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CT Volumes from 2,398 Radiology Practices in the United States: A Real-Time Indicator of the Effect of COVID-19 on Routine Care, January to September 2020

Matthew S. Davenport, MD, Tom Fruscello, MBA, Mythreyi Chatfield, PhD, Stefanie Weinstein, MD, William F. Sensakovic, PhD, David B. Larson, MD, MBA

Abstract

Purpose: To determine the effect of coronavirus disease 2019 (COVID-19) on CT volumes in the United States during and after the first wave of the pandemic.

Methods: CT volumes from 2,398 US radiology practices participating in the ACR Dose Index Registry from January 1, 2020, to September 30, 2020, were analyzed. Data were compared to projected CT volumes using 2019 normative data and analyzed with respect to time since government orders, population-normalized positive COVID-19 tests, and attributed deaths. Data were stratified by state population density, unemployment status, and race.

Results: There were 16,198,830 CT examinations (2,398 practices). Volume nadir occurred an average of 32 days after each state-of-emergency declaration and 12 days after each stay-at-home order. At nadir, the projected volume loss was 38,043 CTs per day (of 71,626 CTs per day; 53% reduction). Over the entire study period, there were 3,689,874 fewer CT examinations performed than predicted (of 18,947,969; 19% reduction). There was less reduction in states with smaller population density (15% [169,378 of 1,142,247; quartile 1] versus 21% [1,894,152 of 9,140,689; quartile 4]) and less reduction in states with a lower insured unemployment proportion (13% [279,331 of 2,071,251; quartile 1] versus 23% [1,753,521 of 7,496,443; quartile 4]). By September 30, CT volume had returned to 84% (59,856 of 71,321) of predicted; recovery of CT volume occurred as positive COVID-19 tests rose and deaths were in decline.

Conclusion: COVID-19 substantially reduced US CT volume, reflecting delayed and deferred care, especially in states with greater unemployment. Partial volume recovery occurred despite rising positive COVID-19 tests.

Key Words: COVID-19, pandemic, resource utilization, socioeconomic

INTRODUCTION

In early 2020, the coronavirus disease 2019 (COVID-19) pandemic spread rapidly across the United States, causing death; critical illness; shortages in personal protective equipment; capacity constraints in hospitals, intensive care units, and ventilators; and widespread financial and societal disruption [1-5]. Health care systems and governments responded by restricting access to routine (ie, nonurgent) medical care [5-9]. The belief was that performing routine care could consume resources and leave facilities unable to...
care for the unknown number of future patients with COVID-19. Additionally, it was unclear whether it would be safe to care for patients with contagious yet potentially unknown COVID-19 at a time when routine testing was not available, effective treatment was uncertain, and best practices for personal protective equipment were in flux. These actions were deemed necessary at the time but carried the potential for paradoxical unintended harm from delayed or deferred care [9-11]. Determining the optimal time to re-engage routine care while balancing these competing issues was critical [1,3,5,6,9-11].

Early data, based primarily on single- or multi-institutional reports with small numbers of participating institutions, indicated the first wave of the COVID-19 pandemic led to expected marked reductions in routine care [6-8]. However, the specific effects by state with reference to governmental executive orders, positive COVID-19 tests and COVID-19 attributed deaths, socioeconomic indicators, and timing and stability of volume recovery remain unclear. The ACR Dose Index Registry provides a powerful real-time method of studying imaging volumes in the United States and can serve as a real-time indicator of health care access. The purpose of this study was to determine the effect of COVID-19 on CT imaging volumes in the United States during and after the first wave of the pandemic.

METHODS
This study was exempt from institutional review board oversight because it used aggregated administrative data. No patient-level data were accessed or utilized.

Study Population
CT imaging volumes from 2,398 US radiology practices (academic [n = 190], community hospital [n = 1,329], multispecialty clinic [n = 131], freestanding imaging center [n = 621], other [n = 127]) in 50 states and the District of Columbia participating in the ACR Dose Index Registry [12-15] from January 1, 2020, to September 30, 2020, were analyzed. January 1, 2020, was chosen as a start date to provide a baseline period before the pandemic. September 30, 2020, was chosen as an end date to reflect data during and after the first wave of the pandemic. CT volume data were assessed with respect to time since state stay-at-home order, time since state state-of-emergency declaration, and population-normalized positive COVID-19 tests and attributed deaths.

Data Sources
The Dose Index Registry was launched by the ACR in 2011 [12-15]. It receives data on over 20 million examinations per year from participating practices. Once a practice has voluntarily initiated participation (nominal annual fee), daily practice meta-data and CT dose index data for all CT examinations performed contemporaneously at that site are automatically transmitted to the ACR [12-15]. Although the primary purpose of the Dose Index Registry is to monitor and compare radiation doses, the registry can be used as a strong and robust real-time sample of CT imaging volumes across the United States.

Additional sources of data included:
- Positive COVID-19 test volume by state (Data.World) [16]
- Deaths attributed to COVID-19 by state (Data.World) [16]
- State population densities (US Census Bureau) [17]
- State populations (US Census Bureau) [18]
- Weekly insured unemployed proportion (US Department of Labor) [19]
- Estimated total US CT volume for 2019 (Amber Diagnostic) [20]
- Statewise state-of-emergency orders, stay-at-home orders, and reopening dates (New York Times) [21]
- State populations in urban areas and urban clusters (US Census Bureau) [22]
- State populations by race (US Census Bureau) [23]

Statistical Analysis
CT imaging volumes from January 1, 2020, to September 30, 2020, submitted to the ACR Dose Index Registry were compared with projected CT volumes using 2019 CT Dose Index Registry normative data. Projected volumes were from sites that submitted data in 2019 for the same period, by day, with an assumed 3% annual growth rate.

Data were analyzed with respect to time since state stay-at-home order, time since state-of-emergency declaration, and population-normalized positive COVID-19 tests and attributed deaths. Data were stratified into quartiles by state population density (actual state-level data: ≤43.1 people per square mile, 48.5-96.3 people per square mile, 101.2-211.8 people per square mile, ≥231.1 people per square mile), insured unemployed proportion (actual state-level data: ≤9.91%, 10.15%-12.95%, 13.04%-17.26%, ≥17.35%), urban population proportion (actual state-level data: ≤64.8%, 66.0%-73.3%, 74.2%-87.2%, ≥87.9%), and people of color population proportion (actual state-level data: ≤13.05%, 13.06%-13.39%, 19.41%-28.07%, ≥29.44%). Practices were self-categorized by type (academic, community hospital, multispecialty clinic, freestanding imaging center, other; pediatric care availability; trauma center designation) and by practice-referent population density (metropolitan [≥100,000 people], suburban [50,000-99,999 people], rural [<50,000 people]).
State-level analyses were considered to have insufficient data if there were fewer than six reporting facilities or if there were fewer than an average of 100 CT examinations submitted per day during the reporting period.

Practice locations that joined the Dose Index Registry after January 2019 were not included in the estimates of CT volume lost.

RESULTS

There were 16,198,830 CT examinations analyzed from 2,398 practices, including 9,224,549 in metropolitan centers, 5,091,059 in suburban centers, and 1,883,222 in rural centers (Table 1). Only 2.2% (53 of 2,398) were pediatric hospitals; 29% (693 of 2,398) had a trauma center designation (Table 1).

CT volume nadir occurred an average of 32 days after each statewide state-of-emergency declaration and 12 days after each statewide stay-at-home order (Fig. 1). At the nadir, the projected volume loss was 38,043 CTs per day (of 71,626 CTs per day; 53% reduction; Fig. 2). Over the entire study period, there were 3,689,874 fewer CT examinations performed than predicted (of 18,947,969 predicted; 19% reduction). On September 30, CT volume was 84% (59,856 of 71,321) of the predicted amount. Recovery of CT volume occurred as positive COVID-19 tests rose and deaths were in decline and was maintained despite COVID-19-attributed deaths rising a second time (Fig. 1). In general, there was no particular relationship between statewide CT volumes and statewide local COVID-19 incidence (Fig. 3).

DISCUSSION

The first wave of the COVID-19 pandemic substantially reduced CT imaging volume in the United States, likely reflecting a combination of delayed and deferred routine care. At its nadir (average: 32 days after each

### Table 1. Characteristics of US radiology practices (n = 2,398) submitting CT imaging volume data to the ACR’s Dose Index Registry from January 1, 2020, to September 30, 2020

| Characteristic                        | Metropolitan (>100,000 People) | Suburban (50,000-100,000 People) | Rural (<50,000 People) | Total |
|--------------------------------------|-------------------------------|----------------------------------|------------------------|-------|
| All practices (n)                    | 1,077                         | 869                              | 452                    | 2,398 |
| Academic or university               | 150                           | 34                               | 6                      | 190   |
| Community hospital                   | 517                           | 442                              | 370                    | 1,329 |
| Multispecialty clinic                | 44                            | 57                               | 30                     | 131   |
| Freestanding imaging center          | 265                           | 319                              | 37                     | 621   |
| Other                                | 101                           | 17                               | 9                      | 127   |
| Pediatric hospitals (no. of practices)| 51                            | 2                                | 0                      | 53    |
| All trauma centers (no. of practices) | 368                           | 195                              | 130                    | 693   |
| I                                    | 163                           | 33                               | 7                      | 203   |
| II                                   | 123                           | 85                               | 23                     | 231   |
| III                                  | 60                            | 59                               | 39                     | 158   |
| IV                                   | 22                            | 18                               | 61                     | 101   |
| No trauma designation                | 709                           | 674                              | 322                    | 1,705 |
| CT imaging volume (no. of examinations)| 9,224,549                    | 5,091,059                        | 1,883,222              | 16,198,830 |
statewide state-of-emergency declaration, 12 days after each statewide stay-at-home order), daily CT volume had been reduced by 53%. All states and practice types were severely affected; although states with greater population density and more unemployment experienced more of a decline in CT volume than states with less population density or less unemployment. Incomplete CT volume recovery followed, slower than the initial decline, and remained steady across the country despite an increase in the number of positive COVID-19 tests and increased deaths after the initial wave. By September 30, 2020, CT volume was 84% of predicted based on 2019 normative data and was in plateau. The reason for the incomplete recovery is unclear and not explainable by our results but probably relates to the ongoing pandemic and fear about safe re-engagement of routine care. These data are potentially important because CT is a common diagnostic tool for many clinical indications and has a substantial effect on clinical decision making [24,25]. It is probable that the prevalence of non-COVID-19 disease that would be detected by CT did not meaningfully change during the reduction in services, indicating that diagnoses were likely delayed or misdirected during the period of suppression. The fact that CT volume never recovered to predicted levels suggests that a substantial proportion of reduced care likely was not just deferred but was not provided at all.

Large reductions in diagnostic and interventional radiology volumes have been reported elsewhere in community and academic sites [8,26-29]. Naidich et al [27] reported imaging volumes within a large New York health system during a 16-week period from January 1, 2020, to April 18, 2020, and found a 12.29% decline in overall imaging weeks 1 to 16 and an 88% decline in outpatient imaging during week 16. These data were corroborated by Duszak et al [8], who assessed imaging metadata from nine US community hospitals from January 2019 to May 2020 and found that overall imaging volume was 52% less than predicted during the volume nadir. Kansagra et al [28] analyzed data on 231,753 patients from 856 US hospitals July 1, 2019, to April 27, 2020, and found that imaging for stroke declined by 39% (1.18 patients per day per hospital to 0.72 patients per day per hospital) in the early pandemic epoch, indicating that urgent care likely was being affected in addition to routine care during the first wave of the pandemic. Each of these studies [8,27-28] showed the initial decline we observed but did not include
statewide analysis or a recovery period assessment or show relationships to COVID-19 data.

When considering the cessation or re-engagement of routine medical care during the course of a pandemic, the following principle should be followed: “If the risk of illness or death to a health care worker or patient from health care-acquired COVID-19 is greater than the risk of illness or death from delaying care, the care should be delayed; however, if the opposite is true, the care should proceed in a timely fashion” [6]. In the early days of the COVID-19 pandemic, risk-benefit calculations were fraught by insufficient data. Therefore, an aggressive conservative approach was assumed and much routine care was discontinued abruptly by health care systems, governments, and patients [8,26–35]. The rationale was complex but generally reflected (1) a desire to avoid overburdening intensive care units and hospital beds in anticipation of a surge of critically ill patients and (2) a desire to avoid transmitting COVID-19 to patients or to health care workers.

As the indirect harms of routine care discontinuation were felt (ie, lapses in cancer detection, stage migration, delayed presentation of cardiovascular illnesses) [30–35] and the attributed deaths from COVID-19 declined [16], health care systems attempted to safely re-engage care despite a rising number of positive COVID-19 tests [16]. This re-engagement of routine care was further motivated by financial considerations. In the United States, where health care is largely privatized, a side effect of discontinuation was severe economic strain on health care systems and their employees, resulting in billions of dollars of losses across the sector and employment contraction [6,36]. Whether re-engaging care was safe was unclear at the time it occurred [6]. However, data have since shown that the risk to patients interacting with ambulatory health care facilities during the COVID-19 pandemic is probably low [37]. Reale et al [37] performed a nested case-control study of pregnant patients who were (n = 93) and were not (n = 372) diagnosed with COVID-19 and determined there was no association between the number of in-person visits and the probability of a COVID-19 diagnosis (in-person visits: 3.1 ± 2.2 cases versus 3.3 ± 2.3 controls, odds ratio: 0.93 [95% confidence interval: 0.80–1.08]).

Our study has potential limitations. The start and end dates of the study period were partially arbitrary and designed to incorporate dates before, during, and after the first wave of the COVID-19 pandemic. COVID-19 testing capacity changed across the country during the study period. Absolute
numbers of positive COVID-19 tests do not directly indicate disease prevalence. Accurate determination of COVID-19 attributable deaths is complicated for a variety of reasons, and thus the death data we analyzed are not likely to be accurate; however, the trends are likely to be [38,39]. There was statewide variation in the number of radiology practices participating in the ACR CT Dose Index Registry and in the quality and accuracy of COVID-19 reporting. This heterogeneity impairs the accuracy of state-by-state comparisons. However, the large sample size (2,398 practices; 16,198,830 CTs) and national sample provide a robust estimate of CT use across the United States.

In conclusion, the first wave of the COVID-19 pandemic substantially reduced CT imaging volume in the United States because of delayed and deferred care, especially in states with greater unemployment. This was followed by broad-based but slower and incomplete volume recovery that occurred despite rising positive COVID-19 tests. At the conclusion of the study period, CT volume was 84% of predicted and in plateau. The incomplete blunted recovery likely is due to many factors, including but not limited to (1) safety concerns of patients and health care workers regarding re-engaging routine care, (2) social distancing policies constraining access, (3) a decline in staff who may have been furloughed because of the economic impact of the pandemic, and (4) loss of health insurance by prospective patients. Further study investigating the indirect clinical impact of temporarily discontinuing clinical services are needed. These data provide a use case illustrating how the ACR CT Dose Index Registry might be used as a leading real-time indicator of routine care patterns in the United States.

TAKE-HOME POINTS

- From January 1, 2020, to September 30, 2020, there were 3,689,874 fewer CT examinations performed in the United States than predicted (of 18,947,969; 19% reduction) because of effects of COVID-19 pandemic.
- CT volume nadir occurred an average of 32 days after each state state-of-emergency declaration and 12 days after each state stay-at-home order.
- By September 30, 2020, CT volume had returned to 84% (59,856 of 71,321) of predicted; recovery of CT volume occurred as positive COVID-19 tests rose and deaths were in decline.
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ADDITIONAL RESOURCES
Additional resources can be found online at: https://doi.org/10.1016/j.jacr.2020.10.010.

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