

Original Article



A Multicenter Survey on the Trend of Chest CT Scan Utilization: Tracing the First Footsteps of COVID-19 in Iran

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Abstract

Background: Chest computed tomography (CT) scan has been used widely to diagnose COVID-19 in Iran.

Objectives: To trace the footsteps of COVID-19 in Iran by exploring the trend in using chest CT scans and its economic impact on radiology departments.

Methods: In this cross-sectional study, the number of imaging examinations from 33 tertiary radiology departments in 9 large cities of Iran was collected from September 23, 2019 to March 20, 2020 (Months 1 to 6) and the corresponding months in 2018–2019.

Results: A 50.2% increase was noted in the chest CT scan utilization in 2019–2020 compared to 2018–2019. This increase was +15%, +15%, +27%, +2%, +1% in Months 1–5 of 2019–2020, respectively. In Month 6 of 2019–2020, a 251% increase in the acquisition of chest CT scans was observed compared to the Month 6 of 2018–2019. Following negative balance of revenue from Month 1 to 5 with respect to the inflation rate, the total income in Month 6 was further 1.5% less than the same Month in 2018–19.

Conclusion: The observed peak in chest CT utilization in Month 3 prior to the surge in Month 6 could be explained by the seasonal influenza. However, unawareness about an emerging viral disease, i.e. COVID-19, might have underutilized chest CT in Months 4 and 5 before the official announcement in Month 6. The unbalanced increase in the workload of radiology departments in the shortage of cardiothoracic radiologists with the simultaneous decrease in income initiated a vicious cycle that worsened the economic repercussions of the pandemic.

Keywords: COVID-19, Hospital, Multicenter Study, Multidetector computed tomography, Radiology department, Public health

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic has caused 593 000 deaths in 13.9 million infected individuals as of July 17, 2020,¹ which has resulted in an unprecedented increasing workload for the healthcare system. The need for accurate and rapid tests to diagnose the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is crucial for optimal clinical management of the patients and effective control of the COVID-19 pandemic.

Iran was one of the first countries struggling with surging numbers of COVID-19 patients.² At the time of writing, more than 269 000 individuals have been diagnosed with the disease and 13 000 have died in Iran.¹ Although these numbers appear to be significantly underestimated,³ Iran suffers from the highest burden of the disease in the Middle East.

Limited availability of the reverse-transcriptase polymerase-chain-reaction (RT-PCR) test kits for SARS-CoV-2 and the reportedly higher sensitivity of chest computed tomography (CT)⁴ in patients with a high pretest probability of the disease⁵ forced the healthcare system to implement chest CT in the initial diagnostic workup of patients with suspect COVID-19. Therefore, tracing the number of chest CT studies since early fall 2019 could potentially give us the footsteps of the disease.

The implementation of chest CT in the initial workup of patients with respiratory symptoms has been a valuable step in controlling the pandemic. A notable shift to the imaging of chest with a possible drop in imaging of other organs, however, may raise concerns on the job security for the radiologists who have been involved in other subspecialties without enough experience in thoracic imaging. The economic consequences could also be a matter of concern for the radiology departments, which have already been influenced by economic sanctions and currency depreciations in Iran.

This study aimed to explore the trend and pattern of utilization of imaging modalities in 2019–2020 in 9 big cities of Iran with a total population of more than 20 million. The trend in chest CT utilization is applied to trace COVID-19 footprint and address the pros and cons of radiology subspecialization. The economic impact of the change in workflow and imaging requisitions on the radiology departments and imaging centers is also studied.

Materials and Methods

Data Source

For this cross-sectional study, data were obtained from health information systems and picture archiving and communication systems at 33 radiology departments/imaging centers in 9 large cities in Iran, as capitals of the provinces. These centers were tertiary main referral imaging centers in their corresponding provinces including radiology departments of 28 university teaching hospitals and three major private imaging centers (Table 1). The

names and populations of these cities are as follows: Tehran (8 737 510), Mashhad (3 372 660), Isfahan (2 243 249), Shiraz (1 869 001), Tabriz (1 733 033), Rasht (956 971), Kerman (738 724), Yazd (656 474), and Gorgan (480 541). With a total population of 20 788 163, these cities constitute 5 out of the 6 most populated cities and more than 26% and 35% of total and urban population in Iran, respectively.⁶

Patient and Public Involvement

The public were not involved in the design, or conduct, or recruitment the data for this study. The results of this study will be disseminated to the public according to the journal's policies.

Data Classification

The number of obtained imaging modalities was collected on a monthly basis per two 6-month periods, which correspond to the flu season. The first period, i.e. 2018–2019, started from September 2018 to March 2019 and the second, i.e. 2019–2020, covers September 2019 to March 2020. Due to the difference in the Persian (Solar Hijri) and Gregorian calendars, the data from each Month are depicted in the numerical order. For example, the month of 'Mehr' in Persian Calendar year 1397 corresponds to September 23 to October 22, 2018 in Gregorian Calendar, which was considered as "Month 1" in this study. Accordingly, Month 2 (*Aban*) = October 23 to November 21; Month 3 (*Azar*) = November 22 to December 21; Month 4 (*Dey*) = December 22 to January 20; Month 5 (*Bahman*) = January 21 to February 19; and Month 6 (*Esfand*) = February 19 to March 20. The same order applies to the second 6-month period (2019–2020) from September 23, 2019 to March 20, 2020.

The data were categorized as: 1. Chest CT scan (CT with or without IV contrast, high-resolution CT, CT angiography of the pulmonary arteries, etc.); 2. Brain CT scan [with or without IV contrast, CT angiography (CTA), CT venography (CTV), etc.]; 3. Abdominopelvic CT scan (with or without IV contrast, CTA, CTV, CT Urography, etc.); and 4. Others (facial, orbital, paranasal sinuses, temporal bone CT, spine, and extremities). The total number of magnetic resonance imaging (MRI) studies, regardless of the body part, was also collected.

Data Analysis

STATA statistical software, Release 14, StataCorp LLC, was used. The trend in utilization of each imaging modality was depicted. The income of radiology departments was determined as follows. The cost per each modality was calculated by the total number of the imaging studies multiplied by the official tariffs set by the Iranian health authorities in 2018–2019 and 2019–2020. Then, the costs of all imaging studies were summed up per Month in 2019–2020 and compared to that in 2018–2019. A Heat

map figure was used to illustrate the ratio of two odds according to the following formula:

$$\text{Chest odds ratio} = \frac{\text{odds of ordered chest CT to the ordered CT scans for all other organs in month 6 of 2019 – 2020}}{\text{odds of ordered chest CT to the ordered CT scans for all other organs in month 6 of 2018 – 2019}}$$

Table 1. Characteristics of the Enrolled Hospitals and Imaging Centers That Provided Data for the Study

Center/Hospital	City, Province	Center/Hospital Type	General Beds/ICU Beds	CT Scanners No.	MRI Machines No.	General Radiologists	Fellowship-Trained Radiologist	In Training Residents
Shariati Hospital	Tehran, Tehran	Teaching	520/73	2	1	7	2	28
Sina Hospital	Tehran, Tehran	Teaching	486/51	2	1	7	1	27
Amir A'lam Hospital	Tehran, Tehran	Teaching	280/28	1	1	3	1	20
Shohada-E-Tajrish Hospital	Tehran, Tehran	Teaching	485/39	2	1	7	2	25
Masih Daneshvari Hospital	Tehran, Tehran	Teaching	330/33	1	0	6	0	4
Shahid Modarres Hospital	Tehran, Tehran	Teaching	265/38	1	0	3	2	5
Shahid Labbafinejad Hospital	Tehran, Tehran	Teaching	225/10	1	0	3	0	5
Taleghani Hospital	Tehran, Tehran	Teaching	481/20	1	0	3	0	10
Loghman Hakim Hospital	Tehran, Tehran	Teaching	365/32	1	0	4	0	15
Imam Hossein Hospital	Tehran, Tehran	Teaching	605/22	1	1	4	0	25
Mofid Hospital	Tehran, Tehran	Teaching	219/12	1	0	1	0	5
Mahdieh Hospital	Tehran, Tehran	Teaching	134/7	1	0	2	0	6
Akhtar Hospital	Tehran, Tehran	Non-teaching (Public)	114/8	1	0	1	0	0
Torfeh Hospital	Tehran, Tehran	Non-teaching (Public)	110/0	1	0	1	0	0
Mofatteh Hospital	Tehran, Tehran	Non-teaching (Public)	148/7	1	1	1	0	0
Pakdasht Hospital	Tehran, Tehran	Non-teaching (Public)	157/7	1	0	1	0	0
Damavand Hospital	Tehran, Tehran	Non-teaching (Public)	108/0	1	0	1	0	0
Shohada Gomnam Hospital	Tehran, Tehran	Non-teaching (Public)	120/0	1	0	1	0	0
Imam Reza Hospital	Mashhad, Khorasan-e-Razavi	Teaching	1028/97	1	1	6	2	44
Amin Hospital	Isfahan, Isfahan	Teaching	160/39	1	0	3	0	80
Ayatollah Kashani Hospital	Isfahan, Isfahan	Teaching	220/30	2	1	3	1	80
Sepahan Imaging Center	Isfahan, Isfahan	Private	N/A	1	2	3	1	N/A
Namazi Hospital	Shiraz, Fars	Teaching	824/91	3	2	11	5	87
TABA Imaging Center	Shiraz, Fars	Private	N/A	1	1	8	1	N/A
Imam Reza Hospital	Tabriz, Azarbayjan-e-Sharghi	Teaching	800/129	3	1	11	2	60
Razi Hospital	Rasht, Guilan	Teaching	300/10	1	0	3	0	10
Poursina Hospital	Rasht, Guilan	Teaching	263/29	2	1	3	0	9
Afzalipour Hospital	Kerman, Kerman	Teaching	505/120	1	0	6	0	16
Sadoughi Hospital	Yazd, Yazd	Teaching	520/48	1	1	4	2	32
Rahnemun Hospital	Yazd, Yazd	Teaching	220/36	1	1	2	0	6
5 Azar Hospital	Gorgan, Golestan	Teaching	400/30	2	0	6	0	13
Golestan Imaging Center	Gorgan, Golestan	Private	N/A	1	1	3	0	9
Sayyad Shirazi Hospital	Gorgan, Golestan	Teaching	340/35	1	0	4	2	13

Results

Total Number of Imaging Modalities in 2019–2020 and 2018–2019

The total number of CT and MRI studies in the second period decreased by 0.3% compared to the previous period: 430617 and 431817 in 2019–2020 and 2018–2019, respectively. Abdominopelvic CT, brain CT, and MRI scans decreased by 4.3%, 10.8%, and 13.9%, in 2019–2020 compared to 2018–2019, respectively. In contrast,

a more than 50.2% increase was seen in the total number of chest CT scans in 2019–2020 compared to 2018–2019 (Figure 1).

Trend in the Number of CT scans

The total number (percentage) of chest CT increased by 1274 (+14.6%), 1243 (+15.1%), 2443 (+27.3%), 191 (+1.9%), 62 (+0.7%) and 21848 (+251.5%) in the 1st to 6th Months, respectively, in the 2019–2020 period,

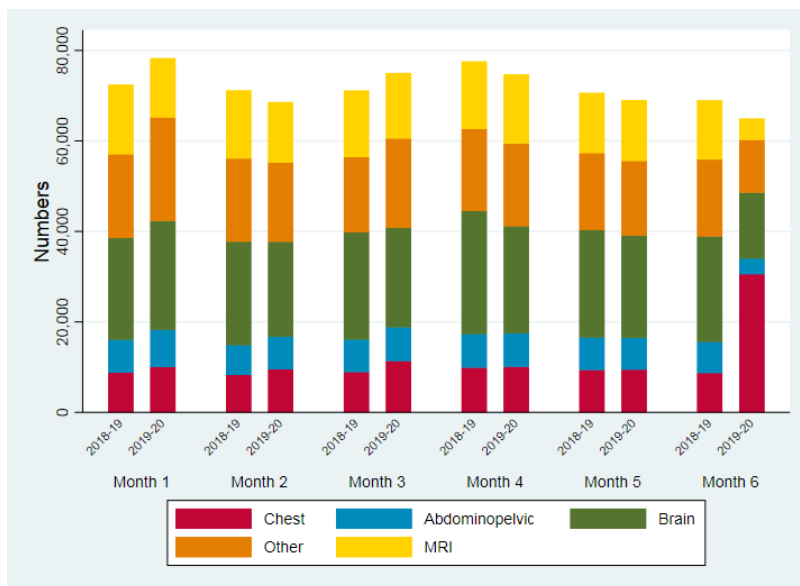


Figure 1. Stacked Bar Chart to Show the Number of CT Studies Per Organ and the Total Number of MRI Examinations from Month 1 To 6 in the Year 2018–2019 Compared to the Year 2019–2020.

compared to the chest CT scans in the corresponding Months in 2018–2019 (Figure 2). The lowest chest odds ratios were 2.15 and 2.64, which corresponded to Fars and East Azerbaijan provinces, respectively. The highest chest odds ratios were 18.83 and 18.74, which were seen in Gorgan (Golestan province) and Rasht (Guilan province), respectively (Figure 3). In 2018–2019, brain CT was the most common CT imaging study used, followed by others, chest, and abdominopelvic exams. This pattern was unchanged until Month 6, when a substantial increase was noted in the percentage of chest CT scans.

The number of abdominopelvic CT scans was higher in Months 1, 2, and 3 in 2019–2020 than in the same Months of 2018–2019. A substantial decrease in the number of abdominopelvic CT scans was seen in Month 6 in 2019–2020 compared to the same Month in 2018–

2019. Similar patterns were seen in brain and other CT scans in 2019–2020 compared to 2018–2019 (Figure 4).

Trend in the Number of MRI Examinations

The total number of MRI examinations was 4712 in Month 6 of 2019–2020 period, which showed a 63.9% decrease compared to the same Month of the previous year.

Analysis of the Income

The total income of all radiology departments and imaging centers was IRR 32.1 and IRR 31.6 billion in 2018–2019

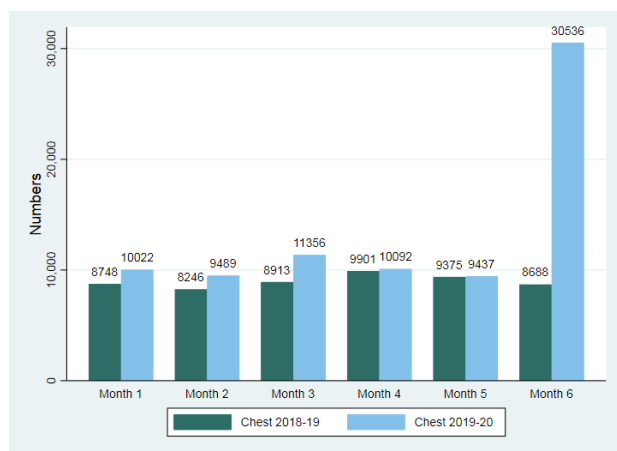


Figure 2. Bar Chart to Illustrate the Total Number of Chest CT Studies in All Departments from Month 1 to 6 in the Year 2018–2019 Compared to the Year 2019–2020.

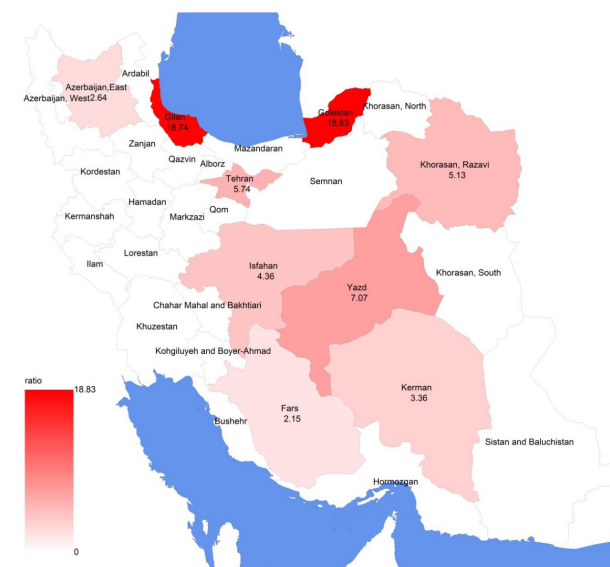


Figure 3. Heat Map to Illustrate Ratios of Two Odds Including Odds of Chest CT Numbers to the Number of Non-Chest CT Studies in Month 6, 2019-2020 Divided by the Same Odds in Month 6 of 2018–19 for Each of 9 Provinces.

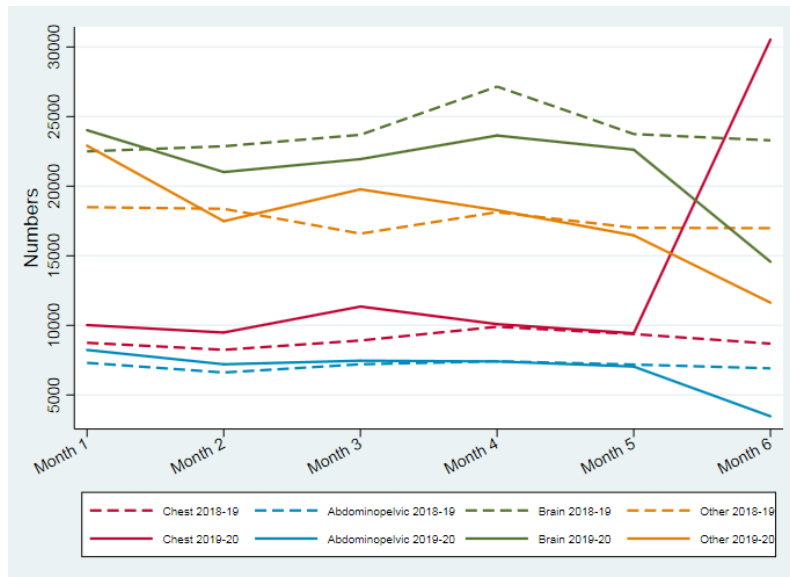


Figure 4. Line Chart to Display Trends in the Number of CT Studies Per Organ in All Departments from Month 1 to 6 in the Year 2018–2019 Compared to the Year 2019–2020.

and 2019–2020, respectively. This income was increased in Months 1 to 5 of 2019–2020 compared to the same period in 2018–2019. The last Month, however, showed a decrease in the income by 1.5% (Figure 5).

Discussion

Catching the First Glimpse of Pandemic

The outbreak of COVID-19 in China was first reported in late December 2019.⁷ Some reporters, however, recently figured out that the patient zero might be traced back to November 17, 2019.⁸ Although the first case of COVID-19 in Iran was confirmed on February 19, 2020,² tracing the actual first patient has been cumbersome because it was an unknown respiratory disease outbreak during the flu season. One way to trace the first signs of the outbreak is to look for the number of diagnostic tests ordered in the referral hospitals. It has been very difficult to monitor the disease outbreak in the large cities of Iran, due to the limited number of available molecular diagnostic assays and RT-PCR kits. Therefore, a chest CT scan was initially implemented in the diagnostic workup of the patients with respiratory signs and symptoms in Iran.^{4,5}

In this survey, the total number of chest CT acquisitions in the 2019–2020 period was 50% higher than the same period of 2018–2019. This increase consisted of 15%–27% rise in the first three Months of 2019–2020 compared to the previous period, followed by a two-month trend of unchanged volume. A substantial 251% increase in the number of CT scans was seen in Month 6 of 2019–2020 compared to Month 6 of 2018–2019. This pattern could be explained by two hypotheses: first, higher incidence of seasonal influenza-associated pneumonia with the highest peak in Month 3. Seasonal waves of influenza are commonly expected every year, which may

present a complex spatiotemporal pattern depending on the biological, sociodemographic, and environmental factors.⁹ The second hypothesis based on the higher peak of chest CT utilization in Month 3 might be attributed to the other causes of acute respiratory diseases like unknown viruses (e.g. COVID-19). However, unawareness of the healthcare system, especially physicians, about the presence of a confirmed new virus in Iran might have led to a relative decrease in chest CT utilization in Months 4 and 5 before a considerable surge in Month 6. On the other hand, a part of notable overutilization of chest CT in Iran in 6 was derived from the panic of being infected by COVID-19, which resulted in significantly increased requisitions without sufficient clinical indications. Nevertheless, the hypothesis of earlier COVID-19 spread to Iran could have been supported if the earlier peak in Month 3 had been continuously extended to Months 4 and 5, then to the highest peak in Month 6.

The Pattern of Utilization of Imaging Studies and Economic and Workload Consequences

In contrast to chest CT scans, radiology departments have faced a remarkable reduction in the number of brain CT, abdominopelvic CT, other CT scans, and MRI examinations in 2019–2020 compared to 2018–2019. In a large healthcare system in New York, the United States, a substantial decline, i.e. 28%, was reported in all imaging volumes. Mammography, MRI, nuclear medicine, and ultrasound witnessed the largest decrease in acquisition. However, more detailed information was not provided about the change in the volume of imaging for each body part, e.g. chest CT.¹⁰ In another study in the United States, the number of brain imaging declined by as much as 50% during the pandemic.¹¹

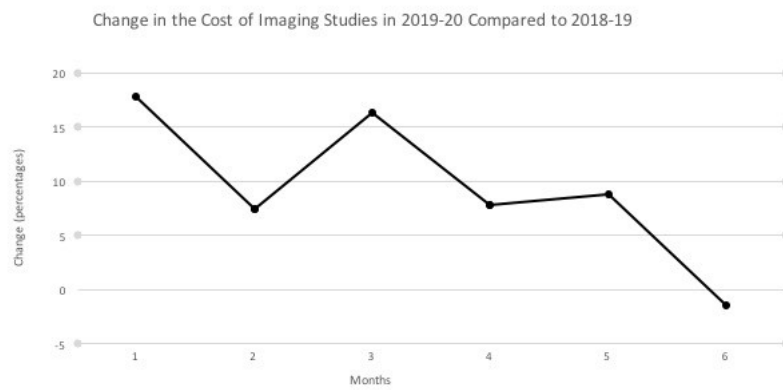


Figure 5. Line Chart to Show the Trend of Income Change Presented as Percentage for All Departments from Month 1 to 6 in the Year 2019-2020 with Respect to Year the 2018-2019.

These changes have substantial economic consequences for the radiology departments. The economic impact has been warned in Germany, Austria, and Switzerland where the nuclear medicine services were notably reduced 3 weeks after the SARS-CoV-2 pandemic.¹² In the United States, a huge reduction of 50%-70% has been anticipated in imaging volumes for at least 3-4 months. This reduction will be most prominent in outpatient practices.¹³ In the present study, the total income of the radiology departments in 2019-2020 from CT and MRI was only partially offset in the first five Months by the increased total number of chest CTs. The worst economic impact of the pandemic on the radiology departments was observed in Month 6 of 2019-2020. In this Month, although the 1.5% decrease in the income of these departments may seem insignificant, radiology departments have faced a significant drop in their revenue considering the inflation rate of 35% in Iran.

The quality of providing service was already compromised when the maintenance service for the imaging equipment had been reduced due to the economic sanctions and Iranian currency (IRR) depreciation, with a 12-month inflation rate of 34.8% ending in Month 6 (i.e. *Esfand*), 2019-2020.¹⁴ The apparently increased income of the radiology departments from Month 1 to Month 5 (Figure 5) in 2019-2020 compared to the same period in the previous year must be interpreted and adjusted according to the heavy impact of the high inflation rate. This declining trend of income was further accentuated in Month 6 of 2019-2020 when the curve dropped to a negative value. The international community sent humanitarian aids to Iran including diagnostic kits, medicine, and protective equipment while no aids were sent to support the equipment of radiology centers. Needless to say, this negative economic impact may significantly threaten the survival of imaging centers and overutilization may shorten the availability of the CT scanners for the rest of the fight against the pandemic.

The Pros and Cons of Radiology Subspecialization in Iran

With the significant increase in the workload of radiologists, the radiology departments in Iran were not fully capable of dealing with the pandemic. A couple of reasons might explain this deficit: first, the number of cardiothoracic imagers available is not sufficient to meet the increased demand in a pandemic of such respiratory diseases in Iran, where there is no dedicated cardiothoracic imaging fellowship program. Second, many radiologists in Iran are working as sonographers without any experience or involvement in cross-sectional imaging. Therefore, health authorities must be prepared for any possible future pandemic by investment and planning for training subspecialized cardiothoracic radiologists as well as other healthcare staff necessary for these situations. This specific shortage of fellowship-trained radiologists in thoracic imaging adds to the already described shortage of medical providers in the country. Although small cities, non-academic centers, and rural and underserved areas may experience the shortages more severely, the need for subspecialty-trained radiologists is felt everywhere. The downside of subspecialization can be highlighted by looking at the odds of chest CT studies to all other CTs in Month 6, 2019-2020 compared to the same odds in Month 6 of 2018-2019 (odds ratio 2-19; Figure 4). This shows how other subspecialties like abdominal, neuro-, or musculoskeletal radiologists may suffer from job insecurity.

Several limitations should be considered when interpreting the results. First, we did not have data from the other 22 provinces of Iran to conduct a comprehensive national survey. However, covering more than 35% of the urban population could provide important information about the trend and pattern of imaging utilization. Second, three enrolled private centers were excluded from income analysis because of the different tariffs they use for imaging. This exclusion could not significantly skew our results since most of the individuals were referred to the teaching (public) hospitals thanks to the benefits of insurance coverage. Finally, although it was not the

primary question of this study, data from patients referred to hospitals due to respiratory symptoms could provide more granular data regarding the onset and footprint of COVID-19 in Iran.

In conclusion, the results of this study could provide a valuable overview of the trend and pattern of imaging utilization in a wide multi-province setting during the COVID-19 outbreak in Iran. Compared to the same period in 2018–2019, a significant increase was identified in the acquisition of chest CT studies in Month 3, 2019–2020 (two months before official announcement of SARS-CoV-2 in Iran) without a persistent increase in months 4 and 5. This might be attributed to the seasonal waves of influenza or lack of healthcare system awareness about presence of an emerging viral infection, i.e. COVID-19. This might have caused the underutilization of chest CT in months 4 and 5. The increased burden on the radiology workforce initiated a vicious cycle in which the resulting burnout, financial hardship, and lack of maintenance service worsened the economic repercussions of the pandemic. The shortage of thoracic radiologists and job insecurity for non-thoracic radiologists (including those who strictly focus on ultrasonography) in Iran should also alert the health authorities to choose wiser policies in the future.

Further studies are warranted on a wider scale and a higher temporal resolution of data collection focusing on the imaging and clinical findings to better track COVID-19 footsteps in different countries in more details.

Authors' Contribution

AR and AG contributed equally as co-first authors. They were involved in the study design, conduct, data gathering, analysis of the data, and writing and editing the manuscript. SAM was involved in statistical analysis, manuscript writing and editing. AK was involved in the statistical analysis. NN, RML, RJR, AD, AH, ASR, MPR, RNM, HS, AE, MA, GJS, AS, MM, RJ, MB, TFL, MR, AA, PD, HBM, and HH provided data and participated in manuscript writing and editing. MST was involved in study design and conduct, data management and audit, and manuscript editing.

Conflict of Interest Disclosures

All authors have nothing to disclose.

Ethical Statement

The study was approved by the ethics committee of the National Institute for Medical Research Development in Iran (ID: IR.NIMAD.REC.1399.011).

Data Sharing Statement

Data will be available upon request to the corresponding author.

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