International Journal of Medical Informatics 161 (2022) 104726

Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.elsevier.com/locate/ijmedinf

Impact of telemedicine on clinical practice patterns for patients with chest pain in the emergency department

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ARTICLE INFO

Keywords:
Telemedicine
Emergency department
Care delivery
Chest pain

ABSTRACT

Background: The outbreak of the COVID-19 pandemic has led to the rapid adoption of novel telemedicine programs within the emergency department (ED) to minimize provider exposure and conserve personal protective equipment (PPE). In this study, we sought to assess how the adoption of telemedicine in the ED impacted clinical order patterns for patients with chest pain. We hypothesize that clinicians would rely more on imaging and laboratory workup for patients receiving telemedicine due to limitation in physical exams.
Methods: A single-center, retrospective, propensity score matched study was designed for patients presenting with chest pain at an ED. The study period was defined between April 1st, 2020 and September 30th, 2020. The frequency of the most frequent lab, imaging, and medication orders were compared. In addition, poisson regression analysis was performed to compare the overall number of orders between the two groups.
Results: 455 patients with chest pain who received telemedicine were matched to 455 similar patients without telemedicine with standardized mean difference < 0.1 for all matched covariates. The proportion of frequent lab, imaging, and medication orders were similar between the two groups. However, telemedicine patients received more orders overall (RR, 1.19, 95% CI, 1.11, 1.28, p-value < 0.001) as well as more imaging, lab, and nursing orders. The number of medication orders between the two groups remained similar.
Conclusions: Frequent labs, imaging, and medications were ordered in similar proportions between the two cohorts. However, telemedicine patients had more orders placed overall. This study is an important objective assessment of the impact that telemedicine has upon clinical practice patterns and can guide future telemedicine implementation after the COVID-19 pandemic.

1. Introduction

The adoption of telemedicine in the emergency department (ED) greatly increased during the COVID-19 pandemic in order to minimize provider exposure and conserve personal protective equipment (PPE). However, it has been unclear whether this rapid adoption impacted clinical practice patterns.

Prior to the COVID-19 pandemic, ED telemedicine is primarily used for specialty consultation [1–3], triage-intake, [4] or management of low acuity patients to increase ED capacity.[5] During the COVID-19 pandemic, the application of ED telemedicine evolved into a clinical practice strategy to enable on-site physicians to conduct medical evaluation and screening for ED patients with infection risks.[6]

While ED telemedicine was implemented out of necessity during the pandemic, we sought to examine whether this practice has affected care delivery. On the one hand, telemedicine may reduce the friction of patient assessment by forgoing the need to don and doff PPE, but it could possibly change clinical practice patterns due to limitations in physical exams or potential technological issues interfering with assessment. Studying the current telemedicine practice will help us identify areas of improvement in the care processes, as telemedicine will likely continue to serve as an important modality for care delivery after the COVID-19

Abbreviations: ED, Emergency Department; COVID-19, Coronavirus Disease 2019; PPE, Personal Protective Equipment; IQR, Interquartile Range; SMD, Standardized Mean Difference; EHR, Electronic Health Record; ECG, Electrocardiogram; RR, Rate Ratio.

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https://doi.org/10.1016/j.ijmedinf.2022.104726
Received 9 August 2021; Received in revised form 19 February 2022; Accepted 21 February 2022
Available online 23 February 2022

pandemic.

In this study we investigated the impact of telemedicine in the care delivery for patients presenting with chest pain in an academic emergency department. Specifically we studied clinical practice patterns by comparing the most frequent laboratory, imaging and medication orders for these patients. We also sought to assess the overall frequency of orders placed in the ED. Chest pain was chosen as the chief complaint for analysis due to the relatively standardized work-up in the ED, high acuity level, and well-defined quality measures.

2. Methods

We performed a single-center, retrospective, propensity score matched study to examine the effects of ED telemedicine on clinical practice patterns for patients presenting with chest pain. The ED in this study is a suburban Level 1 trauma center with an annual volume of 80,000 patients and part of a 605 bed tertiary academic referral center in California. The study period was defined between April 1st, 2020 and September 30th, 2020. A robust ED telemedicine program was in place by April 1st with the introduction of iPads that were enabled with Zoom (Zoom Communications, San Jose, CA), which allowed for video based communications with patients without entering the patient room.[8] This telemedicine program was designed for patients who were at high suspicion for COVID-19 infection, either due to a previous positive COVID-19 test or symptoms consistent with COVID-19. Other patients were treated with standard protocols.

Telemedicine was not directly documented in the electronic health record (EHR). Therefore, we used strict inclusion criteria to define the patients who would have likely received telemedicine interventions. Any adult patient who had airborne isolation precautions documented within an hour of triage initiation as well as a COVID-19 test ordered during their ED visit was considered an ED telemedicine patient. Those who had no isolation precautions documented and no COVID-19 test performed were considered controls. Those with isolation precautions documented but no COVID test or those with COVID-19 tests but no isolation precautions documented were excluded. Within each group, those with chest pain were identified via a documented chief complaint of chest pain, chest tightness, or chest discomfort or an ICD10 diagnosis code of R07, I21, I22, I23, or I24, consistent with previous studies.[2,9] Chest pain was chosen as the chief complaint for analysis due to the relatively standardized work-up in the ED, high acuity level, well defined quality measures, and ease of defining a cohort. A separate sensitivity analysis was performed where telemedicine was defined by documentation of isolation procedures regardless of COVID-19 testing as many of the COIVID-19 tests were performed as surveillance in the ED.

The cohort was then 1:1 propensity score matched on age, gender, ED disposition, insurance status, and evaluation/management level with a caliper width of 0.05 times the standard deviation of the propensity score. Balance was assessed between the two groups using standardized mean difference (SMD). An SMD < 0.1 for each matched covariate was considered acceptable.

The top ten most frequent lab orders and top 5 most frequent imaging orders for the cohort were determined and compared between the two groups. The total number of orders and the total number of specific types of orders were compared between the two groups using a quasi-poisson regression that accounted for overdispersion. Two models were constructed, one that without any adjustment and another that was adjusted for variables used for propensity score matching to eliminate residual confounding and the patients' total length of stay in the ED. All cancelled orders were removed from the analysis. After matching, all isolation and COVID-19 orders were excluded when comparing order frequencies.

As a secondary analysis, we also investigate how telemedicine impacted the timeliness of care by calculating three specific time-based quality metrics for each patient: arrival to first ECG obtained, arrival to Troponin I order, and arrival to aspirin administration if given. For these metrics, only orders placed in the first hour of triage were analyzed.

All continuous values were reported as medians with interquartile range (IQR). All discrete values were reported as percentages. P-values for continuous values were calculated using a Wilcox signed-rank test and a chi-squared test was used for categorical comparisons. All statistical tests were two-sided and a p-value of < 0.05 was considered significant. All statistical analysis was performed using R 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

A total of 29,457 visits from 21,934 unique patients occurred during the study period (Fig. 1). Patients who were not eligible or unlikely to receive ED telemedicine were excluded, including patients seen at the ED solely for COVID-19 testing, patients<18 years old, trauma activations, and psychiatric holds. This resulted in 23,925 patient visits eligible for analysis. Of these eligible patient visits, 15,917 (66.53%) had a COVID-19 PCR test ordered anytime during their ED visit of which 8,186 also had airborne precautions documented within one hour of triage and were considered the cohort of patients receiving telemedicine. Of the 8,008 (33.47%) patients who did not have a COVID-19 test ordered, 7,777 did not have airborne precautions documented and were considered part of the control cohort.

Propensity score matched patient characteristics between the telemedicine and control cohorts are shown in Table 1. Propensity score matched variables were well balanced, with an SMD < 0.1 for all matched covariates. The median age of the telemedicine cohort was 43.0 years (IQR, 33.0, 55.0) compared to 44.0 (IQR, 33.0, 56.0) for the control group (SMD, 0.023). A majority of both cohorts were discharged home after their ED encounter (410/455 (90.1%) for the telemedicine cohort, 404/455 (88.8%) for the control cohort, SMD, 0.054). Patients in the telemedicine cohort tended to have longer ED stays (4.72 h for the telemedicine cohort (IQR, 3.55, 6.32) compared to 4.07 h for the control cohort (IQR, 2.93, 5.50)).

The proportion of patients receiving the 10 most frequent lab orders was compared over the course of their ED visit (Table 2). Generally, patients receiving telemedicine had more tests ordered compared to controls and only the proportion of patients who had a Brain Natiuretic Peptide (BNP) ordered was significantly different between the two groups (4.6% for controls, 10.3% for telemedicine patients, p-value, 0.002). In terms of imaging orders, telemedicine patients again generally had more orders placed but no group received a statistically significant higher proportion compared to the controls. Medication orders placed were also similar between the two groups.

Quasi-poisson regression revealed that overall, patients who received telemedicine in the ED has more total orders placed (rate ratio (RR), 1.21, 95% CI, 1.12, 1.29, p-value < 0.001), a trend which continued after adjustment for matching covariates and length of stay (RR, 1.19, 95% CI, 1.11, 1.28, p-value < 0.001) (Table 3). This trend was also observed across all subtypes of orders with the exception of medication orders, which was similar between the two groups (RR, 0.86, 95% CI, 0.69, 1.06, p-value, 1.153)

Time metrics for the two cohorts for three time-sensitive chest pain orders were calculated: 12-lead ECG, troponin I, and aspirin administration (Table 4). When comparing the time between ED arrival and placing the order, only time to order a 12-lead ECG took a statistically significant longer period of time (5.0 min for controls, 8.0 min for telemedicine cohort, p-value < 0.001, median of differences, 2.0 min). When considering the total time from arrival to order result, both troponin I (104 min for controls, 123 min for telemedicine cohort, p-value < 0.001, median of differences, 15.0 min) and a 12-lead ECG (12 min for controls, 18 min for telemedicine cohort, p-value < 0.001, median of differences 4.0 min) took longer in the telemedicine cohort. This trend was not observed for aspirin orders.

A sensitivity analysis was performed where assignment to telemedicine or control was based on isolation procedures documented in the

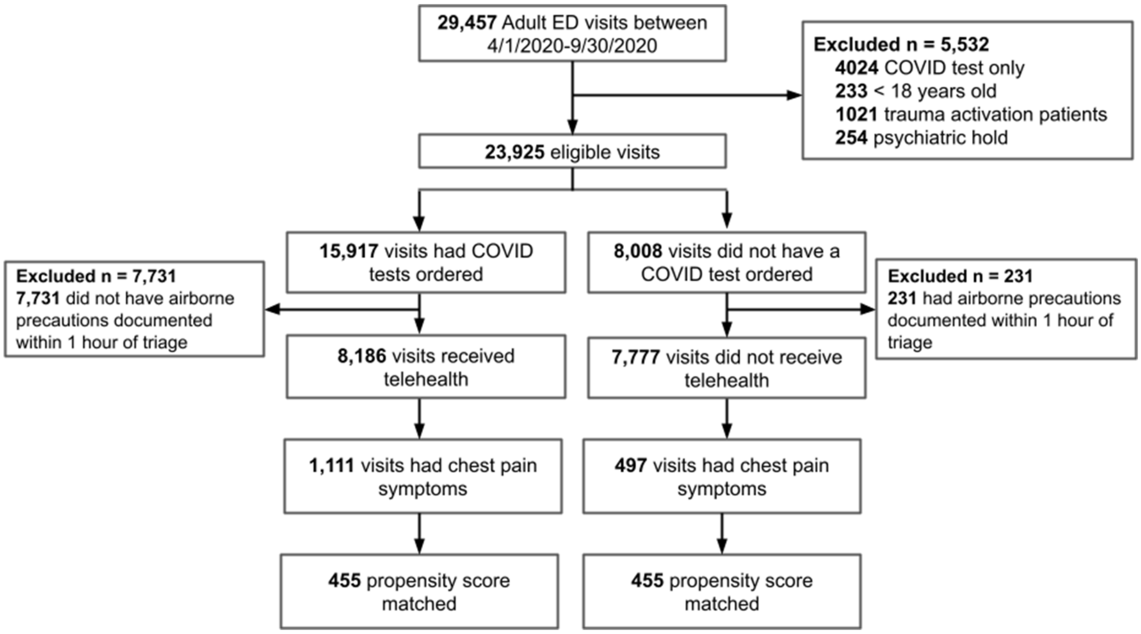

Fig. 1. Study cohort definition.

Table 1
Patient characteristics, SMD: Standardized Mean Difference.

Variable	Control (n = 455)	Telemedicine (n = 455)	SMD
Age, years, median [IQR]	43.0 [33.0, 55.0]	44.0 [33.0, 56.0]	0.023
Male, n (%)	227 (49.9)	228 (50.1)	0.013
Disposition			0.054
Admit to Inpatient, n (%)	27 (5.9)	29 (6.4)	
Discharge, n (%)	410 (90.1)	404 (88.8)	
Place in Observation, n (%)	9 (2.0)	12 (2.6)	
Against Medical Advice, n (%)	5 (1.1)	5 (1.1)	
Other, n (%)	4 (0.9)	5 (1.1)	
Evaluation/Management Level			0.080
Critical Care, n (%)	8 (1.8)	8 (1.8)	
Level 2, n (%)	5 (1.1)	6 (1.3)	
Level 3, n (%)	108 (23.7)	107 (23.5)	
Level 4, n (%)	257 (56.6)	244 (53.6)	
Level 5, n (%)	65 (14.3)	76 (16.7)	
No Acuity, n (%)	12 (2.6)	14 (3.1)	
Insurance Status			0.069
Private, n (%)	217 (47.7)	227 (49.9)	
Public, n (%)	220 (48.4)	207 (45.5)	
Other, n (%)	8 (1.8)	11 (2.4)	
Self-Pay, n (%)	10 (2.2)	10 (2.2)	
ESI Triage Level			0.147
1, n (%)	2 (0.4)	2 (0.4)	
2, n (%)	59 (13.0)	77 (16.9)	
3, n (%)	386 (84.8)	373 (82.0)	
4, n (%)	8 (1.8)	3 (0.7)	
5, n (%)	0 (0.0)	0 (0.0)	
LOS, hrs, median [IQR]	4.07 [2.93, 5.50]	4.72 [3.55, 6.32]	0.304

Table 2
Comparison of the proportion of patients receiving frequent orders. Note that COVID-19 PCR orders were excluded from lab orders.

	Control (n = 455)	Telemedicine (n = 455)	p-value
Lab Order			
ECG 12-Lead	384 (84.4)	424 (93.2)	0.170
Metabolic Panel	333 (73.2)	358 (78.7)	0.361
Complete Blood Count (CBC)	319 (70.1)	351 (77.1)	0.231
Troponin I	322 (70.8)	335 (73.6)	0.640
Prothrombin Time	48 (10.5)	65 (14.3)	0.132
Partial Prothrombin Time (PTT)	43 (9.5)	64 (14.1)	0.053
Lipase	60 (13.2)	62 (13.6)	0.927
D-Dimer	34 (7.5)	49 (10.8)	0.124
Magnesium	45 (9.9)	51 (11.2)	0.610
Brain Natriuretic Peptide (BNP)	21 (4.6)	47 (10.3)	**0.002**
Imaging Study			
Chest X-Ray	271 (59.6)	286 (62.9)	0.553
Echoocardiogram	7 (1.5)	6 (1.3)	1.000
CT Chest Angiography	11 (2.4)	17 (3.7)	0.344
CT Head	9 (2.0)	8 (1.8)	1.000
CT Abdomen Pelvix	6 (1.3)	4 (0.9)	0.751
Medication			
Normal Saline	49 (10.8)	57 (12.5)	0.497
Acetaminophen	49 (10.8)	48 (10.5)	1.000
Aspirin	30 (6.6)	31 (6.8)	1.000
Lidocaine	31 (6.8)	18 (4.0)	0.086
Alum-Mag	25 (5.5)	16 (3.5)	0.211

EHR regardless of COVID-19 testing. In this analysis, of the 23,925 patients who were eligible, 8417 had isolation precautions documented within 1 h of triage (telemedicine cohort) ,14,544 had no isolation precautions documented (control cohort), and 964 patients who had isolation precautions documented more than one hour after triage were excluded from the analysis. 954 patients with chest pain from both groups were matched using the same propensity score matching parameters. SMD between the two groups were all<0.1. Results were generally similar (see supplemental table S1-S3).

4. Discussion

We performed a propensity-score matched, retrospective cohort study to analyze the impact of telemedicine for patients who presented with chest pain in the emergency department at an academic institution.

Overall telemedicine does not affect the frequency of orders placed compared to controls based on an analysis of the most frequent laboratory, imaging and medication orders. However, there appears to be some evidence that patients in the telemedicine group have more orders placed overall and more diagnostic studies performed in terms of labs

Table 3
Quasi-Poisson regression model comparing order counts between telemedicine and control cohorts. The adjusted rate ratios were adjusted for age, gender, billing level, insurance status, and length of stay. Note that COVID-19 PCR and isolation orders were excluded from orders prior to this analysis.

Order Class	Controls (median, IQR)	Telemedicine (median, IQR)	Raw Rate Ratio (95% CI)	p-value	Adj Rate Ratio (95% CI)	p-value
All	9 (6, 12)	10 (7, 14)	1.21 (1.12, 1.29)	<0.001	1.19 (1.11, 1.28)	<0.001
Imaging	1 (0, 1)	1 (1, 1)	1.19 (1.07, 1.33)	0.002	1.16 (1.04, 1.30)	0.006
Labs	6 (4, 8)	6 (5, 8)	1.09 (1.02, 1.17)	0.012	1.08 (1.01, 1.16)	0.020
Medications	0 (0, 1)	0 (0, 1)	0.86 (0.69, 1.06)	0.153	0.89 (0.72, 1.10)	0.279
Nursing Orders	0 (0, 1)	1 (1,4)	1.88 (1.58, 2.25)	<0.001	1.87 (1.56, 2.23)	<0.001

Table 4
Time metrics for time-sensitive chest pain related orders.

Order Name	Control (n = 455)	Telemedicine (n = 455)	p-value	Median of Difference [95% CI]
ECG 12-Lead				
Arrival to Order, minutes, median (IQR)	5.0 (3.0, 9.8)	8.0 (4.0, 14.0)	**<0.001**	2.0 (1.0, 3.0)
Order to Result, minutes, median (IQR)	6.0 (4.0, 9.0)	8.0 (5.0, 13.0)	**<0.001**	2.0 (1.0, 3.0)
Arrival to Result, minutes, median (IQR)	12.0 (8.0, 19.0)	18.0 (11.0, 26.0)	**<0.001**	4.0 (3.0, 6.0)
Troponin I				
Arrival to Order, minutes, median (IQR)	24.0 (10.0, 40.0)	25.0 (14.0, 40.0)	0.247	2.0 (-1.0, 4.0)
Order to Result, minutes, median (IQR)	77.0 (64.0, 95.0)	92.0 (75.0, 114.0)	**<0.001**	13.0 (9.0, 17.0)
Arrival to Result, minutes, median (IQR)	104.0 (87.0, 130.0)	123.0 (102.0, 143.0)	**<0.001**	15.0 (11.0, 21.0)
Aspirin				
Arrival to Order, minutes, median (IQR)	34.0 (16.5, 46.5)	40.5 (30.0, 55.0)	0.088	9.0 (-1.0, 20.0)
Order to Admin, minutes, median (IQR)	16.0 (9.0, 33.0)	18.0 (9.8, 24.3)	0.956	0.0 (-8.0, 5.0)
Arrival to Admin, minutes, median (IQR)	51.0 (32.0, 81.0)	56.5 (48.3, 74.5)	0.475	5.0 (-9.0, 18.0)

and imaging orders. This suggests that physician workflow due to isolation precautions might be altered to rely less upon physical exam and more on objective assessments. Importantly, medication orders remained the same between the two groups, suggesting that the interventions delivered did not change as a result of this workflow change.

When comparing to the control group, we observed telemedicine is associated with increased door-to-ECG time and troponin order-to-result time. The difference is likely related to the time needed for donning and doffing PPE when staff performed ECG and blood draw for these patients but the additional friction introduced by telemedicine could also impact timeliness. Regardless, the effect size of these differences is rather small (4 min and 13 min respectively) [10].

These changes in clinical care processes have important implications for the future use of telemedicine in the ED as well as patient safety. Any future implementation of telemedicine within the ED should consider the impact of more diagnostic test orders on workflow and clinical decision making. Another important financial implication of these changes is an increase in cost of ED visits to patients. While the impact on timeliness of care was minimal for this cohort, other patient populations studied could demonstrate further delayed care due to telemedicine that might have a meaningful clinical impact. Future implementations should outline and monitor important time-based quality metrics for patient subgroups to ensure that emergency care is not delayed and patient safety is not compromised.

There have been several studies published over the course of the COVID-19 pandemic that describe proof-of-concept implementations of telemedicine within the hospital and out of the hospital.[12–15] These studies demonstrated several advantages to these types of systems, including minimizing provider exposure [6] and managing surge capacity[16] as well as potential drawbacks such as device connectivity issues[12], difficulty performing physical exams[17], and variability in patient receptiveness to telemedicine.[12] While some recent evidence has cast doubt upon if inpatient telemedicine truly conserves PPE[18], several studies have described innovative approaches to emergency care using telemedicine which have blossomed from improved telemedicine infrastructure including monitoring of high-risk discharged patients [19], remote consults to the ED[20], or training of new providers.[21] This study moves beyond simply describing the implementation process and begins to examine how telemedicine actually impacts clinical process metrics within the ED considering the changes in clinical workflow that telemedicine necessitates. These data can help ED leadership understand how telemedicine impacts care that is being delivered, make changes to telemedicine programs to correct for any potential patient safety or quality of care, and consider how future implementations of telemedicine beyond COVID-19 will impact clinical operations in the ED.

There are several limitations of this study. First, this is a single center study which may affect generalizability. Second, given lack of documentation of telemedicine use, we relied on a proxy based upon COVID-19 testing status and airborne precautions when defining our cohort. Lastly, our study focused on process measures only, and future studies should investigate whether telemedicine could impact clinical outcomes. While the process metrics examined in this study show minor changes to clinical workflow, the most meaningful outcomes to both patients and physicians are comparisons of meaningful clinical outcomes, such as in-hospital or 30-day mortality. Once enough telemedicine encounters occur within our healthcare system, powering a study to examine these clinical outcomes would be possible. In the interim, reliance upon proxy measures such as process metrics is necessary.

Nevertheless, our study establishes important first steps in understanding the impact of ED telemedicine in care delivery processes which will help improve future telemedicine implementation, as there will be an ongoing need for telemedicine to serve populations with poor access to ED services even after the COVID-19 pandemic abates.

5. Conclusion

For patients presenting with chest pain in an academic emergency department, the proportion of frequent orders placed remained the same but telemedicine was associated with more orders placed overall, particularly imaging and lab orders. Further study is needed to determine whether such differences may lead to changes in clinical outcomes.

6. Summary Table

What was already known on the topic

(continued on next page)

(*continued*)

- Remote telemedicine delivery has always played an important role in care delivery in the Emergency Department by improving access to specialists and decreasing in-person provider care burden.
- The COVID-19 pandemic forced the rapid adoption of telemedicine as a tool to preserve personal protective equipment and decrease provider infection risk.

What this study added to our knowledge

- Patients who receive telemedicine had more orders placed overall as well as more imaging and laboratory orders, potentially due decreased reliance upon a physical exam to guide orders.
- Although the impact upon clinical outcomes is still unknown, telemedicine alters ED provider practice patterns in a fashion that may increase the testing burden for patients and result in more expensive ED visits.

Author contributions

All authors contributed substantially to this work. WI originally conceived of the project. IB initially collected data. NO and WI performed data analysis and wrote the initial manuscript. IB and RL gave critical revisions. All authors have read and approved this manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

None.

Author contributions

All authors contributed substantially to this work. WI originally conceived of the project. IB initially collected data. NO and WI performed data analysis and wrote the initial manuscript. IB and RL gave critical revisions. All authors have read and approved this manuscript.

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