ED release to the catheter laboratory increased, the main delay was likely due to catheter laboratory availability. In addition, extra precautions taken due to COVID-19, added to the delay. These included designated and protected transport and additional time for laboratory staff to don protective gear. This is contrary to our hypothesis that the effect was only due to structural changes in the ED and that COVID-19 virus can mimic symptoms of a cardiac event, mainly due to respiratory system complaints; thus, prolonging diagnosis and catheterization.[18]

More severe TIMI risk scores and extended DTB times may have caused the prolonged catheter laboratory time, leading to more intense ICU care and longer hospital stays. Nevertheless, in-hospital and 30-day follow-up outcomes showed that optimal, quality treatment was provided despite the pandemic circumstances.

To our knowledge, this is the first study to examine changes in stroke HQI during the COVID-19 period. While a stable 97.2% of all patients with suspected CVA/TIA underwent imaging, the mean waiting time increased, and the percentage undergoing imagining in ≤29 minutes decreased significantly in 2020. This was in part due to patients who delayed arriving because of COVID-19 and needed additional consultation because they had missed the therapeutic window. Highly-suspected stroke cases received relatively prompt treatment according to clinical intake and diagnosis.

The HQI of thrombolytic brain treatment did not suffer from the delays in arrival and imaging. Although IV-rt-PA administration from symptom start increased 20%, the percentage of patients receiving one or both treatments decreased slightly compared to 2019.

This is the first study to examine direct changes in treatment costs, including 30-day hospital follow-up, due to the COVID-19 pandemic. These innovative findings demonstrated an increase in both STEMI and stroke patients' costs compared to previous years. Excluding procedure costs led to a decrease in stroke costs, while STEMI costs remained higher than in previous years.

The main factor causing increased costs for STEMI patients was extended LOS, especially ICU stays. This suggests that although event severity did not increase, factors, such as delayed diagnosis and treatment, shown by higher DTB time, may have worsened a patient's condition, requiring prolonged and more intensive care.

Delays in patients' arrivals, combined with imaging and diagnosis delays, led to more patients missing the therapeutic window for IV-rt-PA. This resulted in a significant increase of 72.2% of patients in the >3.5-hour group undergoing brain catheterization. A decrease in LOS of stroke patients led to a parallel decrease in costs. When procedure costs were included, increased catheter procedures led to higher costs, especially in the>3.5-hour group.

Strengths and limitations

Our innovative comparisons, first by year and then by comparing 2020 with the other 3 years together, strengthens the findings that changes during the first wave of COVID-19 arose directly from the effect of the pandemic. We assumed that fewer arrivals and decreases in hospital occupancy, together with the increased availability of procedure rooms would lead to better treatment outcomes. However, it appears that the new logistic structure, together with staff quarantines and ED safety precautions led to a decrease in HQI and as a result, an additional extensive, economic burden on the healthcare system.

This study examined information from one medical centre; albeit the largest in Israel and the first to receive COVID-19 patients. During the study, the weighted average of COVID-19 patients was about 15% of all the country's patients, although the medical centre constitutes only 7% of the hospital beds in Israel, indicating a higher morbidity burden. Accordingly, the logistical, clinical, and managerial arrangements were different than those in other medical centres, and may not represent the true impact of the pandemic on other centres and on the healthcare system in Israel.

We assume that the decrease in ED arrivals was due to COVID-19 restrictions and that the incidence of STEMI and stroke was similar to previous years. Accordingly, excess deaths at home affected the profile of patients attending the medical centre.[19]

In-hospital complications such as infection, thrombosis, etc. which can explain prolonged LOS where not included in the study design.

Non-statistically significant differences found could be due to the small sample size, resulting from the short period examined or multi-year comparisons.

Interpretation within the context of the wider literature

ED admissions were in the lower range of the 12–43% reported decline in STEMI admissions, [8,20–22] 17-40% in stroke admissions, [23–25] and 33-50% in total ED visits.[26]

While the main reasons for fewer ED arrivals might be due to a combination of public awareness and fear of infection, as well as a desire not to overload the ED for the benefit of other patients[27], the relatively low decrease was related to greater availability of community medical facilities and a better understating of emergencies both by the public and primary caregivers, which led to quick treatment in the community and hospital referrals. This is contrary to the findings of the European SHARE study, which found that Israelis had the highest proportion of forgoing medical treatment (27%) and postponing appointments (20%) compared to other countries.[28]

Similar to our study, no significant changes in risk scores were found for STEMI[8,27] and stroke,[9,23–25,29] or in the time from initial stroke symptoms to hospital arrival[9,24,29] and time from hospital arrival to imaging for stroke, although the Israeli National Stroke Registry study did not focus on the HQI itself.[29]

A non-significant change in mean DTB time was similar to that reported in most studies,[8,20,21,25,27] while some reported prolonged DTB time.[1,22]

ED and hospital readmissions as well as mortality did not change significantly during study periods, similar to other studies regarding STEMI[8,22] and stroke.[24,29] The

STEMI quality indicator of PCI within 90 minutes, which declined, was addressed only in one study that found no difference over time.[8]

Contrary to our findings, several studies reported at least a one day decrease in LOS during the COVID-19 period and shorter ICU duration for STEMI[22,27] and stroke patients.[24]

Implications for policy, practice and research

Lockdowns and social distancing might have led patients with acute medical conditions to avoid medical care. Increased social isolation may also have decreased the likelihood of friends and family members recognizing that a patient required medical attention. The MOH should provide public education on awareness of stroke and cardiac symptoms, when to seek emergency care, and to seek medical care during a pandemic, just as during normal times.

In addition, people with COVID-19 can have symptoms similar to those of a heart attack, including chest pain, shortness of breath and ECG changes[18], which can delay diagnosis and treatment. The public and healthcare professionals, especially primary and emergency caregivers should be aware of this, to ensure patients receive appropriate care as soon as possible.

A more comprehensive study should be conducted to understand the full impact of the pandemic, using three main vectors. First, a similar study should be conducted in other hospitals with results normalized to the pandemic burden. Second, additional HQI, including hospital, community, emergency services, etc. should be examined to understand the functionality of all parts of the healthcare system. Third, longer post-discharge follow-up should be evaluated, and readmissions should be explored for changes in patient behaviour. Lessons learned during this pandemic can be applied to future healthcare emergencies.

Conclusions

Similarities in patients' characteristics over the study period, together with only minor changes in event severity showed that despite restrictions related to the COVID-19 pandemic, patients sought emergency care and arrived at the hospital after minimal delay. Fewer patients arriving to the ED can be explained by a combination of public awareness, preparedness in designated hospitals and fear of medical treatment, caused by the extended risk of exposure and a desire not to overload the ED for the benefit of other patients.[27] This led to a decrease in demand for hospital and community healthcare services in general, and in ED admissions in particular.

We assume that structural, patient flow and treatment protocol changes that required additional examinations, waiting for COVID test results and time needed to don protective gear, together with staff shortages due to quarantine and other tasks (e.g., an additional respiratory ED), may have led to a shift in managerial and staff focus regarding key treatment principals.

Contributorship: AG Conceived of, designed and led the study, extracted the data and planned the statistical analysis. **RM** Conceived of and designed of the work, supervised the study, planned the statistical analysis, reviewed the final version of the manuscript for intellectual content. **AEZ** Reviewed the final version of the manuscript for intellectual content. **BO** Planned, performed the statistical analysis, reviewed the final version of the manuscript for intellectual content. **EZ** Conceived of and designed the work, supervised the study, reviewed the final version of the manuscript for intellectual content. **All authors** assisted with interpretation of the data, as well as provided critical feedback related to the research and manuscript revision

Ethical considerations: The study was approved by the Sheba Medical Center Institutional Review Board, SMC-7546-20, on 9/30/2020. Patient informed consent was waived.

Conflicts of interest: The authors have no conflicts of interest to declare.

Data availability: Data will be made available upon reasonable request from Alex Galper, alex.galper@gmail.com

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Table 1. STEMI patients' demographic and clinical characteristics

Characteristic	Variable	2020	2019	2018	2017	p-value	Total / Average 2017-2019	p-value
n		47	58	36	45		139 / 46	
Sex	Male (%)	36 (76.6)	45 (77.6)	32 (88.9)	35 (77.8)	0.49	112 (80.6)	0.707
Age, years	Mean, SD	62.9 (11.9)	63.0 (12.0)	62.5 (12.2)	67.8 (14.9)	0.16	64.4 (13.2)	0.479
	<49, n (%)	7 (14.9)	6 (10.3)	5 (13.9)	7 (15.6)	0.063	18 (12.9)	0.58
	50-59, n (%)	12 (25.5)	20 (34.5)	11 (30.6)	7 (15.6)		38 (27.3)	
	60-69, n (%)	15 (31.9)	13 (22.4)	9 (25.0)	13 (28.9)		35 (25.2)	
	70-79, n (%)	10 (21.3)	15 (25.9)	7 (19.4)	5 (11.1)		27 (19.4)	
	>80, n (%)	3 (6.4)	4 (6.9)	4 (11.1)	13 (28.9)		21 (15.1)	

Comorbidities	Diabetes, n (%)	16 (34.0)	24 (41.4)	7 (19.4)	15 (33.3)	0.18	46 (33.1)	1
	Smoking, n (%)	24 (51.1)	20 (34.5)	13 (36.1)	21 (46.7)	0.28	54 (38.8)	0.195
	Hypertension, n (%)	22 (46.8)	30 (51.7)	15 (41.7)	21 (46.7)	0.82	66 (47.5)	1
	Heart disease, n (%)	10 (21.3)	9 (15.5)	6 (16.7)	12 (26.7)	0.52	27 (19.4)	0.949
ECG	Anterior ST elevation, n (%)	3 (6.4)	8 (13.8)	1 (2.8)	8 (17.8)	0.10	17 (12.2)	0.397
Laboratory and vital signs	Creatinine (SD)	0.98 (0.41)	1.00 (0.47)	1.11 (0.75)	2.43 (9.24)	0.32	1.49 (5.28)	0.505
	Abnormal cardiac enzymes (%)	39 (83.0)	47 (81.0)	26 (72.2)	41 (91.1)	0.17	114 (82.0)	1
	Pulse, mean (SD)	84.7 (18.7)	79.5 (14.1)	73.72 (14.3)	75.5 (19.6)	0.009*	76.7 (16.2)	0.005
	Systolic blood pressure (SD)	139.8 (23.5)	138.1 (23.9)	137.3 (21.3)	140.9 (27.7)	0.89	138.8 (24.4)	0.804
	Weight (kg) mean (SD)	80.5 (17.1)	82.3 (16	81.1 (13	76.2 (21	0.33	80.0 (17.4)	0.881

			.1)	.1)	.4)			
TIMI flow	0 (%)	18 (38.3)	29 (50.0)	23 (63.9)	26 (57.8)	0.013*	78 (56.1)	0.099
	1 (%)	12 (25.5)	15 (25.9)	6 (16.7)	1 (2.2)		22 (15.8)	
	2 (%)	5 (10.6)	9 (15.5)	3 (8.3)	6 (13.3)		18 (12.9)	
	3 (%)	12 (25.5)	5 (8.6)	4 (11.1)	12 (26.7)		21 (15.1)	
Killip score	1 (%)	41 (87.2)	51 (87.9)	31 (86.1)	39 (86.7)	0.60	121 (87.1)	0.639
	2 (%)	2 (4.3)	4 (6.9)	3 (8.3)	3 (6.7)		10 (7.2)	
	3 (%)	3 (6.4)	0 (0.0)	1 (2.8)	3 (6.7)		4 (2.9)	
	4 (%)	1 (2.1)	3 (5.2)	1 (2.8)	0 (0.0)		4 (2.9)	
TIMI risk score	0 – 2 (%)	24 (51.1)	33 (56.9)	24 (66.7)	38 (84.4)	0.024*	95 (68.4)	0.04
	3 – 7 (%)	23 (48.9)	24 (41.4)	11 (30.6)	7 (15.6)		42 (30.2)	
	≥8 (%)	1 (2.1)	1 (1.	1 (2.	0 (0.		2 (1.4)	

			7)	8)	0)			
Grace risk score	<10% (%)	16 (34.0)	15 (25.9)	14 (38.9)	8 (17.8)	0.32	29 (30.9)	0.75
	10%-<20% (%)	17 (36.2)	29 (50.0)	13 (36.1)	17 (37.8)		42 (44.7)	
	20%-<40% (%)	9 (19.1)	8 (13.8)	5 (13.9)	10 (22.2)		13 (13.8)	
	≥40% (%)	5 (10.6)	6 (10.3)	4 (11.1)	10 (22.2)		10 (10.6)	

*After adjustment for multiple comparisons, this was no longer significant

Table 2. Stroke patients' demographic and clinical characteristics

Characteristic	Variable	2020	2019	2018	2017	p-value	Total/ Average 2017-2019	p-value
n		155	185	158	136		479/160	
Sex	Male (%)	83 (53.5)	103 (55.7)	89 (56.3)	77 (56.6)	0.92	269 (56.2)	0.634
Admission age, years	Mean (SD)	74.4 (11.4)	72.5(13.2)	73.9(13.3)	73.0 (14.9)	0.53	73.1 (13.72	0.289
	<49 (%)	4 (2.6)	9 (4.9)	9 (5.7)	11 (8.1)	0.112	28 (5.8)	0.103
	50-59 (%)	9 (5.8)	24 (13.0)	13 (8.2)	15 (11.0)		49 (10.2)	

	60-69 (%)	37 (23.9)	44 (23.8)	38 (24.1)	25 (18.4)		108 (22.5)	
	70-79 (%)	52 (33.5)	51 (27.6)	41 (25.9)	30 (22.1)		118 (24.6)	
	>80 (%)	53 (34.2)	57 (30.8)	57 (36.1)	55 (40.4)		176 (36.7)	
Smoking	Current (%)	7 (4.5)	12 (6.5)	8 (5.1)	11 (8.1)	0.706	31 (6.5)	0.49
Vital signs	Pulse (SD)	79.1 (15.2)	78.1 (17.3)	79.7 (18.9)	77.1 (15.11)	0.44	78.3 (17.2)	0.631
	Systolic blood pressure (SD)	154.0 (29.4)	157.6 (27.2)	155.2 (28.4)	148.4 (28.9)	0.075	153.9 (28.4)	0.976
	Weight (kg) (SD)	76.4 (14.9)	76.3 (17.0)	75.4 (14.2)	76.0 (17.1)	0.88	75.9 (16.2)	0.769
Admission NIHSS	Median [IQR]	6 [2,16]	6 [2,10]	6 [3,13]	8 [3,16]	0.13	6 [3, 13]	0.861
	0-5 (%)	26 (48.2)	28 (49.1)	25 (50.0)	17 (39.5)		70 (46.7)	
	6-13 (%)	11 (20.4)	20 (35.1)	13 (26.0)	12 (27.9)	0.35	45 (30.0)	0.3
	14+ (%)	17 (31.5)	9 (15.8)	12 (24.0)	14 (32.		35 (23.3)	

					6)			
Baseline MRS	Median [IQR]	0 [0, 1]	0 [0, 1]	0 [0, 0]	0 [0, 1]	0.40	0 [0, 1]	0.51
	0-2 (%)	57 (90.5)	60 (89.6)	52 (88.1)	N/A	0.97	112 (88.9)	1
	3-6 (%)	7 (9.5)	7 (10.4)	7 (11.9)	N/A		14 (11.1)	
Discharge MRS	Median [IQR]	2.00 [1.00, 4.00]	3.00 [1.00, 4.25]	3.00 [1.00, 5.00]	2.00 [1.00, 4.00]	0.64	3.00 [1.00, 5.00]	0.374
	0-2 (%)	47 (54.7)	43 (48.9)	33 (45.8)	N/A	0.52	76 (47.5)	0.35
	3-6 (%)	39 (45.3)	45 (11.1)	39 (54.2)	N/A		84 (52.5)	

MRS, Modified Ranking Scale; NIHSS, National Institutes of Health Stroke Scale

Table 3. STEMI patients' clinical outcomes

Outcome	Variable	2020	2019	2018	2017	p-value	Total/ Average 2017-2019	p-value
	N	47	58	36	45		139 / 46	
Door to balloon, minutes	mean (SD)	77.34 (130.1)	58.3 (92.30)	46.03 (34.42)	145.70 (293.9)	0.48	83.4 (182.4)	0.58
	<90 minutes (%)	38 (80.9)	55 (96.5)	34 (94.4)	31 (68.9)	<0.001	89 (94.7)	0.022
Length of stay, days	Total (SD, N)	6.4 (4.5, 47)	5.6 (5.5	5.4 (3.0	6.8 (14.	0.823	5.9 (8.9, 139)	0.738

			, 58)	, 36)	2, 45)			
	Cardiac ICU (SD, N)	3.6 (2.2, 47)	2.8 (2.0, 58)	3.4 (2.4, 36)	2.8 (2.8, 45)	0.241	2.9 (2.4, 139)	0.116
	Cardiology (SD, N)	2.3 (1.3, 39)	2.4 (2.9, 51)	2.1 (1.1, 30)	2.6 (2.2, 39)	0.781	2.4 (2.3, 120)	0.745
	Other departments (SD, N)	7.3 (7.7, 6)	10.3 (12.5, 4)	3.0 (2.0, 3)	13.0 (26.1, 6)	0.845	9.9 (18.4, 13)	0.755
PCI duration, minutes	Mean (SD)	38.2 (16.8)	35.64 (14.71)	44.39 (20.62)	46.80 (20.22)	0.04*	41.5 (18.8)	0.29
Mortality	In hospital (%)	2 (4.3)	2 (3.4)	1 (2.8)	3 (6.7)	0.86	6 (4.3)	1
	30-day (%)	2 (4.25)	3 (5.17)	2 (5.56)	3 (6.67)	0.97	8 (5.8)	1
Readmission	ED (%)	3 (6.4)	2 (3.45)	0	0	0.21	2 (1.4)	0.08
	Hospital (%)	8 (12.8)	7 (12.1)	1 (2.8)	2 (4.4)	0.09	10 (7.2)	0.08

* After adjustment for multiple comparisons, this was no longer significant

Table 4. Stroke patients' clinical outcomes and image quality indicators

Outcome	Variable	2020	2019	2018	2017	p-value	Total/ Average 2017-2019	p-value
	N	155	185	158	136		479/160	
Treatment	No treatment (%)	125 (80.6)	153 (82.7)	125 (79.1)	121 (89.0)	0.174	399 (83.3)	0.211
	IV-rt-PA (%)	8 (5.2)	15 (8.1)	14 (8.9)	6 (4.4)	0.41	35 (7.3)	
	Catheter (%)	18 (11.6)	10 (5.4)	16 (10.1)	6 (4.4)	0.82	13 (2.7)	
	Both treatments (%)	4 (2.6)	7 (3.8)	3 (1.9)	3 (2.2)	0.46	32 (6.7)	
	No treatment (%)	125 (80.6)	153 (82.7)	125 (79.1)	121 (89.0)	0.13	524 (82.6)	0.52
	Any treatment (%)	30 (19.4)	32 (17.3)	33 (20.9)	15 (11.0)		110 (17.4)	
Length of stay, days	Total (SD, N)	7.8 (9.8, 155)	8.1 (8.9, 185)	8.6 (8.9, 158)	9.6 (9.7, 136)	0.347	8.7 (9.1, 479)	0.297
	Neurology (SD, N)	7.7 (6.0, 84)	8.8 (5.7, 76)	9.7 (7.5, 71)	9.4 (8.1, 62)	0.301	9.3 (7.1, 293)	0.085
	Neurosurgery (SD, N)	6.8 (7.8, 4)	10.0 (NA, 1)	11.0 (13.9, 3)	13.2 (12.2, 6)	NA	12.2 (11.3, 14)	0.399
	Internal med. (SD,	7.0 (12.0,	6.9 (9.3,	6.9 (7.5,	7.7 (8.8,	0.925	7.10 (8.59, 361)	0.933

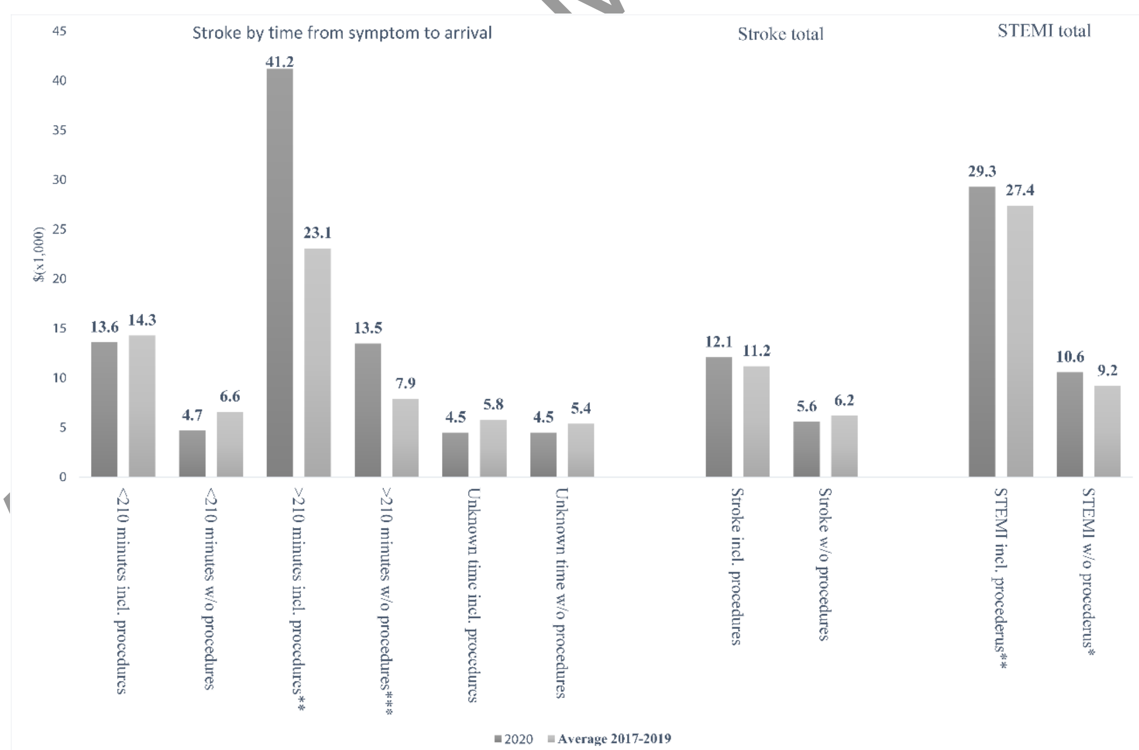
	N)	76)	116)	92)	77)			
Symptom start to treatment, minutes	IV-rt-PA (SD)	235.33 (102.01)	196.64 (61.69)	184.53 (45.24)	153.44 (72.49)	0.12	184.25 (59.54)	0.027
	Catheter (SD)	543.36 (354.20)	592.82 (356.96)	364.42 (122.39)	318.33 (126.04)	0.292	441.49 (264.33)	0.191
Mortality	In-hospital (%)	11 (7.1)	19 (10.3)	13 (8.2)	8 (5.9)	0.51	40 (8.4)	0.74
	30-day (%)	14 (9.0)	23 (12.4)	16 (10.1)	14 (10.3)	0.77	53 (11.1)	0.57
Readmission	ED (%)	5 (3.2)	6 (3.2)	4 (2.5)	3 (2.2)	0.94	13 (2.7)	0.78
	Hospital (%)	8 (12.8)	8 (4.3)	3 (1.9)	12 (8.8)	0.055	23 (4.8)	1
Symptom to arrival time	<210 min (%)	56 (36.1)	78 (42.2)	67 (42.4)	57 (41.9)	0.91	202 (42.2)	0.41
	>210 min (%)	18 (11.6)	18 (9.7)	18 (11.4)	14 (10.3)		50 (10.4)	
	unregistered (%)	81 (52.3)	89 (48.1)	73 (46.2)	65 (47.8)		227 (47.4)	
Length of stay, days	<210 min (SD)	6.4 (5.6)	8.7 (10.2)	8.6 (9.9)	10.5 (11.2)	0.15	9.2 (10.4)	0.05
	>210 min (SD)	18.8 (21.2)	8.7 (6.8)	13.1 (8.5)	12.5 (11.1)	0.16	11.4 (8.8)	0.04
	unregistered (SD)	6.4 (5.9)	7.4 (8.2)	7.6 (7.6)	8.2 (7.6)	0.5	7.7 (7.8)	0.16

Imaging ≤29 minutes	Suspected (%)	25 (24.3)	50 (43.1)	44 (51.8)	59 (43.7)	0.0001	153 (45.5)	<0.001
	Confirmed (%)	24 (37.5)	42 (58.3)	40 (61.5)	43 (45.3)	0.016*	125 (53.9)	0.029
Admission to image time, minutes	mean (SD)	44.7 (36.0)	38.5 (44.4)	34.8 (39.0)	51.3 (53.8)	0.104	43.7 (48.4)	0.88
	median [IQR]	32.00 [22.0,51.3]	25.0 [19.0,39.8]	22.0 [17.0,33.0]	28.5 [19.0,70.3]	0.012	25.0 [18.0,46.0]	0.05

*After adjustment for multiple comparisons, this was no longer significant

Figure legend

Figure 1. STEMI and stroke patient costs by year in USD (thousands)



*p=0.02, **p=0.08, ***p=0.04