Impact of the COVID pandemic on emergency department CT utilization: where do we go from here?

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Received: 5 May 2022 / Accepted: 13 June 2022 / Published online: 21 June 2022
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Abstract

Purpose To analyze the impact of the coronavirus disease (COVID) pandemic on emergency department (ED) computed tomography (CT) utilization.

Methods A retrospective observational study was conducted assessing seven hospitals’ ED imaging volumes between Jan. 6, 2019, and Feb. 27, 2021. Weekly CT utilization is reported as CTs ordered per 100 ED visits. Utilization was ascertained in aggregate and by body area. Interrupted time series analysis was performed to assess significance of utilization change. Prespecified sensitivity analysis was performed for influenza-like or COVID-like illness (ILI/CLI).

Results Weekly ED CT utilization increased from 35.9 CTs per 100 visits (95% confidence interval [95% CI] 35.8–36.1) to 41.8 per 100 visits (95% CI 41.7–42.0) in pre- and post-pandemic periods. Weekly ED CT chest utilization increased immediately following the pandemic declaration (+0.52 chest CTs per 100 ED visits, 95% CI 0.01–1.03, p < 0.05) and compared to pre-pandemic period (+0.02 per 100 ED visits, 95% CI 0.02–0.05, p < 0.02). For both CT abdomen/pelvis and CT head, there was neither an immediate effect (+0.34 CT-AP per 100 ED visits, 95% CI −0.74 to 1.44, p = 0.89; −0.42 CT-H per 100 ED visits, 95% CI −1.53 to 0.70, p = 0.46) nor a change in weekly CT utilization (+0.03 CT-AP per 100 ED visits, 95% CI −0.01 to 0.05, p = 0.09; +0.03 CT-H per 100 ED visits, 95% CI −0.01 to 0.06, p = 0.10).

Conclusion These data may help formulate future strategies for resource utilization and imaging operations as we envision a future with COVID and other federal mandates affecting imaging utilization and appropriateness.

Keywords COVID-19 · Emergency radiology · Imaging utilization · Computed tomography · Emergency department · Clinical operations

Introduction

The COVID pandemic resulted in a significant impact on most aspects of the US healthcare system. Since the World Health Organization (WHO) first declared COVID a global pandemic on March 11, 2020 [1], US federal and state policies and procedures have been implemented in an attempt to limit the spread and impact of this pandemic [2, 3]. To reduce the risk of COVID-19 transmission, hospitals, health systems, and medical societies recommended the cancellation or postponement of nonurgent medical procedures and imaging services. These restrictions, in conjunction with local “stay at home” orders, resulted in a significant decline in hospital-based healthcare services across the globe, including imaging and emergency services [4–6]. ED patient visit volumes decreased 40–75% [7–9], and ED imaging volumes decreased by 28–58% [10–14]. While some proportion of the decreased healthcare utilization is thought to be deferral of elective care [15], a number of studies have also found visits for emergent conditions, such as ST-elevation myocardial infarction and stroke also decreased in the early pandemic [16–20].

Prior to COVID, national ED visit volumes had been increasing annually at rates higher than anticipated based on population growth, with a 10-year volume changes up as much as 32% and a 20-year volume changes up to 57%
With the background of CT utilization increasing, several studies have evaluated patterns of CT use during the COVID pandemic, finding a decline in the absolute number of CT orders [10, 15, 28–31]. These decreases have been attributed to decreased imaging of lower acuity patients [10]; however, the data are difficult to interpret given that EDs nationwide experienced a nearly 40% reduction in visit volumes during the early COVID pandemic [7, 32]. Looking more specifically at CT chest utilization in the pandemic context, one prior study analyzing data in a single health system during the first 3 months of the pandemic noted a significant increase in CT chest utilization, despite a 46% drop in overall CT utilization; however, these data were not analyzed relative to the dynamic changes in ED volume [30]. CT chest imaging may have increased because early studies suggested that CT chest imaging can improve diagnostic accuracy when added to molecular testing for COVID [33, 34] as well as an increased risk for thromboembolic disease in patients with COVID [35].

In the setting of previously rising ED volumes and CT utilization, it remains to be seen how the impact of the COVID pandemic on ED volumes and resource utilization will affect ED clinician’s decision making practices and imaging utilization going forward. Prior researchers have called for further studies demonstrating how the pandemic has affected imaging utilization and ordering practices [30].

The purpose of this study was to describe CT utilization in the ED setting since the start of the global pandemic across a single health system. These data will add to the body of literature detailing the influence of COVID-19 on CT utilization which, in turn, may aid others in predictions and institutional preparedness efforts for the current pandemic as well as future states.

**Methods**

**Study design**

This was a retrospective time series analysis of ED visits and imaging volumes in one large Midwestern academic health system from January 6, 2019, to February 27, 2021. The health system is the largest integrated academic health system in Illinois with a cumulative volume of 400,000 annual ED visits in fiscal year 2019. The current study includes seven EDs across five counties, including one super high-volume urban academic tertiary care center.

**Data collection and extraction**

Aggregated imaging volume data and ED operational data were abstracted from the electronic data warehouse (EDW) using structured query language. Weekly volume data for total CT imaging studies as well as the total subcategorized by body area (CTs of the brain, abdomen/pelvis, and chest) were collected from seven of the EDs in the health system over the study period.

**Statistical analysis**

We tabulated the weekly number of CT scans ordered during ED visits from 1/6/19 to 2/27/21 to compare CT utilization trends before and after the onset of the COVID pandemic. Due to known substantial declines in ED visit volumes during the pandemic, we standardized weekly CT utilization by the total ED visit volumes in order to present adjusted CTs ordered per 100 ED visits [21].

We then evaluated weekly CT utilization trends using single group interrupted time series analyses with ordinary least squares regression and Newey-West standard errors, adjusting for the following a priori selected covariates: median age and ED length of stay and proportion of ED visits of female sex and admitted to the hospital. After selecting lag intervals based on Cumby-Huizinga tests for autocorrelation, we set the intervention time as the week beginning on 3/8/20 to capture the WHO pandemic declaration issued on 3/11/20 (week 62) [1]. We considered the pandemic to have a significant effect on adjusted CT utilization if either the immediate effect coefficient or the change in post-intervention trend over time was significant at \( p < 0.05 \). Our primary focus was on the utilization of CT chest orders, but we performed the same interrupted time series analyses for CT abdomen/pelvis and CT head orders for comparative purposes. All statistical analyses were performed in Stata v14.2 (StataCorp, College Station, TX) using the itsa and actest packages.

To confirm the robustness of our results, we conducted a sensitivity analysis evaluating only CT utilization among ED visits with an influenza-like or COVID-like illness, defined by a system-wide infectious disease screening protocol for symptoms of fever with cough or shortness of breath, or the presence of a COVID-19 diagnosis.

This retrospective observational study was approved by the Institutional Review Board at our institution. The need to obtain informed consent was waived. Aggregate data on ED demand and CT utilization from the health system were pooled without individual patient level identification. We adhered to the STROBE reporting guidelines.

**Results**

There were 618, 972 ED visits and 237, 053 CTs obtained during the 112 week-long study period. Mean ED visit volumes decreased from 6,063 visits/week in the pre-pandemic
period to 4,885 visits/week in the pandemic period. The first COVID diagnosis in the health system was the week of 3/1/20, followed by a sharp weekly increase into bimodal peaks of 449 and 780 weekly COVID-19 diagnoses during the weeks of 4/19/20 and 11/8/20, respectively. ED visits in the pandemic period were older (44.4 years vs 40.6 years, \( p < 0.001 \)), less likely to be female (55.0 vs 55.6\%\), \( p < 0.001 \), and had a higher admission rate (22.7\% vs 20.4\%, \( p < 0.001 \)) than those in the pre-pandemic period. The median ED lengths of stay were similar (3.2 vs 3.4 h, \( p = 0.08 \)).

Weekly ED CT utilization increased from a mean of 35.9 CTs per 100 visits (95% confidence interval [95% CI] 35.8–36.1) in the pre-pandemic period to 41.8 CTs per 100 visits (95% CI 41.7–42.0) in the post-pandemic period. Figure 1 displays the weekly adjusted ED CT utilization and COVID-19 diagnoses.

Figure 2 displays the interrupted time series analysis of weekly ED CT chest utilization, adjusted for age, sex, admit rate, and ED length of stay. Prior to the pandemic declaration during the week of 3/8/20 (Week 62), there was no significant change in the weekly ED CT chest utilization rate of 4.4 CTs per 100 ED visits (\( p = 0.15 \)). In the first week following the pandemic declaration, there was an immediate significant increase in ED CT chest utilization (+0.52 chest CTs per 100 ED visits, 95% CI 0.01–1.03, \( p < 0.05 \)) and a significant increase in the pandemic weekly rate of ED CT chest utilization compared to the pre-pandemic period (+0.02 chest CTs per 100 ED visits, 95% CI 0.02–0.05, \( p < 0.02 \)). The mean weekly ED CT chest utilization reached a bimodal peak during the post-pandemic period of 7.05 and 8.56 CTs per 100 ED visits during the weeks of 4/19/20 and 11/15/20, respectively, coinciding with bimodal peaks in COVID-positive cases (Fig. 1).

Interrupted time series analyses for CT abdomen/pelvis and CT head utilization are presented in eFigs. 1 and 2. For both CT abdomen/pelvis and CT head, there was neither an immediate effect following the pandemic declaration (+0.34 CT-AP per 100 ED visits, 95% CI −0.74 to 1.44, \( p = 0.89 \); −0.42 CT-H per 100 ED visits, 95% CI −1.53 to 0.70, \( p = 0.46 \)) nor a change in the post-pandemic weekly rate of CT utilization compared to the pre-pandemic period (+0.03 CT-AP per 100 ED visits, 95% CI −0.01 to 0.05, \( p = 0.09 \); +0.03 CT-H per 100 ED visits, 95% CI −0.01 to 0.06, \( p = 0.10 \)).

We found similar findings in the sensitivity analysis of only those ED visits for whom an influenza-like or COVID-like illness (ILI/CLI) was suspected (i.e., fever with cough or shortness of breath). Prior to the pandemic declaration (Fig. 3), there was no significant change in the weekly ED CT chest utilization rate of 4.4 CTs per 100 ED visits (\( p = 0.29 \)). In the first week following the pandemic declaration, there was an immediate significant increase in ED CT chest utilization (+0.77 chest CTs per 100 ED visits, 95% CI 0.14–1.40, \( p = 0.02 \)), and in the following weeks, there was a significant increase in the pandemic weekly rate of ED CT chest utilization compared to the pre-pandemic period (Fig. 3).
looking at the absolute number of imaging studies (rather than imaging rates) that demonstrated decreased overall imaging volumes [10–14]. Despite the decreased ED patient arrivals resulting from the onset of the COVID pandemic, CT utilization per 100 visits increased in our study. Our data, therefore, argue against theories that ordering clinicians may have changed behavior with a more conservative utilization of diagnostic imaging services [15]. In contrast, it is possible that the increased CT use may reflect additional factors such as local practice patterns (which contributed to the pre-pandemic CT utilization of 35.9/100 ED visits), as well as rising patient acuity, admission rates, and patient age may all have contributed [36–38].

When evaluating ED CT chest utilization specifically, our data show a significant increase in ED CT chest utilization following the start of the COVID pandemic compared to historical control time period. The CT chest utilization increase aligns with prior research [30] and is likely attributable to the increase in respiratory-related ED visits as well as CT chest’s utility in the diagnostic evaluation and prognostic assessment of COVID-19 and its associated complications [35, 39, 40]. We did not identify any significant immediate changes in CT abdomen/pelvis or CT brain utilization. However, there were continued nonsignificant increases in both exam types from the pre-pandemic to pandemic timeframes. It is possible that some component of these increases represents the continuation of historical trends that predated the pandemic, such as our local health system ED CT utilization and local practice patterns. Other factors contributing to the increase may be that delayed and deferred care related to the pandemic may have led to an increased need for advanced imaging as patients presented later with worsened clinical conditions [36–38].

The sensitivity analysis of only those ILI/CLI-related ED visits found similar results to our overall study population. Although weekly CT chest utilization in the sensitivity analysis cohort reached bimodal peaks coinciding with the trends observed in the main analysis (Fig. 3; 5.45 and 7.64 CTs per 100 ED visits during the weeks of 4/19/20 and 11/15/20, respectively), CT utilization notably decreased in the weeks between these bimodal peaks to a level below that of the pre-pandemic rate (nadir 2.68 CTs per 100 ED visits on 8/30/20).

### Discussion

Compared to pre-pandemic baseline, there was a significant increase in rates of both overall ED CT utilization and ED CT chest utilization following the start of the COVID pandemic. The collateral effect of the COVID pandemic on healthcare utilization, including its effect on ED visit number and severity of disease as well as need for advanced diagnostic imaging, has been a concern for emergency physicians throughout the stages of the pandemic. Our study found an increase in overall ED CT utilization rates following the start of the COVID pandemic, which contrasts to prior studies looking at the absolute number of imaging studies (rather than imaging rates) that demonstrated decreased overall imaging volumes [10–14]. Despite the decreased ED patient arrivals resulting from the onset of the COVID pandemic, CT utilization per 100 visits increased in our study. Our data, therefore, argue against theories that ordering clinicians may have changed behavior with a more conservative utilization of diagnostic imaging services [15]. In contrast, it is possible that the increased CT use may reflect additional factors such as local practice patterns (which contributed to the pre-pandemic CT utilization of 35.9/100 ED visits), as well as rising patient acuity, admission rates, and patient age may all have contributed [36–38].

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various comorbid conditions, as well as utility of CT chest in both diagnosis and prognostic assessment of suspected COVID and the exclusion of related conditions (e.g., pulmonary embolism) [34, 35, 39–42].

These data add a more detailed understanding of how CT imaging use has evolved during this crisis, which is particularly important as we consider a future state during which clinicians will be required to consult tools to determine appropriateness of select high impact imaging studies [43]. EDs are currently encountering a large volume of patients with a relatively new disease process, one in which investigations are ongoing regarding how to best incorporate CT chest into an appropriate and evidence-based diagnostic evaluation, and for which clinical practice guidelines are yet to be developed [39]. This dynamic environment may inadvertently result in imaging being deemed inappropriate, impacting institutional compliance and performance relative to any relevant future mandates.

This study has several limitations. It is a retrospective design, which limits our analysis to correlation only. The study was conducted in a single health system and, however, included a large variety of ED types, volumes, and locations. One may note that the pre-pandemic ED CT utilization in our health system (35.9/100 ED visits) is well above national average across all types of EDs. However, this ED CT utilization is similar compared to like institutions, including only adult EDs (32/100), those with 80 k–100 k annual ED visits (32/100), and level 1 or 2 trauma centers (31/100) [21]. Additionally, the local medicolegal environment in Illinois as well as concerns regarding diagnostic accuracy likely contribute to increased ED diagnostic test utilization [44, 45]. An additional limitation is that our analysis focuses on presentation to the ED and is not able to capture those patients who may have been evaluated in the outpatient setting by primary care or other providers as well as may have sought evaluation in private outpatient only radiology centers, both of which could have provided a perception of safer, less risky care.

**Conclusion**

These data may help formulate future operational strategies for resource utilization and imaging indications as we look towards a future with endemic or annual COVID-19 seasons. Further, the dynamic changes in utilization highlight future challenges in universally applying appropriateness criteria to emergency imaging in the setting of a global pandemic or emerging disease process.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10140-022-02071-z.

**Author contribution** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Daniel S. Cruz, Howard S. Kim, Danielle M. McCarthy, and Timothy M. Loftus. The first draft of the manuscript was written by Timothy M. Loftus and Emily G. Wessling, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Funding** Research reported in this publication was supported, in part, by the National Institutes of Health’s National Center for Advancing Translational Sciences, Grant Number UL1TR001422.

**Declarations**

**Conflict of interest** The authors declare that they no conflict of interest.

**Disclaimer** The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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