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Increased per-patient imaging utilization in an emergency department setting during COVID-19

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ABSTRACT

Introduction: COVID-19 has resulted in decreases in absolute imaging volumes, however imaging utilization on a per-patient basis has not been reported. Here we compare per-patient imaging utilization, characterized by imaging studies and work relative value units (wRVUs), in an emergency department (ED) during a COVID-19 surge to the same period in 2019.

Methods: This retrospective study included patients presenting to the ED from April 1-May 1, 2020 and 2019. Patients were stratified into three primary subgroups: all patients (n = 9580, n = 5686), patients presenting with respiratory complaints (n = 1373, n = 2193), and patients presenting without respiratory complaints (n = 8207, n = 3493). The primary outcome was imaging studies/patient and wRVU/patient. Secondary analysis was by disposition and COVID status. Comparisons were via the Wilcoxon rank-sum or Chi-squared tests.

Results: The total patients, imaging exams, and wRVUs during the 2020 and 2019 periods were 5686 and 9580 (41%), 6624 and 8765 (24%), and 4988 and 7818 (36%), respectively, and the percentage patients receiving any imaging was 67% and 51%, respectively (p < .0001). In 2020 there was a 170% relative increase in patients presenting with respiratory complaints. In 2020 patients without respiratory complaints generated 24% more wRVU/patient (p < .0001) and 33% more studies/patient (p < .0001), highlighted by 38% more CTs/patient.

Conclusion: We report increased per-patient imaging utilization in an emergency department during COVID-19, particularly in patients without respiratory complaints.

1. Introduction

The disruptive effects of the COVID-19 pandemic have caused significant declines in imaging volume in emergency departments. Absolute decreases in imaging volume have ranged between 28 and 55% across all patient service locations (e.g. inpatient, outpatient, and emergency departments) in recent studies. Emergency department (ED) imaging volume has similarly been affected by the pandemic, with absolute imaging volumes decreasing 42% compared to pre-COVID levels. While recent studies on imaging volume in the context of the pandemic have highlighted absolute declines in imaging utilization and corresponding work relative value unit (wRVU) data, specific data on changes in per-patient utilization, including data by modality and corresponding wRVU, have not been reported. Such data may be of benefit to recently published models detailing financial recovery predictions as hospitals aim to resume operations. Lastly, with widespread news of decreased ED imaging volumes and concern that sick patients are avoiding the ED secondary to fear of contracting COVID-19, analyzing imaging utilization on a per-patient basis may support anecdotal reports of the increasing complexity of presenting patients – low-acuity patients who are less likely to be imaged may be avoiding the ED.

This study compares per-patient imaging utilization, characterized by imaging studies and work relative value units, in patients presenting

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to the ED during a 2020 COVID-19 pandemic surge to the same period in 2019. We hypothesize that there was increased imaging utilization across all patients in the ED, regardless of COVID status or respiratory-related chief complaint.

2. Methods

2.1. Study design and setting

This single-institution, retrospective collection of aggregate data was compliant with the Health Insurance Portability and Accountability Act and approved with exemption by the Institutional Review Board.

All patients who presented to our ED, housed within a large, urban academic medical center, from April 1–May 1, 2020 and April 1–May 1, 2019 were included. In 2020, this time period was largely considered the height of the COVID-19 pandemic in Massachusetts. At the time of this manuscript, Massachusetts had amassed >121,000 cases and >8700 deaths. We retrospectively identified all patients seen in our ED via our built-in electronic health record (EHR, Epic Systems, Verona WI) reporting system during the study periods; there were no exclusions. Imaging utilization included only studies ordered and performed in the Emergency Department and was quantified by calculating 1) imaging studies/patient (including stratification by modality) and 2) imaging wRVUs/patient. We compared 2020 and 2019 cohorts to identify broad differences according to presenting symptoms, and then sub-analyzed the cohorts by disposition and COVID test status.

2.2. Participants

Both the 2020 and 2019 patient cohorts were stratified into three primary subgroups (Figs. 1 and 2): (I) All Patients, (II) Patients presenting with respiratory complaints, (III) Patients presenting without respiratory complaints. Further secondary subgroups included: (IV) Admitted patients (V) Discharged patients, as well as (VI) COVID+ (defined as any positive test in the patient’s three most recent tests) and (VII) non-COVID+.

Subgroups II and III were intended to highlight the primary respiratory-centered presenting complaints of COVID-19 patients, and to quantify this impact by utilization year-over-year. Distinction between subgroups II and III was based on the chief complaint as recorded by the ED clinician. This field allows for both pre-defined text input and manually entered free-text, and is logged in our EHR and typically recorded upon initial patient presentation to the ED. The vast majority entered are pre-defined text, followed by a mix of pre-defined and free text, and finally less than 1% free text only. The criteria terms for inclusion in subgroup II were: “aspiration”, “asphyxia”, “asthma”, “bronchitis”, “chills”, “cough”, “COVID”, “COPD”, “crackles”, “fever”, “hypoxemia” “hypoxia”, “nasal congestion”, “phlegm”, “pleural”, “pneumonia”, “pulmonary”, “pulmonary embolism”, “rales”, “shortness of breath”, “sore throat”, “sputum”, “stridor”, and “wheeze”. Upon categorizing the patient in either subgroup II or III or VI and VII, all imaging studies associated with the patient, regardless of body part or modality, were included in the per-patient calculations for these groups.

Patient descriptive data, including age and gender, were collected from the EHR. All corresponding imaging exam codes and classes performed in our ED imaging locations were also collected during the study period. To calculate wRVUs, we obtained a list of all exam classes, and manually correlated these to the 2020 National Physician Fee Schedule Relative Value File July Release.

2.3. Variables

The primary study outcome was per-patient imaging utilization, defined as overall/modality-specific studies/patient and wRVUs/patient, among the primary subgroups. Modalities analyzed included computed tomography (CT), ultrasound (US), magnetic resonance imaging (MRI), and conventional radiograph (CR). Per-patient utilization in this context is the number of imaging studies or wRVUs during the study period divided by the total number of presenting patients in each subgroup, regardless of if they received imaging. Using wRVU allows generalizability to practice outside of our geographic location, and further generalizability between facility and non-facility practices. It is understood that using only the wRVU component of reimbursement likely results in more conservative, but also more generalizable, results. Secondary study outcomes included imaging utilization as previously defined in the secondary subgroups - by disposition and COVID test status.

Fig. 1. Flow chart of the study cohort with subgroups by symptom profile and COVID test status.

Patients presenting to the ED

April 1 – May 1, 2019 (n=9580)

Patients presenting with respiratory complaints (n=1373)

Patients presenting without respiratory complaints (n=8207)

COVID+ (n=327)

COVID- (n=9273)

non-COVID (n=1866)

Fig. 2. Flow chart of the study cohort with subgroups by disposition.

wRVU = work relative value unit.
2.4. Study size

The number of patients presenting to the ED during the 2020 and 2019 study periods determined the sample size.

2.5. Statistical methods and analysis

Patient demographics were reported via descriptive statistics. If a patient presented to the ED for multiple visits during the study period, each visit was treated as a separate patient encounter. Statistical comparison of the subgroups was performed via either the Wilcoxon rank-sum test (for comparison of values) or the Chi-squared test (for comparison of proportions). Comparisons of mean studies per-patient and mean wRVU per-patient and modality subgroups were performed via the Wilcoxon rank-sum test. Confidence intervals (CIs) of the mean studies/patient and mean wRVU/patient were calculated with non-parametric bootstrapping (resampling) to calculate CIs. For all statistical tests, a significance level of \( p = .05 \) was used.

3. Results

3.1. Participants and descriptive data (Table 1)

The total number of patients presenting to the ED during the 2020 and 2019 study periods was 5686 and 9580 respectively, an approximate 41% decrease for 2020. All patients presenting to the ED were included. The total number of imaging exams during the 2020 and 2019 study periods was 6624 and 8765, an approximate 24% decrease for 2020. The number of patients receiving any imaging during the 2020 and 2019 study periods were and 66.92% (3805/5686) and 50.89% (3076/6053) respectively, an approximately 36% decrease for 2020. The 2020 cohort included. The total number of imaging exams during the 2020 and 2019 study periods was 6624 and 8765, an approximate 24% decrease for 2020. The number of patients receiving any imaging during the 2020 and 2019 study periods were and 66.92% (3805/5686) and 50.89% (3076/6053) respectively, an approximately 36% decrease for 2020. The absolute number of imaging wRVUs in the study period for 2020 and 2019 were 4988 and 7818 respectively, an approximately 33% decrease for 2020. All patients presenting to the ED were admitted (42.19% [2399/5686] vs. 25.27% [2421/9580]), decreased percentage discharged (49.10% [2792/5686] vs. 67.88% [6503/9580]) and decreased percentage other (6.85% [155/5686] vs. 8.71% [292/9580]). The “other” category, again reflecting ED disposition, includes patients transferred, direct-admits, those sent directly to the operating room, patient demise, or for whom the information was not available (failure of documentation).

3.2. Main results

3.2.1. Per-patient imaging utilization

To examine the data in a granular manner beyond absolute volume and wRVU changes, we examined mean per-patient imaging utilization (Table 2 and Figs. 3 and 4). To reduce confounding by COVID-19 presentations, which are primarily pulmonary in nature, analyzing patients presenting without respiratory complaints provides the most direct comparison of 2020 utilization to 2019. In 2020, this group demonstrated a 24% increase wRVU/patient (1.07 [95% CI, 1.01–1.13] vs. 0.86 [95% CI, 0.83–0.90], \( p < .0001 \), driven increased CT (wRVU/patient 2020 vs. 2019: 0.76 [95% CI, 0.71–0.81] vs. 0.55 [95% CI, 0.53–0.58], \( p < .0001 \)) and CR (wRVU/patient 2020 vs. 2019: 0.12 [95% CI, 0.11–0.13] vs. 0.08 [95% CI, 0.08–0.08], \( p < .0001 \)) wRVU generation. Correspondingly, this group demonstrated a 33% increase in studies/patient (studies/patient 2020 vs. 2019: 1.24 [95% CI] vs. 0.93 [95% CI, 0.90–0.96], \( p < .0001 \), driven by increased CT (studies/patient 2020 vs. 2019: 0.47 [95% CI, 0.44–0.50] vs. 0.34 [95% CI, 0.33–0.36], \( p < .0001 \)) and CR (studies/patient 2020 vs. 2019: 0.65 [95% CI, 0.62–0.68] vs. 0.44 [95% CI, 0.42–0.56], \( p < .0001 \)).

Among all patient groups, compared to 2019 there was an overall 7% increase in imaging wRVU/patient (overall wRVU/patient 2020 vs. 2019: 0.88 [95% CI, 0.83–0.92] vs. 0.82 [95% CI, 0.7852–0.8474], \( p < .0001 \), driven by increased CT (wRVU/patient 2020 vs. 2019: 0.62 [95% CI, 0.59–0.66] vs. 0.53 [95% CI, 0.51–0.55], \( p < .01 \)) and CR (wRVU/patient 2020 vs. 2019: 0.13 [95% CI 0.12–0.13] vs. 0.08 [95% CI, 0.08–0.09], \( p < .0001 \)) wRVU generation. Correspondingly, among all patients, compared to 2019 there was a 27% increase in studies/patient (studies/patient 2020 vs. 2019: 1.17 [95% CI, 1.13–1.20] vs. 0.92 [95% CI, 0.89–0.94], \( p < .0001 \), primarily driven by increased CT (studies/patient 2020 vs. 2019: 0.38 [95% CI, 0.36–0.40] vs. 0.33 [95% CI, 0.31–0.34], \( p = .01 \)) and CR (studies/patient 2020 vs. 2019: 0.70 [95% CI, 0.68–0.72] vs. 0.46 [95% CI, 0.44–0.47], \( p < .0001 \)). Among all patient subgroups, compared to 2019, there was trending towards, but ultimately no significant difference, in MRI or US utilization – this may be in part be due to the relatively low use of these modalities in the ED compared to CT and CR (Supplementary Tables 1 and 2).

3.3. Other analyses

3.3.1. Per-patient imaging utilization by ED disposition

In 2020 there was a 7% increase in studies/patient (studies/patient 2020 vs. 2019: 1.63 [95% CI, 1.56–1.69] vs. 1.53 [95% CI, 1.47–1.60], \( p < .0001 \), but no difference in wRVU per-patient (Table 2). For discharged patients, compared to 2019, there was an approximately 20% increase in studies/patient (studies/patient 2020 vs. 2019: 0.89 [95% CI, 0.85–0.93] vs. 0.74 [95% CI, 0.71–0.77], \( p < .0001 \)) with a 3% increase in wRVU/patient (wRVU/patient 2020 vs. 2019: 0.66 [0.61–0.71] vs. 0.64 [0.61–0.67], \( p < .0001 \), Table 2).

3.3.2. Per-patient imaging utilization by COVID test status

There was no significant difference in imaging utilization when analyzing 2020 COVID+ patients presenting with respiratory complaints and non-COVID+ patients presenting with respiratory complaints, as shown in Table 3 (overall studies/patient COVID+ vs. non-COVID+: 1.07 [95% CI, 0.97–1.17] vs. 1.04 [95% CI, 1.00–1.08], \( p = .93 \) and overall wRVU/patient COVID+ vs. non-COVID+: 0.53 [95% CI, 0.42–0.66] vs. 0.58 [95% CI, 0.54–0.63], \( p = .55 \)).

Table 1

| 2019 | 2020 | \( P \) value |
|------|------|--------------|
| Total patients | 9580 | 5686 | – |
| Patients/day | 309.0 | 183.4 | <.0001 |
| Patients who received any imaging | 4875 (50.89%) | 3805 (66.92%) | <.0001 |
| Total imaging studies | 8765 | 6624 | – |
| Imaging studies/day | 282.7 | 213.7 | <.0001 |
| Total imaging wRVUs | 7818 | 4988 | – |
| Imaging wRVUs/day | 252.2 | 160.9 | <.0001 |
| Age (years) | 45.50 | 50.98 | <.0001 |
| Gender (% M/F/unknown) | 48.32/51.67/0.00% | 44.95/55.05/0.00% | .0002 |
| Patients with respiratory complaints (%) | 1373 (14.33%) | 2193 (38.57%) | <.0001 |
| Respiratory patients who are COVID+ (%) | – | 327 (14.91%) | – |
| ED disposition (%) | 67.88% | 49.10% | <.0001 |
| Discharge | 25.27% | 42.19% | – |
| Other | 6.85% | 8.71% | – |
Table 2
Mean imaging utilization of patients presenting to the ED from April 1–May 1, 2019 and 2020, including analysis by respiratory complaint status and ED disposition. wRVU = work relative value unit.

| Subgroup | Studies/patient | wRVU/patient | P value | P value | P value |
|----------|----------------|--------------|---------|---------|---------|
| Overall  | 2019 (n = 9580) | 2020 (n = 5686) | .001    | .0001   |
| CT       | 0.53 (0.50–0.55) | 0.86 (0.84–0.92) | .0001   | .0001   |
| MR       | 0.11 (0.09–0.13) | 0.08 (0.02–0.20) | .0001   |
| US       | 0.02 (0.02–0.03) | 0.02 (0.02–0.02) | .0001   |
| CR       | 0.26 (0.25–0.27) | 0.16 (0.16–0.17) | .0001   |

Subgroup Studies/patient wRVU/patient | P value | P value |
Overall 2019 (n = 2421) 2020 (n = 3493) | .0001 | .0001 |
CT 0.53 (0.50–0.55) 0.86 (0.84–0.92) | .0001 |
MR 0.11 (0.09–0.13) 0.08 (0.02–0.20) | .0001 |
US 0.02 (0.02–0.03) 0.02 (0.02–0.02) | .0001 |
CR 0.26 (0.25–0.27) 0.16 (0.16–0.17) | .0001 |

Fig. 3. Bar plot of subgroup exams by year, modality, and respiratory status. Data shown as mean (95% of mean).
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wRVU profiles. Parikh et al. demonstrated a decline in ED imaging volume of 38% in the study period compared to 2019. This study reports a relative increase in patients presenting with respiratory complaints — absolute volume contraction and increased lower-wRVU patient presentations — for forecasting quarterly revenue or preparing for additional surges of this or other pandemics. In general, causes for the observed increase in per-patient imaging utilization are likely multifactorial. Clinical uncertainty in the diagnosis and management of COVID-19 may have spurred increased diagnostic testing by clinicians regardless of presenting complaint, thereby leading to increased imaging. Further, as many patients began to avoid the healthcare system to reduce risk of exposure to COVID-19, the average acuity of patients presenting to the ED may have increased. This difference in acuity is suggested by the significant increase in the proportion of patients in the ED that were admitted in 2020 compared to 2019 – 24% and 33% increases in wRVU/patient and studies/patient, respectively. The overall tempered wRVU increase in the context of the 27% overall imaging utilization increase for all patients in 2020 is consistent with the lower average wRVU for respiratory patients (53% of the average wRVU for non-respiratory patients in 2020, and 62% in 2019), which accounted for a 170% relative increase (60% absolute) in ED visits compared to 2019 (38.6% vs. 14.3%). This double financial hit, comprised of (I) absolute volume contraction and (II) increased proportion of lower-value wRVU volume, is significant and can be taken into account by financial managers at all practices – for forecasting quarterly revenue or preparing for additional surges of this or other pandemics.

### 4. Discussion

To our knowledge this is the first report of increased per-patient imaging utilization during the COVID-19 pandemic. Analyzing emergency department patients presenting without respiratory complaints minimizes confounding by pulmonary-centric COVID-19 presentations: in this subgroup we observed a significant 33% increase in imaging studies/patient and 24% increase in wRVU/patient, compared to 2019, including a 38% increase in CTs/patient. Notably, we observed a significant 170% relative increase in patients presenting with respiratory complaints, accounting for 38.6% of all patients in 2020, compared to 14.9% in 2019. As respiratory patients carry just 53% of the average wRVU/patient of a non-respiratory patient, this engenders a double-financial hit to emergency departments and associated imaging operations - absolute volume contraction and increased lower-wRVU patient profiles.

The absolute decline (~24%) in total imaging exams during the 2020 study period compared to 2019 echoes recently published literature. 3,18 Parikh et al. demonstrated a decline in ED imaging volume of 38–58% in the Cleveland metropolitan area. 3 Naidich et al. demonstrated a decrease in ED imaging volume of approximately 27% over a seven-week period amidst the COVID-19 pandemic in New York City. 1 Our prior research demonstrated hospital-wide overall volume decreases of 54–64%. 5 The authors speculate that the magnitude of decline in imaging volume is multifactorial - population density, patient catchment area, severity of COVID-19 outbreaks, and social distancing policies are a few of many possible factors.

#### 4.1. Looking beyond absolute volume contraction

Despite absolute imaging volume contraction, in the 2020 study period there was, across the board, a 7% increase in wRVU/patient and corresponding 27% increase in studies/patient, compared to the same period in 2019. When analyzing non-respiratory presenting patients, these numbers are even more pronounced – 24% and 33% increases in wRVU/patient and studies/patient, respectively. The overall tempered wRVU increase in the context of the 27% overall imaging utilization increase for all patients in 2020 is consistent with the lower average wRVU for respiratory patients (53% of the average wRVU for non-respiratory patients in 2020, and 62% in 2019), which accounted for a 170% relative increase (60% absolute) in ED visits compared to 2019 (38.6% vs. 14.3%). This double financial hit, comprised of (I) absolute volume contraction and (II) increased proportion of lower-value wRVU volume, is significant and can be taken into account by financial managers at all practices – for forecasting quarterly revenue or preparing for additional surges of this or other pandemics.

#### 4.2. Limitations

Regarding imaging utilization in the ED of COVID+ compared to
non-COVID+ patients presenting with respiratory complaints, we found no difference in imaging studies/patient or wRVU/patient. However this secondary analysis has significant limitations as (I) our data was ED-specific, excluding inpatient imaging and (II) our data was collected in aggregate, therefore the COVID+ group could theoretically have included patients with a positive test prior to the ED, patients tested and resulted while in the ED, and patients tested and resulted after ED discharge.

Among all data, the retrospective and aggregate data collection limited assessment for the precise causes for the changes in imaging volume. Geographic and temporal variability in the effects of COVID-19 throughout the United States may limit the ability to extrapolate the results of this study to other radiology practices. Our study period is one-month during the first-wave of COVID, and therefore does not assess longitudinal practice patterns during subsequent waves of the pandemic. Lastly, our study is at a large academic center, and primarily generalizable to similar practices reading ED imaging.

In conclusion, this study is the first to report increased per-patient imaging utilization during COVID-19, characterized by significantly increased studies and wRVUs. We also identified a significantly increased proportion of patients receiving imaging as well as increased admitted patients, suggesting that less-acute patients are avoiding care. As the effects of COVID-19 on radiology practices continue to evolve, knowledge of individualized utilization growth metrics may help departments understand and plan for imaging trends.

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Ethics approval

Approved with exemption by the Institutional Review Board with waiver of consent and assent.

Declaration of competing interest

The authors declare no relevant conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clinimag.2021.06.003.

References

[1] Naidich JI, Boltenkov A, Wang JJ, Chusid J, Hughes D, Sanelli PC. Impact of the coronavirus disease 2019 (COVID-19) pandemic on imaging case volumes. J Am Coll Radiol 2020;17(7):865–72. Jul 1.

[2] Parikh KD, Ramaiya NH, Kikano EG, et al. COVID-19 pandemic impact on decreased imaging utilization: a single institutional experience. Acad Radiol 2020; 5(9).

[3] Cavallo JJ, Forman HP. The economic impact of the COVID-19 pandemic on radiology practices. Radiology 2020 Apr 15;396(1):41–4. 2021.45.

[4] Hartnett KP. Impact of the COVID-19 pandemic on emergency department visits — United States, January 1, 2019–May 30, 2020. MMWR Morb Mortal Wkly Rep 2020;69 [Internet]. [cited 2020 Jul 24]. Available from, https://www.cdc.gov/mmwr/ volumes/69/wr/mm6926e1.htm.

[5] Lang M, Yeung T, Mendoza DP, et al. Imaging Volume Trends and Recovery During the COVID-19 Pandemic: A Comparative Analysis Between a Large Urban Academic Hospital and Its Affiliated Imaging Centers. Acad Radiol 2020;27(10): 1353–62. https://doi.org/10.1016/j.acra.2020.08.008.

[6] Guitton S, Pianykh OS, Susci MD, Lang M, Brink J. COVID-19: recovery models for radiology departments. J Am Coll Radiol 2020 Sep 7;0(0) [Internet]. [cited 2020 Sep 16]. Available from: https://www.jacr.org/article/S1546-1440(20)30963-7/abstract.

[7] Lang M, Yeung T, Shepard JO, Sharma A, Petranovic M, Flores EJ, McLeod TG, Som A, Saini S, Prabhudaraz AM. Operational Challenges of a Low-Dose CT Lung Cancer Screening Program During the Coronavirus Disease 2019 Pandemic. Chest 2021;159(3):1288–91. https://doi.org/10.1016/j.chest.2020.10.045 [Epub 2020 Oct 26]. PMID: 33121979; PMCID: PMC7587133.

[8] Snyder A, Jang S, Nazari IS, Som A, Flores EJ, Succi MD, Little BP. Google search volume trends for cancer screening terms during the COVID-19 pandemic. J Med Screen 2021;28(2):210–2. https://doi.org/10.1177/1744854121999426 [Epub 2021 Mar 4]. PMID: 33663240.

[9] Madhuriyan N, Cheung HMC, Alicia Cheung LH, Jawahar A, Willis MH, Larson DB. Variables influencing radiology volume recovery during the next phase of the coronavirus disease 2019 (COVID-19) pandemic. J Am Coll Radiol 2020 Jul 1;17(7):855–64.

[10] Wong L, Hawkins J, Langness S, Murell K, Irri P, Samman A. Where are all the patients? Addressing Covid-19 fear to encourage sick patients to seek emergency care. NEJM Catalyst Innov Care Deliv 2020 May 14 [Internet]. [cited 2020 Jul 24]; Available from: https://catalyst.nejm.org/doi/abs/10.1056/CAT.20.0146.

[11] Bernstein L, Sellers FS. Patients with heart attacks, strokes and even appendicitis vanish from hospitals. Washington Post [Internet] 2020 Jul 24. Available from: https://www.washingtonpost.com/health/patients-with-heart-attacks-strokes-and-even-appendicitis-vanish-from-hospitals/2020/04/19/9ca6e24-7eb4-11ea-a404-68981f488edd_story.html.

[12] Krumholz HM, Where have all the heart attacks gone? The New York Times [Internet] 2020 Apr 6 [cited 2020 Jul 24]; Available from: https://www.nytimes.com/2020/04/06/well/live/coronavirus-doctors-hospitals-emergency-care-heart-attack-stroke.html.

[13] Deerberg-Wittram Jens, Knothe Christoph. Do not stay at home: we are ready for you. NEJM Catalyst Innov Care Deliv 2020 May 5 [Internet]. [cited 2020 Jul 24]; Available from: https://catalyst.nejm.org/doi/abs/10.1056/CAT.20.0195.

[14] Tam Chor-Cheung Frankie, Cheung Kent-Shek, Lam Simon, et al. Impact of coronavirus disease 2019 (COVID-19) outbreak on ST-segment–elevation myocardial infarction care in Hong Kong, China. Circ Cardiovasc Qual Outcomes 2020 Apr 1;13(4):e006631.

[15] Morelli N, Rota E, Terracciano C, et al. The baffling case of ischemic stroke disappearance from the casualty department in the COVID-19 era. Eur Neurol 2020;83(2):213–5.

[16] Massachusetts coronavirus: 114,320 cases and 8,468 deaths (COVID-19). Worldometer [Internet] 2020 Jul 23. Available from: https://www.worldometers.info/coronavirus/us/maasachusetts/.

[17] CMS-1715-F. CMS [Internet]. [cited 2020 Jul 24]. Available from: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/PhysicianFeeSched/FFS-Federal-Regulation-Notices-Items/CMS-1715-F.

[18] Sharpe Jr RE, Kuszyk BS. RSNA COVID-19 Task Force Members. Special Report of the RSNA COVID-19 Task Force: The Short- and Long-term Financial Impact of the COVID-19 Pandemic on Private Radiology Practices. Radiology 2021;298(1): E11–8. https://doi.org/10.1148/radiol.2020202517.

[19] Lange SJ, Ritchey MD, Goodman AB, et al. Potential indirect effects of the COVID-19 pandemic on use of emergency departments for acute life-threatening conditions — United States, January–May 2020. MMWR Morb Mortal Wkly Rep 2020;69(25):795–800. Jun 26.