



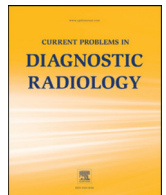
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Trends in coronary calcium score and coronary CT angiography imaging volume during the COVID-19 pandemic

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Objectives: The COVID-19 pandemic disrupted the delivery of preventative care and management of acute diseases. This study assesses the effect of the COVID-19 pandemic on coronary calcium score and coronary CT angiography imaging volume.

Materials and methods: A single institution retrospective review of consecutive patients presenting for coronary calcium score or coronary CT angiography examinations between January 1, 2020 to January 4, 2022 was performed. The weekly volume of calcium score and coronary CT angiogram exams were compared.

Results: In total, 1,817 coronary calcium score CT and 5,895 coronary CT angiogram examinations were performed. The average weekly volume of coronary CTA and coronary calcium score CT exams decreased by up to 83% and 100%, respectively, during the COVID-19 peak period compared to baseline ($P < 0.0001$). The post-COVID recovery through 2020 saw weekly coronary CTA volumes rebound to 86% of baseline ($P = 0.024$), while coronary calcium score CT volumes remained muted at only a 53% recovery ($P < 0.001$). In 2021, coronary CTA imaging eclipsed pre-COVID rates ($P = 0.012$), however coronary calcium score CT volume only reached 67% of baseline ($P < 0.001$).

Conclusions: A significant decrease in both coronary CTA and coronary calcium score CT volume occurred during the peak-COVID-19 period. In 2020 and 2021, coronary CTA imaging eventually superseded baseline rates, while coronary calcium score CT volumes only reached two thirds of baseline. These findings highlight the importance of resumption of screening exams and should prompt clinicians to be aware of potential undertreatment of patients with coronary artery disease.

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Introduction

The disruptive effects of the COVID-19 pandemic have caused significant operational challenges for healthcare systems. As COVID-19 cases peaked in 2020, hospitals faced unprecedented demands related to shortages in healthcare workers, hospital beds, and equipment. While significant hospital resources were diverted towards treatment of patients with COVID-19, healthcare access and utilization were disrupted for many patients with chronic diseases or other healthcare needs.

As many emergency departments were overwhelmed by patients with COVID-19 and outpatient appointments were postponed or cancelled, delivery of preventative care and management of both acute and chronic diseases has been suboptimal.^{1–3} National surveillance data revealed a significant decline in emergency department

utilization, including for acute myocardial infarction and stroke, during the initial months of the pandemic.⁴ In addition, emerging data is beginning to show concerning trends in the wholesale reduction of diagnostic health examinations, including low dose screening chest CT for lung cancer and diagnostic testing for cardiovascular disease.^{5–7} In the setting of cardiovascular screening, coronary calcium score CT has an important preventative role in assessing risk for cardiovascular disease in low and intermediate risk asymptomatic patients.^{8–13} Similarly, coronary CT angiography (CTA) is an important non-invasive examination for assessment of the coronary arteries in symptomatic patients with both stable chest pain and acute chest pain at low-to-intermediate risk of acute coronary syndrome.^{14–17} The aim of this study was to evaluate how coronary calcium score CT and coronary CTA volumes were affected by the COVID-19 pandemic and analyze the subsequent recovery in exam volumes.

Materials and methods

Study setting

A single institution retrospective review was performed in compliance with the Health Insurance Portability and Accountability Act and approved with exemption by the Massachusetts General Hospital

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Institutional Review Board. Data for all coronary CTA and coronary calcium score CT exams performed at our academic medical center were extracted from the electronic medical record for the period January 1, 2020–January 4, 2022. Our institution is a 1063-bed quaternary care urban academic medical center in Massachusetts treating approximately 50,000 inpatients, 98,000 ED patients, and 775,000 outpatients annually.¹⁸

Analysis

Four time periods were defined in this study: a pre-COVID baseline period from January 1, 2020 to March 10, 2020; a COVID-19 peak period from March 11, 2020 to May 2, 2020; a 2020 recovery period from May 3, 2020 to January 4, 2021; and a 2021 recovery period from January 5, 2021 to January 4, 2022. The start of the “COVID-19 peak” period was defined as the declaration of a State of Emergency related to COVID-19 in the state of Massachusetts on March 10, 2020.¹⁹ During the subsequent weeks, a series of measures intended to reduce the transmission of COVID-19 were implemented, including drastic reductions in elective care and imaging. The radiology department at our institution implemented measures in accordance with hospital policies and governmental guidelines, including reduction of daily outpatient imaging slots by 50% and elimination of weekend outpatient cardiac CT imaging. Data for coronary CTA and coronary calcium score CT exams were grouped in 1-week intervals. Coronary CTAs had been assigned scores defined by the Coronary Artery Disease – Reporting and Data System (CAD-RADS) consensus document.²⁰ Calcium scores (CACS) had been calculated by the Agatston scoring method and classified as “no evidence of CAD” (CACS = 0), “minimal” ($0 < \text{CACS} < 10$), “mild” ($10 < \text{CACS} < 100$), “moderate” ($100 < \text{CACS} < 400$), and “severe” ($\text{CACS} > 400$).²¹ Baseline rates are the average of the weekly imaging volumes during the pre-COVID-19 baseline period. Data analysis was performed using R version 3.6.1.²² CAD-RADS 3, 4a, 4b, and 5 were grouped as a “Significant Stenoses Group” – clinically significant stenoses that would prompt further testing and treatment including but not limited to: functional assessment, pharmacotherapy, and/or invasive coronary angiography.²⁰

Results

The average weekly volume of coronary CTA and coronary calcium score CT exams decreased by up to 83% and 100%, respectively, during the COVID-19 peak period compared to the pre-COVID peak period (Fig 1A). Coronary CTA exam volume decreased from 58 ± 7 studies per week at baseline to 21 ± 14 studies during the COVID-19 peak period ($P < 0.001$) and coronary calcium score CT exam volume decreased from 28 ± 8 studies per week at baseline to 4 ± 8 during the COVID-19 peak period ($P < 0.001$). There was gradual recovery of both coronary CTA and coronary calcium score CT exam volumes during the post-COVID-19 peak period (Fig 1B). During the post-COVID-19 peak, mean coronary CTA exam volume reached approximately 84% of baseline in 2020 during the post-COVID-19 peak period (50 ± 10 vs 58 ± 7 , $P = 0.024^*$) and 114% of baseline in 2021 (66 ± 9 vs 58 ± 7 , $P = 0.012^*$). Coronary calcium score CT volume decreased by a relatively larger degree than coronary CTA volume and remained persistently muted throughout the post-COVID-19 peak period (Fig 1B). Mean coronary calcium score CT volume was approximately 52% of baseline in 2020 during the post-COVID-19 peak period (15 ± 8 vs 28 ± 8 , $P < 0.001^*$) and 67% of baseline in 2021 (19 ± 6 vs 28 ± 8 , $P < 0.001^*$) (Table 1).

During the post-COVID-19 2020 and 2021 recovery periods, there was no statistically significant decrease in the volume of coronary CTA exams with clinically significant CAD-RADS 4A and 4B scores compared to baseline, even in the setting of decreased overall volume (Table 1, Fig 2). However, there were statistically significant

decreases in absolute volume of CAD-RADS 1 and 5 scores during the post-COVID-19 peak compared to baseline (Table 1). Overall, there was no significant difference in proportion of each individual CAD-RADS score between the baseline and post-COVID-19 peak periods (Table 2). Furthermore, there was no significant difference in the proportion of patients in the “Significant Stenoses Group” in the post-COVID-19 2020 and 2021 recovery periods compared to baseline.

There were statistically significant decreases in calcium scores demonstrating no evidence of CAD (9 ± 3 vs 6 ± 4 , $P = < 0.001$), mild CAD (6 ± 3 vs 3 ± 2 , $P = 0.001$), moderate CAD (7 ± 3 vs 2 ± 2 , $P < 0.001$), and severe CAD (3 ± 2 vs 2 ± 2 , $P = 0.023$) during the post-COVID 2020 recovery period compared to baseline. During the post-COVID 2021 recovery period, there continued to be statistically significant decreases in calcium scores demonstrating mild CAD (6 ± 3 vs 4 ± 2 , $P = 0.01$), moderate CAD (7 ± 3 vs 3 ± 2 , $P < 0.001$) and severe CAD (3 ± 3 vs 2 ± 2 , $P = 0.01$) compared to baseline (Table 1).

Discussion

This study demonstrates a significant decrease in both coronary CTA and coronary calcium score CT exam volume during the peak COVID-19 period with a subsequent differential recovery over the following 2 years. Notably, there has been a muted recovery of coronary calcium score CT volume compared to coronary CTA volume, with a sustained overall decrease in coronary calcium score CT exam volume compared to baseline even after a year following the peak COVID period. While this may be expected due to the elective nature of coronary calcium CT exams, it has yet to be quantified in the literature.

Coronary CTA exam volume gradually returned to baseline volume in 2020 following the COVID-19 peak period and even exceeded pre-pandemic baseline volumes in 2021. During the peak COVID-19 period, which spanned approximately 8 weeks, there was a significant decrease in coronary CTA volume for all CAD-RADS scores. These results suggest that diminished access to healthcare during the peak COVID-19 period likely prevented patients with acute chest pain from seeking appropriate emergency medical care, a finding which is supported by national surveillance data demonstrating a 23% decrease in patient presentations to the emergency department for myocardial infarction between January and May 2020.⁴ Delays in care for acute emergencies such as acute myocardial infarction have been identified as an important potential contributor to excess mortality during the COVID-19 pandemic.^{23,24}

A concerning finding is the muted recovery of coronary calcium score CT volume during the post-COVID-19 peak period, which represents a reflection of delays in return of elective care. As institutions reduced elective imaging, including coronary calcium score CT, to preserve resources during the pandemic, it is becoming apparent that these temporary policies may have prolonged effects during post-COVID-19 recovery periods. Patients may also have postponed elective screening examinations due to the pandemic, as suggested by previous work documenting a sharp drop in internet search engine queries at the first peak of the pandemic for lung, breast, colon, and endometrial cancer screening terms.²⁵ Average coronary calcium CT exam volumes remained well-below baseline levels even 18 months after the COVID-19 peak period. Coronary calcium score CT exams are an important preventative risk-stratification tool for coronary artery disease in low to intermediate risk patients. While not required for initiation of medical therapy, the reduction in calcium score screening exams could conceivably negatively delay the initiation of optimal medical therapy in appropriate patients.^{26–29}

Overall, the proportion of different CAD-RADS and coronary calcium scores were not significantly different between the peak and post-COVID-19 time periods and baseline. This finding is not surprising for calcium score CT exams given that it is a screening study. Therefore, the decrease in calcium score screening exam volume has likely delayed initiation of appropriate preventive care in patients

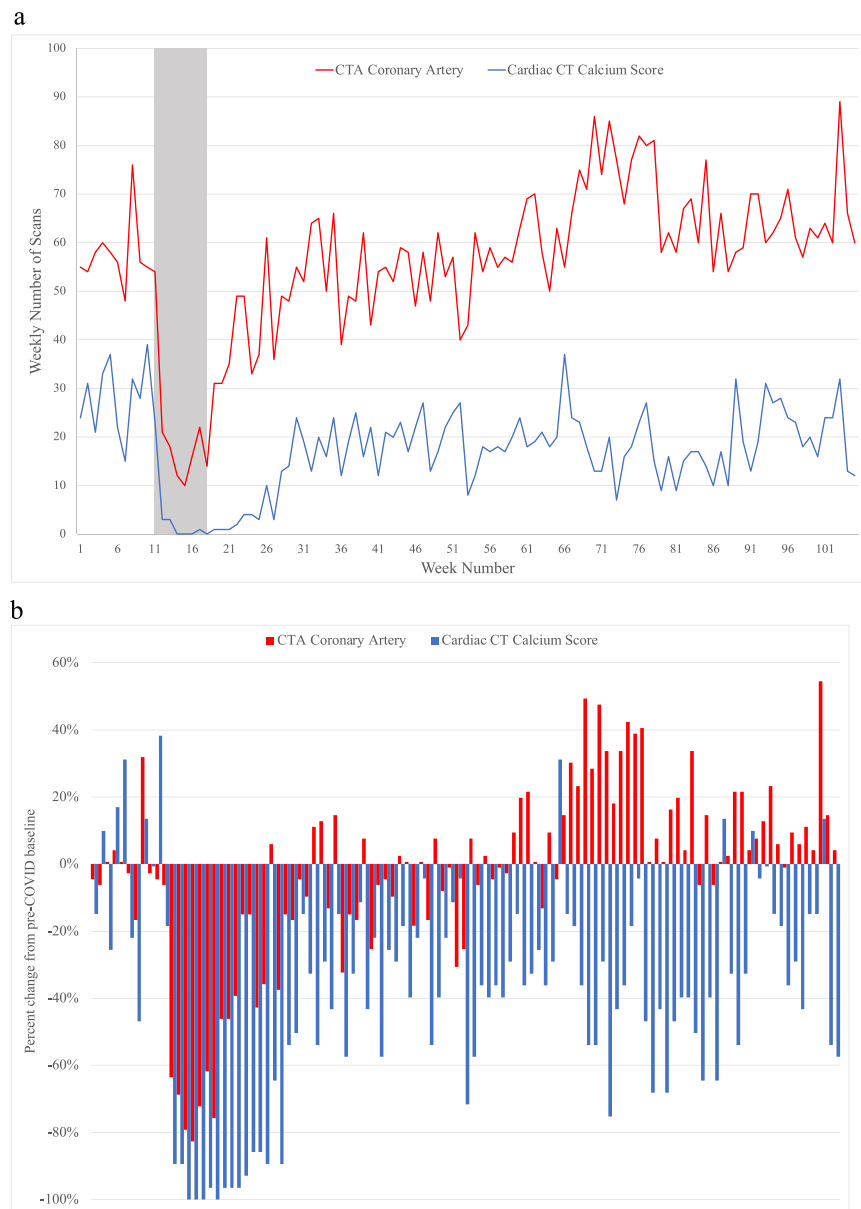


FIG 1. (A) is a graphical representation of the weekly number of coronary CTA and calcium score CT exams over time. The gray shaded box denotes the peak-COVID-19 period where the radiology department implemented measures in accordance with hospital policies and governmental guidelines to reduce imaging volume. (B) Demonstrates the weekly percent change from baseline in volume for both coronary CTA and calcium score CT. (Color version of figure is available online.)

TABLE 1

Comparison of mean studies per week and scoring categories of coronary CTA and cardiac CT for calcium scoring during the peak COVID-19, and post-COVID 2020 and 2021 recovery periods compared to a pre-COVID baseline

	Pre-COVID Baseline	Peak-COVID	P-value	Post-COVID 2020 recovery	P-value	Post-COVID 2021 Recovery	P-value
Coronary CTA	57.6 ± 7.2	20.9 ± 14.0	<0.001	49.7 ± 10.0	0.024	65.7 ± 9.3	0.012
CAD-RADS 0	17.8 ± 4.9	6.5 ± 4.1	<0.001	14.6 ± 4.9	0.075	18.1 ± 4.5	0.832
CAD-RADS 1	12.5 ± 2.1	4.9 ± 3.1	<0.001	8.5 ± 3.2	<0.001	12.0 ± 3.8	0.708
CAD-RADS 2	14.0 ± 3.3	5.0 ± 3.4	<0.001	14.1 ± 4.7	0.958	18.7 ± 4.8	0.004
CAD-RADS 3	3.4 ± 1.5	1.3 ± 1.7	0.011	4.3 ± 1.9	0.186	6.5 ± 2.9	0.002
CAD-RADS 4A	5.7 ± 2.6	1.9 ± 1.6	0.002	5.3 ± 2.4	0.615	6.5 ± 3.0	0.440
CAD-RADS 4B	1.5 ± 1.3	0.4 ± 0.7	0.042	1.5 ± 1.1	0.972	1.7 ± 1.6	0.699
CAD-RADS 5	2.7 ± 1.5	1.0 ± 1.4	0.026	1.5 ± 1.1	0.008	2.1 ± 1.5	0.184
Significant Stenosis	13.3 ± 3.4	4.5 ± 4.5	<0.001	12.5 ± 3.5	0.528	16.8 ± 4.6	0.027
Cardiac CT	28.2 ± 7.6	3.8 ± 7.9	<0.001	14.9 ± 8.4	<0.001	18.9 ± 6.3	<0.001
No CAD (0)	9.0 ± 2.8	0.9 ± 1.8	<0.001	5.7 ± 3.8	0.014	7.2 ± 3.6	0.146
Minimal (1-10)	2.3 ± 1.8	0.4 ± 0.7	0.011	1.7 ± 1.5	0.255	2.3 ± 1.8	0.990
Mild (11-100)	6.4 ± 3.0	0.8 ± 1.4	<0.001	3.3 ± 2.4	0.001	4.2 ± 2.2	0.010
Moderate (101-400)	7.2 ± 2.9	1.4 ± 3.5	0.001	2.4 ± 2.1	<0.001	2.9 ± 1.9	<0.001
Severe (>400)	3.3 ± 2.5	0.4 ± 0.7	0.005	1.8 ± 1.5	0.023	2.3 ± 1.6	0.010

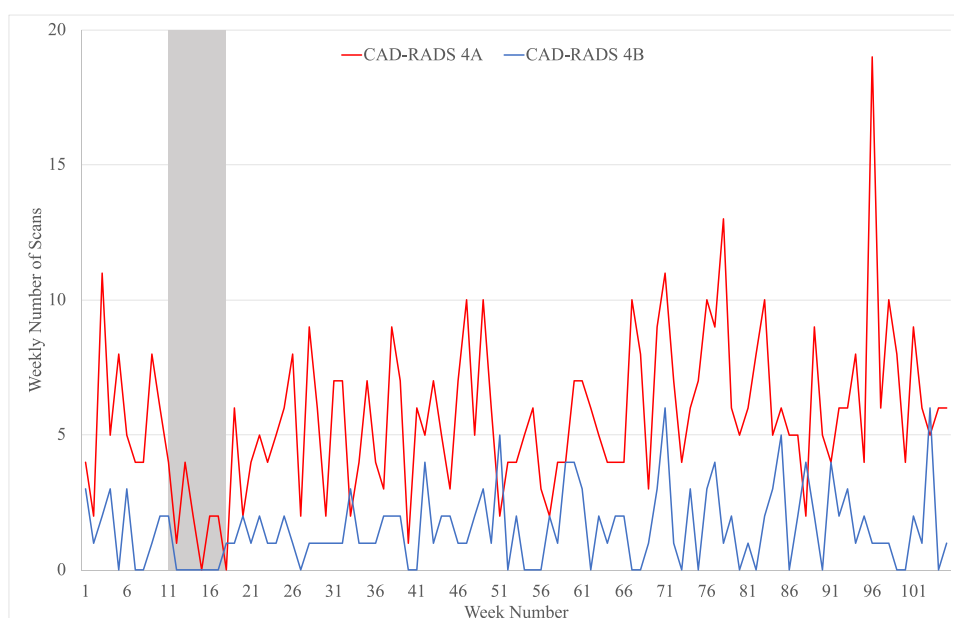


FIG 2. Figure 2 is a graphical representation of the number of coronary CTA exams with CAD-RADS 4A and 4B scores over time. The gray shaded box denotes the peak-COVID-19 period where the radiology department implemented measures in accordance with hospital policies and governmental guidelines to reduce imaging volume. (Color version of figure is available online.)

that qualify. However, the long-term consequences of delaying optimal medical therapy remains unclear. The lack of change in proportion of CAD-RADS scores indicating severe disease during the peak COVID-19 periods despite significant overall decrease in coronary CTA volume provides evidence that some patients with acute coronary syndrome may not have been adequately diagnosed and treated during the COVID-19 pandemic. This finding supports additional studies in the literature that have suggested that delayed care for acute emergencies such as acute myocardial infarction have contributed to excess mortality during the COVID-19 pandemic.^{23,24}

Limitations in this study include lack of patient follow-up, which limits assessment for potential increases in morbidity and mortality related to decreases in cardiovascular imaging during the COVID-19 pandemic. Additional studies would be beneficial to directly assess the consequences of delayed coronary CTA and calcium score CT during the peak COVID-19 period. In addition, it has been demonstrated that the COVID-19 pandemic has disproportionately impacted socio-economically disadvantaged communities. Further investigation is necessary to determine if the decreases in coronary CTA and coronary calcium score CT exam volume observed in this study were even

more pronounced in high-risk and vulnerable patient populations during the pandemic.³⁰ In addition, our study did not assess patient factors that might have affected examination volume, such as reluctance to visit medical facilities during the pandemic. Finally, analysis for changes in specific CAD-RADS scores over time was limited by the small patient population and a high degree of week-to-week variability. More robust data from multiple institutions would help clarify the effect of the COVID-19 pandemic on specific CAD-RADS score volumes.

We present the first report in the literature analyzing differential decrease and recovery of cardiac CTA and calcium scoring CT exam volume related to the COVID-19 pandemic. The results of this study demonstrate that both coronary CTA and coronary calcium score CT volume decreased drastically during the peak COVID-19 period with gradual recovery to baseline levels for coronary CTA exams. However, there was persistent muted recovery for calcium score CT even 18 months following the COVID-peak period. The sharp decrease in coronary CTA volume during the COVID-peak period, even in patients with severe coronary artery disease, was likely related to decreased access to healthcare during the initial peak in COVID-19 cases. From a

TABLE 2
Proportions of individual CAD-RADS scores and Cardiac CT Calcium scores between the baseline, peak COVID, 2020 recovery, and 2021 recovery periods. *P* values reflect comparison to baseline pre-COVID values

	Pre-COVID baseline	Peak-COVID	<i>P</i> -value	Post-COVID 2020 recovery	<i>P</i> -value	Post-COVID 2021 recovery	<i>P</i> -value
Coronary CTA							
CAD-RADS 0	30.9%	31.1%	0.954	29.4%	0.495	27.6%	0.105
CAD-RADS 1	21.7%	23.4%	0.650	17.0%	0.012	18.3%	0.056
CAD-RADS 2	24.3%	24.0%	0.925	28.4%	0.058	28.5%	0.038
CAD-RADS 3	5.9%	6.0%	0.967	8.6%	0.036	9.9%	0.002
CAD-RADS 4A	9.9%	9.0%	0.725	10.6%	0.638	9.9%	0.985
CAD-RADS 4B	2.6%	1.8%	0.550	3.0%	0.631	2.6%	0.997
CAD-RADS 5	4.7%	4.8%	0.956	3.0%	0.052	3.1%	0.056
Significant Stenosis	23.1%	21.6%	0.677	25.2%	0.308	25.5%	0.210
Cardiac CT							
No CAD (0)	31.9%	23.3%	0.334	38.3%	0.074	38.2%	0.055
Minimal (1–10)	8.2%	10.0%	0.728	11.2%	0.179	12.2%	0.060
Mild (11–100)	22.7%	20.0%	0.737	22.1%	0.851	22.3%	0.898
Moderate (101–400)	25.5%	36.7%	0.189	16.2%	0.001	15.3%	<0.001
Severe (>400)	11.7%	10.0%	0.781	12.3%	0.802	12.0%	0.899

population health perspective, the persistently muted recovery of coronary calcium score CT exam volume highlights a concerning trend and suggests the need for improvement in delivery of this important preventative care measure during the COVID-19 pandemic.

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