The impact of the COVID-19 pandemic on neuroimaging volume in New York City

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Abstract

Background and Purpose: The COVID-19 pandemic acutely disrupted all facets of healthcare, with future implications that are expected to resonate for many years. We investigated the effect of the pandemic on neuroimaging volume, hypothesizing that all representative studies would experience a reduction in volume, with those typically performed in the inpatient setting (non-contrast enhanced CT head and CTA head/neck) taking longer to recover to pre-pandemic volumes compared to studies typically performed in the outpatient setting (MR brain with and without and MR lumbar spine without).

Materials and Methods: We retrospectively queried our institution’s radiology reporting system to collect weekly data for 1 year following the World Health Organization declaration of a pandemic (11 March 2020–9 March 2021) and compared them to imaging volumes from the previous year (11 March 2019–9 March 2020). We subsequently analyzed quarterly data (e.g., first quarter comparison: 3/11/2020–6/9/2020 was compared to 3/11/2019–6/9/2019).

Results: All studies experienced decreased volume during the first quarter of the year following onset of the COVID-19 pandemic, with noncontrast enhanced CT head failing to recover to pre-pandemic volumes. CTA head/neck actually surpassed pre-pandemic volume by the second quarter of the year. MRI brain w/wo and MRI lumbar spine without recovered to baseline volume by the second quarter.

Conclusion: Noncontrast enhanced CT head did not recover pre-pandemic imaging volume. CTA head/neck volume initially decreased, however volume increased above pre-pandemic levels during the second quarter; this finding may be attributable to a prothrombotic state in COVID-19 patients.

Keywords
COVID, Computed Tomography, CT angiography, Magnetic Resonance Imaging, utilization

Introduction

The World Health Organization (WHO) declared the COVID-19 viral outbreak a pandemic on 11 March 2020, and by early spring 2020, the epicenter of the pandemic in the United States was New York City. Ultimately, the disease spread to all U.S. states and more than 200 countries. By late-December 2021, the virus had infected over 280 million people globally, with over 5 million deaths; in the United States alone, the virus has resulted in over 800,000 fatalities at the time of this writing, surpassing the total related deaths from the 1918 Spanish flu, previously recognized as the worst pandemic-related death toll in U.S. history.

During the height of the pandemic in New York City, COVID-19 resulted in excess death due to stroke, with some estimating an increase in stroke-related mortality totaling 29.8%. Both recognized and unrecognized COVID-19-related cerebrovascular accidents (CVA) are an important complication of COVID-19 infection. A meta-analysis found COVID-19-infected patients to be greater than 3.5 times more likely to suffer ischemic stroke than non-infected patients experiencing ischemic stroke. Despite the increased incidence of COVID-19-related ischemic CVA, there is a paucity of studies examining the effect of the COVID-19 pandemic on neuroimaging utilization. Furthermore, few have studied the pandemic’s impact on stroke management.

Here we examine the impact of COVID-19 on neuroimaging volume within a neuroradiology department at a tertiary care center in an area of high COVID-19 transmission. Given the persistence of COVID-19 infection in the midst of constantly developing variant viral strains, as well as the threat of future pandemics in a world increasingly reliant on international transportation, our findings provide important information on how infectious disease outbreaks affect neuroimaging volume and thus patient care. Additionally, we attempted to consider inpatient and outpatient studies separately as other groups have done, in order to elucidate differential trends in COVID-19’s impact on various facets of a neuroradiology practice; we expect outpatient neuroradiology imaging volume to recover before inpatient
neuroradiology imaging volume. A greater understanding of neuroradiology imaging trends will better equip practitioners to protect populations at risk for interruptions in care when faced with future, unexpected healthcare disruptions.

Methods

Research design

We obtained a Letter of Exemption from the Internal Review Board in order to retrospectively examine imaging trends over time; we were given exemption since our query did not examine patient information. We searched the radiology reporting system, M*Modal Catalyst (Maplewood, Minnesota) for all reports with labels that corresponded with the type of study being investigated. Supplementary Table 1 lists the exams and corresponding exam labels used in this search.

Weekly volume of the specified imaging studies was collected from Wednesday, 11 March 2020 (the date the World Health Organization declared the SARS-CoV-2 coronavirus-19 a pandemic) to Tuesday, 9 March 2021. We also collected weekly data from 11 March 2019 to 9 March 2020 for comparison. We analyzed data by week and by quarters (subsequently labeled as Q1, Q2, Q3, and Q4): Q1 for 2020 was defined from 3/11/2020 to 6/9/2020; Q2 for 2020 was defined from 6/10/2020 to 9/8/2020; Q3 for 2020 was defined from 9/9/2020 to 12/8/2020; and Q4 for 2020 was defined from 12/9/2020 to 3/9/2021. Comparisons were made between imaging volumes from 2019 to 2020 and 2020 to 2021.

We selected the following imaging studies as representative of neuroradiology imaging at our tertiary care center: noncontrast enhanced CT head (NECT head), CT angiography (CTA) head/neck, MR brain with and without contrast (w/wo), and MR lumbar spine without contrast. We used examination type as a proxy for designating location of image acquisition (i.e., emergency/inpatient versus outpatient setting); during the pandemic, patients frequently boarded in the emergency room for prolonged periods of time due to space limitations and were considered “outpatient” during that time. Thus, we believe that utilizing exam type instead of imaging location was the most accurate way to undergo our analysis, allowing us to circumvent this high volume of misattributed study location that occurred during the pandemic. The following designations were determined by examining general trends of image location for the specified studies at our institution: NECT head and CTA head/neck were considered stereotypical emergency/inpatient examinations; MR brain w/wo and MR lumbar spine without contrast were considered stereotypical outpatient examinations.

Statistical analysis

We used Microsoft Excel (Redmond, Washington) to calculate average image volume per week and the corresponding standard deviations. All statistical analyses for quarterly data were provided through the Columbia University Irving Institute for Clinical and Translational Research. We performed Wilcoxon signed ranks test for each quarter of 2020–2021, and compared them to each quarter of 2019–2020 to assess if there were statistically significant differences between exam numbers during that time period. A value of p < 0.05 was considered statistically significant.

Results

Impact of the COVID-19 pandemic on neuroimaging utilization

All data are summarized in Table 1. We found a significant decrease in volume of NECT head (Figure 1(a)) that persisted the entire year following declaration of the pandemic (Wilcoxon signed rank test for Q1, Q2, Q3, and Q4, respectively: 40.6% decrease in average studies per week, p < 0.001; 13.1% decrease in average studies per week, p < 0.001; 7.1% decrease in average studies per week, p = 0.003; and 11.0% decrease in average studies per week, p = 0.006). Q1 saw the largest decrease in volume, with nearly a 41% decrease in volume per week performed compared to the prior year.

CTA head/neck (Figure 1(b)), MR brain w/wo (Figure 1(c)), and MR lumbar spine without contrast (Figure 1(d)) experienced a decrease in volume during Q1 (Wilcoxon signed rank test for Q1 CTA head/neck, MR brain w/wo, and MR L-spine without volume, respectively: 31.6% decrease in average studies per week, p = 0.001; 48.4% decrease in average studies per week, p < 0.001; and 73.3% decrease in average studies per week, p < 0.001). For CTA head/neck (Figure 1(e)), not only did volume return to prepandemic levels by Q2, the volume was actually significantly

Table 1. Demonstrates the average image volume per week of each quarter for 2019–2020 and 2020–2021. ** denotes a significant decrease in volume for the specified quarter of 2020–2021 compared to 2019–2020. *** denotes a significant increase in volume for the specified quarter of 2020–2021 compared to 2019–2020. A Wilcoxon signed rank test was used to determine significance.

|                      | 2019 Q1 | 2020 Q1 | % change  | 2019 Q2 | 2020 Q2 | % change  | 2019 Q3 | 2020 Q3 | % change  | 2019 Q4 | 2020 Q4 | % change  |
|----------------------|---------|---------|-----------|---------|---------|-----------|---------|---------|-----------|---------|---------|-----------|
| Emergency/Inpatient |         |         |           |         |         |           |         |         |           |         |         |           |
| CT head              | 567     | 337     | -40.6*    | 559     | 486     | -13.1*    | 551     | 512     | -7.1*     | 547     | 487     | -11.0*    |
| CTA head/neck        | 57      | 39      | -31.6*    | 56      | 71      | 26.8**    | 56      | 72      | 28.6**    | 64      | 66      | 3.1       |
| Outpatient           |         |         |           |         |         |           |         |         |           |         |         |           |
| MRI brain w/wo       | 188     | 97      | -48.4*    | 192     | 181     | -5.7      | 197     | 206     | 6.6       | 187     | 184     | -1.6      |
| MRI lumbar spine     | 30      | 8       | -73.3*    | 25      | 27      | 8         | 28      | 31      | 10.7      | 27      | 26      | -3.7      |
higher than pre-pandemic levels during Q2 as well as Q3 (Wilcoxon signed rank test for Q2, Q3, and Q4, respectively: 26.8% increase in average studies per week: p = 0.001; 28.6% increase in average studies per week, p = 0.002; and 3.1% increase in average studies per week, p = 0.60).

Discussion
While other groups have focused on neuroradiology imaging volume for specific studies up to 6 months following the beginning of the COVID-19 pandemic, here we have expanded on these findings by providing insight into imaging trends for a greater number of neuroimaging studies that more accurately represent a neuroradiology practice; additionally, we have examined trends for an entire year following onset of the pandemic. A timeline of our neuroimaging volume recovery corresponding to important dates during the COVID-19 pandemic is outlined in Figure 2.

Similar to Agarwal et al.,10 we found a decrease in NECT head volume during the first 4 weeks of the pandemic; however, we demonstrated this decrease in volume persisted for the entire year following declaration of the pandemic (the following comparisons are expressed as percent change in average studies per week during the specified quarter of 2020 vs. the specified quarter of 2019. Q1: -40.6%, p < 0.001; Q2: -13.1%, p < 0.001; Q3: -7.1%, p = 0.003; and Q4: -11.0%, p =

Figure 1. (a) Demonstrates the average volume of NECT head per week of each quarter (Q1-4) for 2019–2020 and 2020–2021. **"" denotes a significant decrease in volume for the specified quarter of 2020–2021 compared to 2019–2020. (b) Compares trends in volume of CTA head/neck per week of each quarter (Q1-4) for 2019–2020 and 2020–2021. **"" denotes a significant decrease in volume for the specified quarter of 2020–2021 compared to 2019–2020. "**"" denotes a significant increase in volume for the specified quarter of 2020–2021 compared to 2019–2020. (c) Compares trends in volume of MR lumbar spine without contrast per week of each quarter (Q1-4) for 2019–2020 and 2020–2021. **"" denotes a significant decrease in volume for the specified quarter of 2020–2021 compared to 2019–2020. (d) Compares trends in volume of MRI brain w/wo per week of each quarter (Q1-4) for 2019–2020 and 2020–2021. "**"" denotes a significant decrease in volume for the specified quarter of 2020–2021 compared to 2019–2020.

Figure 2. Demonstrates a timeline of important dates during the COVID-19 pandemic in relation to neuroimaging volumes at our institution.
A majority of NECT head at our institution are performed in the emergency/inpatient setting, and common indications include altered mental status, fall, and stroke. There are multiple plausible etiologies for the delayed recovery of NECT head: 1) a scarcity of resources during the pandemic caused imaging to be reserved for patients with very high suspicion for disease; 2) logistical issues potentially contributed to reduced inpatient imaging volume given the challenges of transporting intubated patients, which formed a significant proportion of the inpatient population during the pandemic; and 3) patients may have experienced hesitancy to present to the emergency department given stay-at-home recommendations that were in place, as well as fear of transmission in the medical setting. Nogueira et al. estimated a worldwide decrease of 19% in diagnosed stroke during the first 3 months of the pandemic (coinciding with our Q1 data).11 There are undoubtedly additional sequelae of reduced emergency/inpatient neuroimaging volume that remain to be elucidated.

We also found a decrease in CTA head/neck volume during Q1 (-31.6%, p = 0.001). As CTA head/neck are commonly ordered at our institution as part of cerebral infarct work up, our findings are in accordance with Kansagra et al.’s observation of decreased stroke imaging utilization from March 26 to 8 April 2020.12 Friedlich et al. demonstrated an increasing burden of stroke morbidity in the United States from February to June 2020 (this time frame also corresponds to a portion of our Q1 data), compared to the same time period in 2019.12 Interestingly, we found an increase above pre-pandemic volume of CTA head/neck imaging studies during Q2 (+26.8%, p = 0.001) and Q3 (+28.6%, p = 0.002). These trends coincided with the evolving body of knowledge around COVID-19 and its complications, specifically its association with cerebral infarction and the increased burden of disease for hospitalized COVID-19 patients who suffer stroke compared to non-COVID-19 stroke controls.13,14 Given the fact that CT head is included with CTA head/neck imaging, there is an apparent discrepancy between decreased NECT head volume and increased CTA head/neck during Q2 and Q3 of 2020. We believe this can be reconciled by examining total volumes over this time period: NECT head volume totaled 486 and 512 respectively, while CTA head/neck volume totaled 71 and 72 respectively. Even though NECT head volume decreased and CTA head/neck volume increased compared to baseline volume, NECT volume was higher than CTA; thus, an increase in CTA volume was absorbed by NECT volume.

We observed a decrease in MR brain w/wo and MR lumbar spine without contrast volume during Q1 (-48.4% and -73.3%, respectively; p < 0.001 and p < 0.001); a decrease in MR brain volume was echoed by Min et al.,15 who described these findings from March to May 2020. We found MR brain w/wo and L-spine without contrast volumes returned to baseline volumes by Q2 (-5.7% and +8.0%, respectively; p = 0.06 and p = 0.33). At our institution, these studies are most commonly encountered in the outpatient setting for the evaluation of tumor progression and lower back pain, respectively. This large decrease in MR brain w/wo volume during Q1 is particularly important for patient safety, as decreased imaging volume could impact evaluation of tumor progression while on therapy. Thus, these patients represent a vulnerable population that should be carefully followed in the event of a future widespread disruption to healthcare, in order to ensure that delays in care do not adversely affect their treatment schedule. In May 2020, near the end of Q1, an international consensus of neuro-oncology experts published guidelines recommending close adherence to regularly scheduled MR brain surveillance.16 Therefore, it is reasonable that we observed a return to normal MR brain w/wo volumes by Q2 that coincided with the aforementioned published guidelines.

In their work addressing the pandemic’s effect on imaging volume across all radiology specialties, Naidich et al. found a shift from cross sectional imaging to radiographs in the inpatient setting (CT and MRI accounted for 15% of inpatient imaging volume in 2020 compared to 25% in 2019), accompanied by a decrease of 57% in outpatient imaging volume across all modalities from March 1 through 18 April 2020.8,16 Thus, our data expands on Naidich’s findings: NECT head (stereotypically performed in the emergency/inpatient setting) failed to recover pre-pandemic volume, while MR brain w/wo and MR lumbar spine without contrast (stereotypically performed in the outpatient setting) recovered during Q2. CTA head/neck (stereotypically performed in the emergency/inpatient setting) was an outlier, with volume exceeding pre-pandemic volume by Q2. We hypothesize that outpatient imaging services that were delayed during the height of the pandemic contributed to outpatient volume rebounding faster than inpatient examinations at our institution, due to a backlog of cases that were processed during Q2 and subsequent quarters. Additional contributing factors include: 1) outpatient facilities did not have to significantly divert their resources to care for the large number of COVID-19 patients and 2) outpatient facilities imaged patients who were relatively healthy in the acute setting compared to their hospitalized peers, thus increasing turnaround time for patient imaging, and increasing volume.

Limitations of the study

Limitations of this study included that it was performed at a single center with a disproportionately high burden of COVID-19 infection compared to the rest of the United States, thus limiting generalizability. This study was conducted at a large tertiary center with infrastructure for highly specialized neurology and neuroradiology, which may not represent the volume and distribution of exams seen in the community setting. As a retrospective study, even though we demonstrated marked differences in number of studies, a prospective study would have allowed us to continue to follow these trends as the COVID-19 pandemic continues to progress. Despite this, our data provide the most comprehensive information to date regarding the effect of COVID-19 pandemic on neuroimaging volumes, and may inform neuroradiologists about vulnerable populations in the event of future large-scale disruptions to healthcare.

Conclusion

Here we demonstrate delayed recovery of NECT head volume that persisted during the entire year following declaration of the COVID-19 pandemic. The decrease in NECT
head volume correlates with other groups findings of increasing morbidity of stroke during the pandemic.\textsuperscript{12,17} Conversely, CTA head/neck volume initially decreased during the first quarter; however, volume increased above pre-pandemic volume during the second quarter; this finding may be attributable to previously published data implicating a prothrombotic state in COVID-19 patients. Building on Min et al.’s utilization of natural language processing to describe how the COVID-19 pandemic affected acuity of findings on MR brain imaging, future studies could leverage natural language processing in order to analyze our data at a larger scale, in an attempt to determine trends that we hope will optimize image utilization in future, resource constrained situations.

\textbf{Declaration of conflicting interests}

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\textbf{Supplemental Material}

Supplemental material for this article is available online.

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\textbf{Appendix}

\textbf{Abbreviations}

\begin{center}
\begin{tabular}{ll}
WHO & World Health Organization
CVA & cerebrovascular accident
NECT & noncontrast enhanced computed tomography
Q1 & first quarter of the year following declaration of the pandemic (3/11/2020 to 6/9/2020)
CTA head/neck & CT angiography head/neck
MR Brain w/wo & MRI brain with and without contrast
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