



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

# Variables Influencing Radiology Volume Recovery During the Next Phase of the Coronavirus Disease 2019 (COVID-19) Pandemic

Nikhil Madhuripan, MD<sup>a</sup>, Helen M. C. Cheung, MD, PhD<sup>a</sup>, Li Hsia Alicia Cheong, MD<sup>a</sup>, Anugayathri Jawahar, MD<sup>a</sup>, Marc H. Willis, DO, MMM<sup>b</sup>, David B. Larson, MD, MBA<sup>c</sup>

## Abstract

The coronavirus disease 2019 (COVID-19) pandemic has reduced radiology volumes across the country as providers have decreased elective care to minimize the spread of infection and free up health care delivery system capacity. After the stay-at-home order was issued in our county, imaging volumes at our institution decreased to approximately 46% of baseline volumes, similar to the experience of other radiology practices. Given the substantial differences in severity and timing of the disease in different geographic regions, estimating resumption of radiology volumes will be one of the next major challenges for radiology practices. We hypothesize that there are six major variables that will likely predict radiology volumes: (1) severity of disease in the local region, including potential subsequent “waves” of infection; (2) lifting of government social distancing restrictions; (3) patient concern regarding risk of leaving home and entering imaging facilities; (4) management of pent-up demand for imaging delayed during the acute phase of the pandemic, including institutional capacity; (5) impact of the economic downturn on health insurance and ability to pay for imaging; and (6) radiology practice profile reflecting amount of elective imaging performed, including type of patients seen by the radiology practice such as emergency, inpatient, outpatient mix and subspecialty types. We encourage radiology practice leaders to use these and other relevant variables to plan for the coming weeks and to work collaboratively with local health system and governmental leaders to help ensure that needed patient care is restored as quickly as the environment will safely permit.

**Key Words:** COVID-19, utilization, volumes

J Am Coll Radiol 2020;17:855-864. Copyright © 2020 American College of Radiology

## INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has reduced radiology volumes across the country as providers have decreased elective care to minimize the spread of infection and free up health care delivery system capacity [1,2]. Health care institutions have rapidly implemented

infection control and social distancing protocols [3,4] and are now better prepared to safely accommodate greater numbers of patients. Radiology practices are now beginning to resume routine imaging.

The impact and the severity of the pandemic have varied markedly in different localities across the United States. For example, [Figure 1](#) shows a graph of new cases per 100,000 population every 5 days since mid-March 2020 in an illustrative sample of states, with the peak in the most affected state, New York (253.4), 23 times that of the peak in the least affected state included in the illustration, Montana (9.3). Even within states, there is wide variance in case numbers; for example, there have been 2,298 cases per 100,000 population in New York City, New York, compared with 219 cases per 100,000 population in Monroe County, New York, which includes the city of Rochester [5].

Given the substantial differences in severity and timing of the disease in different geographic regions, it seems

<sup>a</sup>Department of Radiology, Stanford University School of Medicine, Stanford, California.

<sup>b</sup>Associate Chair of Quality Improvement, Department of Radiology, Stanford University School of Medicine, Stanford, California.

<sup>c</sup>Vice Chair of Education and Clinical Operations, Department of Radiology, Stanford University School of Medicine, Stanford, California.

Corresponding author and reprints: Dr David B. Larson, Stanford University School of Medicine, Department of Radiology, 300 Pasteur Drive, Stanford CA 94305-5105; e-mail: [david.larson@stanford.edu](mailto:david.larson@stanford.edu).

The authors state that they have no conflict of interest related to the material discussed in this article. Dr Madhuripan, Dr Cheung, Dr Cheong, Dr Jawahar, Dr Willis, and Dr Larson, are nonpartner, non-partnership track employees.

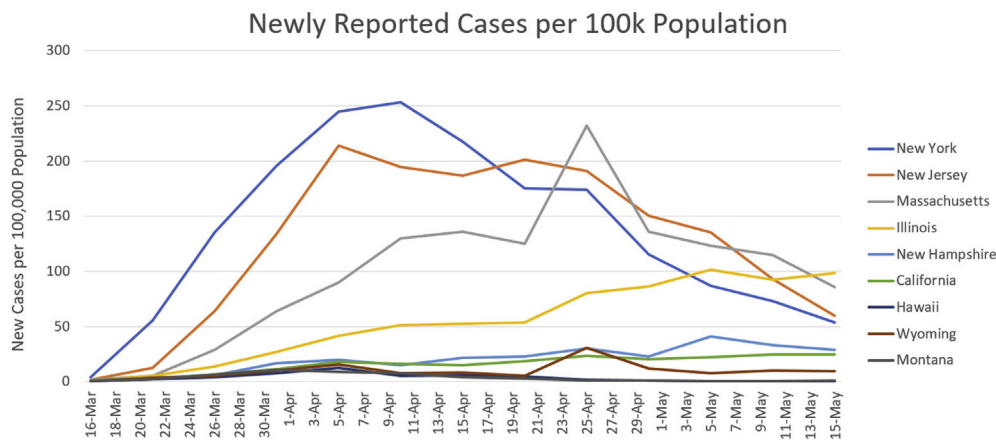


Fig 1. Newly reported coronavirus disease 2019 (COVID-19) cases every 5 days in United States across a sample of illustrative states. (Based on data from CDC [5]).

unlikely that radiology volumes will recover at the same rate across the country. Therefore, estimating resumption of radiology volumes will be one of the next major challenges for radiology practices. To help radiology practices plan for likely imaging volumes in the next phase, we briefly describe the impact of COVID-19 on imaging volumes in our practice to date and identify six variables that we hypothesize will influence the rate and degree to which imaging volumes will recover in the coming weeks.

### EFFECT OF COVID-19 ON OUR INSTITUTION

Stanford Health Care is a tertiary care medical center based in Santa Clara County in the state of California and is the largest hospital system within the Stanford University academic medical center. The acute care facility has a 600-bed capacity and is a level I trauma center and a National Cancer Institute–designated comprehensive cancer center.

Santa Clara County experienced early onset of COVID-19 relative to the rest of the United States [6,7] and on March 17, 2020, became one of the first four counties in the United States to issue stay-at-home orders [6]. The regional severity of COVID-19 has been relatively low, with 127 cumulative reported cases per 100,000 population in the county to date, compared with 200 and 463 cumulative cases per 100,000 population in California and the United States, respectively [8]. The peak COVID-19-related inpatient census numbered 20. The governor announced plans for resuming delayed medical care on April 22, 2020, although the statewide stay-at-home orders remained in place. Our practice resumed normal scheduling of imaging examinations on April 27, 2020, though the medical center did not resume near-normal clinical operations until May 18, 2020.

Our radiology practice began actively rescheduling elective imaging cases at the time the local stay-at-home order was issued on March 17, 2020. All radiology

screening examinations were immediately rescheduled 60 days into the future. For other nonurgent and elective examinations, we quickly collaborated with key referring departments to establish specific guidelines designating which examinations could be rescheduled. We also communicated with all referring providers in the medical center, asking them to submit nonurgent and elective examination orders with a deferred date at order entry.

To evaluate the impact on imaging volumes, we calculated baseline imaging volumes as the average of daily imaging volumes for all nonholiday weekdays from January 6 to February 28, 2020, before the impact of COVID-19. We reviewed imaging volumes from the beginning of 2020, differentiated by emergency department, by inpatient or outpatient status, by radiology subspecialty, and by modality. To evaluate the potential effect of seasonality, we compared the ratio of 2019 imaging volumes from January 7 to March 1, 2019 to those of March 30 to April 26, 2019, which was found to be 1.01, suggesting no significant seasonal variation would have been expected during this time frame in the absence of the pandemic. Imaging volumes were used because relative value unit data were not available in real time.

Total daily average imaging volumes decreased to 46% of baseline for weekdays during the 4-week period of lowest volumes, March 30 to April 26, 2020 (Table 1). Emergency department, inpatient, and outpatient imaging volumes decreased to 64%, 75%, and 31% of baseline for the same period, respectively. The lowest weekday single-day imaging volumes, as a percentage of baseline volumes, were 38% for all examinations on April 16, 2020, 37% for emergency department examinations on April 3, 2020, 65% for inpatient examinations on April 20, 2020, and 27% for outpatient examinations on April 16, 2020. We observed a slight decline in outpatient imaging volumes in the week

**Table 1.** Percentage of baseline imaging volumes by subspecialty and modality

Exam Type By Subspecialty, Modality, Patient Status	Percent of Baseline Volumes
<b>Radiology subspecialty</b>	
Body imaging	51
Breast imaging	28
CV/thoracic imaging	60
IR and NIR	57
MSK imaging	27
Neuro-imaging	52
Nuclear medicine	44
<b>Modality</b>	
Radiography	49
CT	55
MRI	44
Ultrasound	40
Fluoroscopy	35
Mammography	20
Nuclear medicine	24
PET	63
<b>Patient status</b>	
Emergency department	64
Inpatient	75
Outpatient	31
<b>All examinations</b>	<b>46</b>

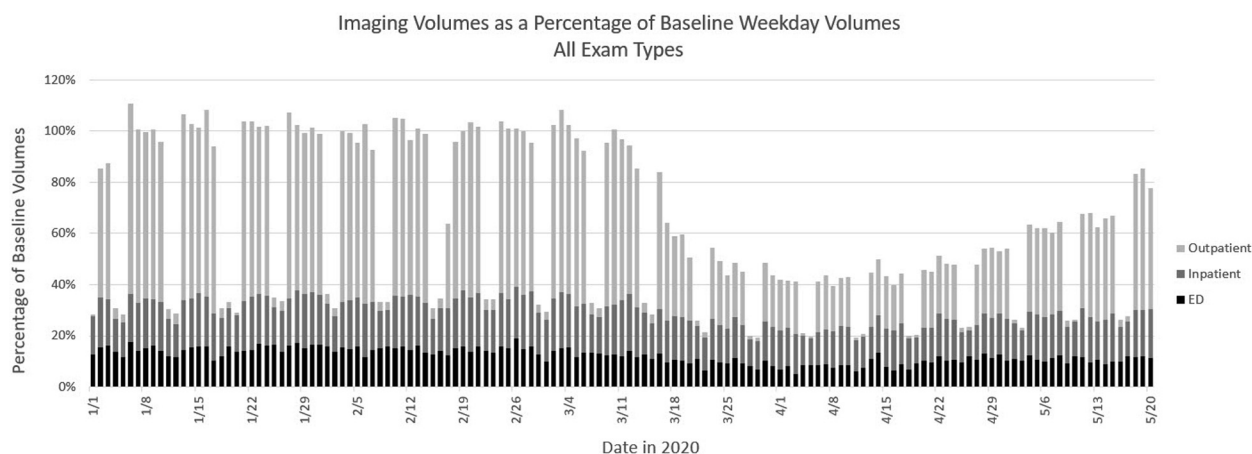
Volumes correspond to examinations performed between March 30 and April 26, 2020. Baseline volumes correspond to the number of examinations performed between January 6 and February 28, 2020. CV = cardiovascular; IR = interventional radiology; MSK = musculoskeletal; NIR = neuro-interventional radiology.

before the implementation of the stay-at-home order on March 17, 2020 (Fig. 2). A gradual increase in outpatient imaging volumes began to occur the last week of April 2020, primarily reflecting an increase in outpatient imaging volumes (Fig. 2).

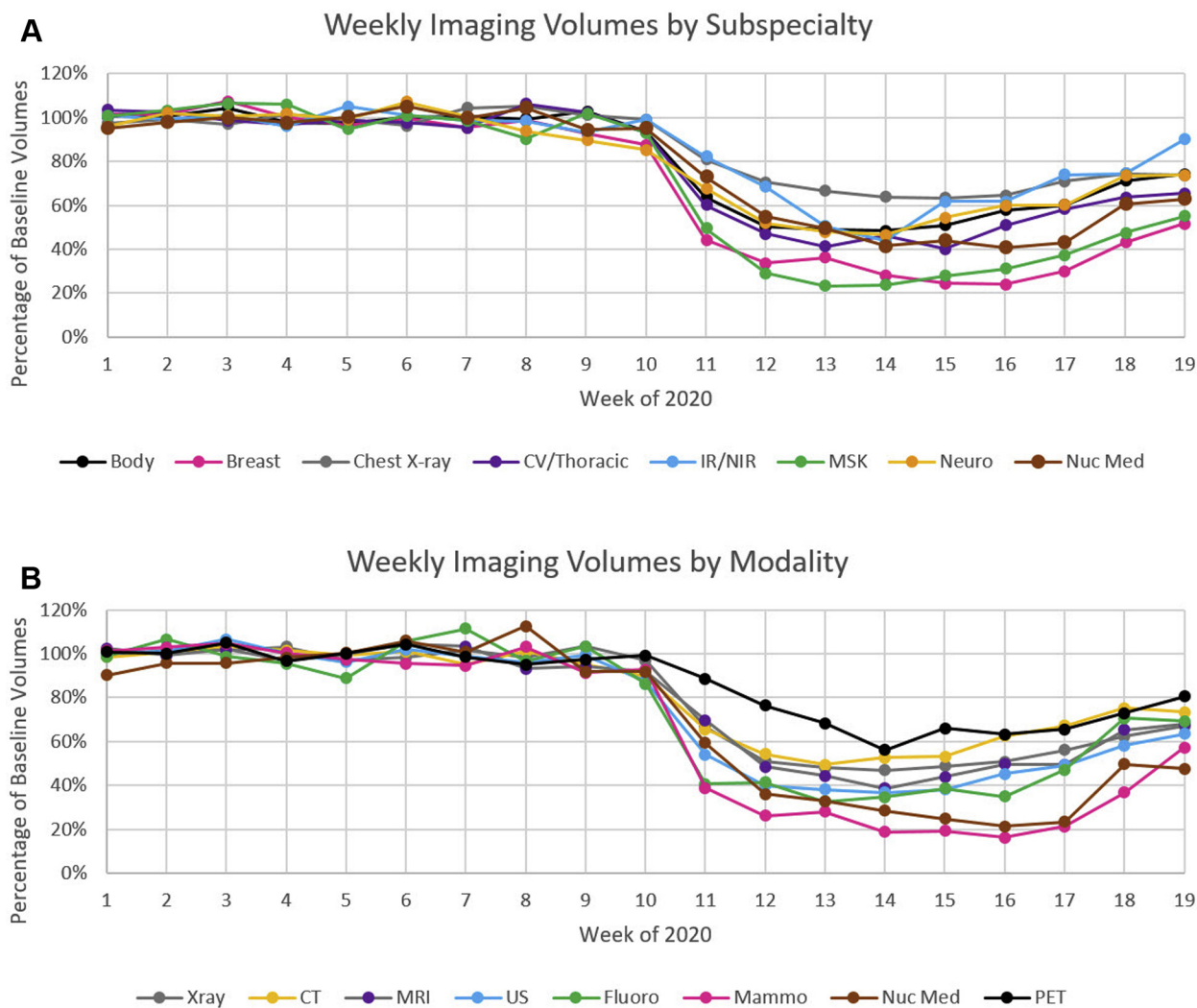
Daily average imaging volumes varied substantially by radiology subspecialty (Fig. 3). Musculoskeletal imaging was most impacted, with a decrease to 27% of baseline imaging volumes during the 4-week period of lowest volumes (Table 1). Breast imaging decreased to 28% of baseline imaging volumes during this period, with a decrease in mammograms to 20% of baseline. Nuclear medicine imaging decreased to 44% of baseline when considering PET (including PET/CT) examinations together with other nuclear medicine examinations. When considered separately, PET examination volumes were found to decrease to 63% of baseline, whereas other nuclear medicine examination volumes decreased to 24%. Cardiovascular and thoracic imaging experienced the smallest decline in volumes to 60% of baseline volumes, with a decrease to 64% and 41% of baseline volumes for x-ray and CT/MRI, respectively. Interventional radiology and neuroimaging also experienced substantial but relatively smaller declines, with decreases to 57% and 52% of baseline volumes, respectively.

## VARIABLES INFLUENCING IMAGING VOLUMES

In the absence of a validated prediction model for imaging volumes in the near future, our practice is closely observing the following six variables as part of our



**Fig 2.** Imaging volumes as a percentage of baseline volumes. Inpatient, outpatient, emergency department (ED), and total volumes at a single institution are depicted. Active deferral of elective examinations began on March 17, 2020. Resumption of examination scheduling began April 27, 2020.



**Fig 3.** Weekly imaging volumes from January to April 2020. Volumes are shown by radiology subspecialty in (A) and by modality in (B). County stay-at-home orders were issued in week 11. The governor announced plans for resuming delayed medical care in week 16. Our practice resumed normal scheduling of patients beginning week 17. CV = cardiovascular; Fluoro = fluoroscopy; IR = interventional radiology; Mammo = mammography; MSK = musculoskeletal; Neuro = neuroimaging; NIR = neuro-interventional radiology; Nuc Med = nuclear medicine; US = ultrasound.

planning efforts. For each variable, we describe a low-impact scenario, which would lead to less severe decreases in imaging volumes, and a high-impact scenario, which would lead to lower imaging volumes, recognizing that actual outcomes will likely fall somewhere in between (Table 2). In Table 2, we have listed assumptions, including values that may represent high-impact and low-impact scenarios based on national data, as available, or based on our local experience.

### Severity of Disease in the Local Region

We expect the severity and duration of the acute phase of the COVID-19 pandemic in the local region to be the primary driver of radiology volumes in the acute phase, with

continued impact in the recovery phase and in the intermediate term. In the low-impact scenario, lower regional severity of disease will likely result in lower decreases in imaging volume for a shorter amount of time and with a more rapid recovery period (Fig. 4A). In the high-impact scenario, higher regional severity of COVID-19 infection will likely result in greater decreases in imaging volumes for a more sustained period of time and with a longer recovery period.

Public health officials anticipate potential subsequent “waves” of infection, referring to renewal of growth in numbers of infections in the community [9]. The impacts on radiology volumes would likely mirror those of the original wave of infection, although they may be less pronounced, because health care institutions would have had more time to prepare and implement COVID-19 protocols.

**Table 2.** Variables affecting rate of imaging volume recovery

Variable	Description	High Impact	Low Impact	Comments
Severity of disease in the local region	Intensity and duration of local disease burden	High disease burden causing greater loss of and delayed return to normal imaging volumes (10 wk of daily new cases >10 per 100,000 population, eg, New York, New Jersey, Massachusetts [5])	Low disease burden with less initial loss of and more rapid return to normal imaging volumes (peak daily new cases <10 per 100,000, eg, New Hampshire, California, Wyoming [5])	Subsequent waves likely to have similar effects, though possibly to lesser degree
Lifting of government social distancing restrictions	Rapidity of lifting of social distancing restrictions for medical imaging	Delayed lifting of restrictions with delayed return to normal imaging volumes (restrictions on medical care lifted >8 wk after peak)	Prompt lifting of restrictions with more rapid return to normal imaging volumes (restrictions on medical care lifted <4 wk after peak)	May be related to severity of disease and other geopolitical factors
Patient concern	Public perception of leaving home or entering a health care facility	High concern with patients deciding to postpone or forgo care, leading to delayed return to normal imaging volumes (>50% of people staying at home [19])	Low concern with rapid return to normal imaging volumes (<35% of people staying at home [19])	May require multichannel communication to educate patients on safety protocols
Management of pent-up demand for imaging	Ability of the medical system to promptly re-order, reschedule, and perform postponed imaging examinations	Delays in re-ordering, rescheduling, and performing examinations to delayed return to normal volumes (full scheduling restored and postponed examinations rescheduled greater than 8 wk after lifting of social distancing restrictions)	Rapid rescheduling and performance of examinations, leading to an initial increase over normal imaging volumes before returning to baseline (full scheduling restored and postponed examinations rescheduled within 3 wk of lifting of social distancing restrictions)	Can have a positive impact on volumes if examinations can be quickly re-ordered and rescheduled and efficiently performed, while accounting for enhanced infection control protocols
Impact of economic downturn	Decreased ability to pay for health care, including unemployment, loss of insurance	High, widespread, and sustained unemployment, leading to delayed return to normal imaging volumes (real unemployment rate of 25%, lasting >6 months [14])	Rapid improvement in economic outlook leading to more rapid return to normal imaging volumes (real unemployment rate of <8% within 6 months, from prepandemic rate of 4.4% [14])	Insurance prior authorization requirements may also affect rate of rate of recovery and intermediate-term volumes

(continued)

Table 2. Continued

Variable	Description	High Impact	Low Impact	Comments
Radiology practice profile	Nature of examinations performed and availability of resources	Radiology practices with greater proportion of elective imaging, leading to greater loss of and delayed return to normal imaging volumes (> 50% elective examinations)	Radiology practices with smaller proportion of elective imaging, leading to less initial loss of and more rapid return to normal imaging volumes (<20% elective examinations)	Although not an environmental variable, this factor will likely substantially affect radiology practices

The effect of each variable for each region is hypothesized to be on a spectrum between high-impact and low-impact scenarios. The overall impact on imaging volumes is likely to represent a cumulative effect of all variables. Values that may represent high-impact and low-impact scenarios based on national data, as available, or based on our local experience are included in parentheses.

## Lifting of Government Social Distancing Restrictions

In response to the pandemic, most states have mandated some version of social distancing restrictions (including a stay-at-home order) for the population beginning mid-March 2020. Governments are now starting to lift those restrictions, although in a nonuniform manner across the country [1,10]. Lifting of these restrictions will clearly impact imaging volumes. In the low-impact scenario, prompt lifting of restrictions will likely lead to more rapid return of imaging volumes (Fig. 4B). In the high-impact scenario, gradual or delayed lifting of restrictions will likely lead to more delayed return to normal imaging volumes (Fig. 4B).

In regions in which social distancing restrictions are being lifted in a staged fashion, as long as routine medical care is included in essential services, such staged lifting of restrictions should not directly result in prolonged imaging volume decreases, though it will likely have an impact on patient concern, discussed in the next section.

## Patient Concern

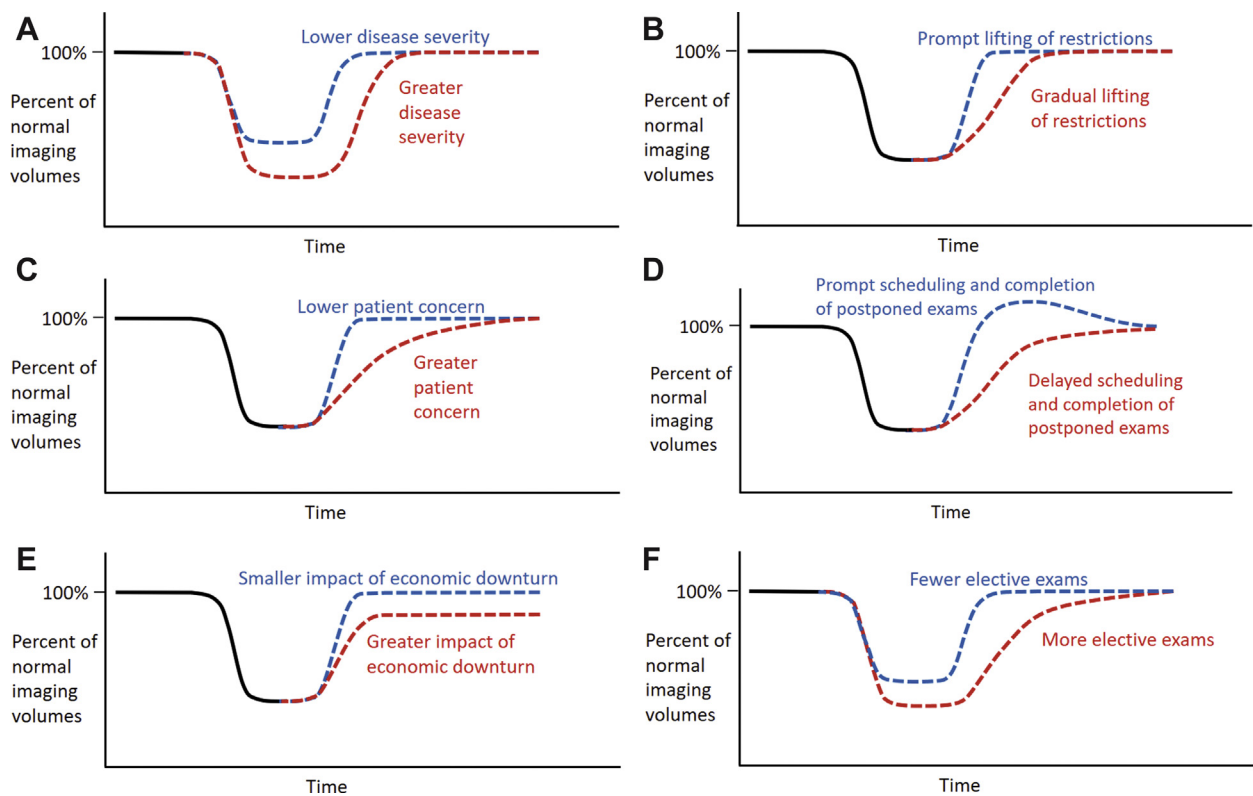
Public perception of the risk of leaving home or entering health care facilities to undergo medical imaging likely will influence the rate of restoration of radiology volumes. Even if government stay-at-home restrictions are lifted, patients may still choose to forgo or delay care during the pandemic. Disparities in the share of people leaving home again by county, which do not directly correlate with severity of disease of lifting of restrictions, have been published, suggesting variation in patient concern by region [11,12].

In the low-impact scenario, a lower level of patient concern will likely lead to more rapid return to normal imaging volumes (Fig. 4C). In the high-impact scenario, a higher level of patient concern will likely lead to more gradual return to normal volumes.

Achieving prepandemic levels of patient confidence in safety may take time and repeated interactions with the public and with patients. Our medical center's strategy is to combine a public information campaign with general messages to patients and specific scripting when scheduling examinations.

## Management of Pent-up Demand for Imaging

As radiology practices have postponed less urgent examinations and referring clinicians have deferred elective care, a backlog of unordered and ordered-but-not-yet-performed imaging examinations has accumulated [13]. The size of this backlog depends on the severity and duration of the decrease of imaging in the acute phase [14].



**Fig 4.** Illustration of how key variables may affect imaging volumes. For each variable, two scenarios are presented: a low-impact scenario (associated with higher imaging volumes, in blue) and a high-impact scenario (associated with lower imaging volumes, in red). (See Table 2 for further explanation.) (A) Effect of severity of disease in the local region, (B) effect of lifting of government social distancing restrictions, (C) effects of patient concern, (D) management of pent-up demand for imaging, (E) impact of the economic downturn, and (F) effect of the radiology practice profile.

Institutions may respond to this pent-up demand in two ways. In the low-impact scenario, delayed examinations would be quickly scheduled and performed, leading to an initial bump in imaging volumes above those that would otherwise be expected, potentially even above normal operating capacity (Fig. 4D). In the high-impact scenario, delayed examinations would take time to schedule and perform, causing a delayed return to normal radiology volumes. Limiting factors may include limited resources to reschedule examinations, decreased efficiency due to enhanced cleaning protocols, limited availability of personal protective equipment, and requirements for greater social distancing in waiting rooms. These likely will vary by practice type; practices with fewer available resources to absorb inefficiencies will likely experience greater impact.

It is important to note that this is the only variable that has a potential positive impact on volumes, which could help offset losses from delayed resumption of volumes from other causes. This is also the variable that is presumably most under control of radiology practices and health care systems.

### Impact of Economic Downturn

Since the onset of the pandemic, the real unemployment rate has been reported to be close to 25% [15]. The economic downturn will likely affect radiology volumes, primarily through loss of insurance coverage or inability to pay deductibles or copays for medical imaging due to unemployment or underemployment [16]. Economic consequences will likely be widespread, although regional socioeconomic factors such as types of dominant employers, ethnic diversity, and strength of social safety nets will likely vary by locale.

In the low-impact scenario, a small number of individuals would lose access to health care coverage, leading to a return to the prepandemic baseline of imaging volumes (Fig. 4E). In the high-impact scenario, a large number of individuals would lose access to full health care coverage, leading to a resumption of imaging volumes to a level lower than the prepandemic level, potentially extending into the long term.

CMS recently issued guidelines for Medicare Advantage Organizations, giving them the discretion to waive or relax



prior authorization requirements to improve access [17]. Physician organizations including the ACR have urged private insurers to implement similar policies [18,19]. These steps may improve the rate of recovery to baseline volumes.

### Radiology Practice Profile

Examinations that are considered to be more elective in nature likely will be more susceptible to be deferred than those that are considered more urgent. The elective nature of an examination is difficult to define and is context dependent but will likely become more apparent in the coming weeks. Although it may not be clear exactly how it will be manifested, it is likely that radiology practices that perform different types of examinations, with different referral patterns, and with different ratios of emergency, inpatient, and outpatient imaging settings, will likely be impacted differently, even within the same geographic region.

Practices with a lower proportion of elective examinations will likely experience less of a decrease in imaging volumes and a faster return to baseline levels than those with a higher proportion of elective examinations (Fig. 4F).

### APPLICATION OF THE PREDICTIVE MODEL TO OUR PRACTICE

In applying the model to our local practice, we found the following: The severity and duration of disease in our region has been relatively low, with the peak never reaching 10 cases per day per 100,000 population. We were allowed to resume imaging relatively early, before new cases reached peak in the state, although patient concern seems to remain relatively high in our region, with approximately 50% of people staying at home as of May 20, 2020 [19]. Our ability to manage pent-up demand for imaging is relatively favorable; recent opening of new facilities have added capacity to our system that may offset inefficiencies due to infection control and social distancing, and medical center operations were restored to near normal within 5 weeks after lifting of social distancing orders. We believe that our region will be substantially impacted by the economic downturn, though perhaps to a lesser degree than other regions. Our health system and radiology practice care for a relatively high number of patients with cancer and other nonelective types of conditions, which we consider to constitute >80% of our cases. In aggregate, our model has been reasonably predictive, with volumes reaching as high as 85% within 4 weeks of restoration of normal scheduling (Fig. 2). Assuming local disease prevalence remains low, the question of whether volumes will now level off or continue to rise to prepandemic levels will likely depend primarily on continued patient concern and the effects of the economic downturn.

### DISCUSSION

The abrupt decrease in imaging volumes at our institution to approximately 30% to 60% of baseline volumes from March 30 to April 26, 2020 corresponds to findings reported by other authors [16,20]. Imaging volumes began to increase in late April 2020, with progressive restoration of elective procedures and normalization of volumes. It has been 3½ weeks since we resumed normal scheduling; increases in volumes have been relatively prompt, as our model would predict. At our institution, it was widely recognized that radiology needed to resume services before other clinical specialties because many of those specialties critically depend on imaging support. We started performing these examinations approximately 3 weeks before resumption of full clinical services to reduce the backlog of pending orders, although some clinical programs had been gradually increasing services during this time.

An understanding of likely imaging volumes in coming weeks and months is important for radiology practices' planning efforts because, as Cavallo and Forman recently discussed, sustained volume decreases could lead to delay in care for patients and substantial financial losses for practices [16]. Snow and Taylor recently outlined a four-step approach to managing fluctuating radiology volumes during the COVID-19 pandemic [21], and Davenport et al outlined seven categories of recommendations to help radiology practices resume nonurgent radiology care [22]. Practices that are likely to experience low volumes may need to reduce staffing to preserve financial viability; however, excessive reductions in staffing could have the potential side effect of limiting imaging capacity to accommodate a possible subsequent surge in imaging volumes, further exacerbating financial losses. This is especially critical during the recovery phase; practices that do not invest additional resources in quickly scheduling and performing additional examinations may find it difficult to perform those examinations later, especially if another wave of infection in the local region requires resumption of stay-at-home restrictions.

Prediction of imaging volumes may also help practices make accommodations for inefficiencies of practices, including infection control and social distancing efforts [22,23]. These inefficiencies will likely become increasingly important as volumes increase.

We recognize a number of limitations of our analysis. The dynamic nature of the COVID-19 pandemic makes accurate predictions of future radiology volumes difficult. Although this article attempts to address some of the variables that we believe may affect radiology volumes in the future, they are admittedly hypothetical and are likely neither exhaustive nor mutually exclusive. We have

expressed the impact in qualitative terms. Additionally, our simplified model illustrates predictions based on a single wave of infection and recovery, which is unlikely to be the case and would need to be adapted for additional waves of infection. The data presented in this article represent the experience of a single academic institution in one US region, primarily for the purpose of providing context to the discussion of estimating imaging volumes. Given the wide variability of radiology practices and the impact of COVID-19 across the country, the experiences of others may differ from ours, although we believe they are likely to be directionally similar.

In conclusion, as has been true broadly for radiology practices in the United States, we have observed substantial decreases in imaging volumes associated with the acute phase of the COVID-19 pandemic. Our early experience has shown a gradual but steady restoration of imaging volumes, consistent with our predictive model. Because of the highly variable impact of the disease in different regions in the United States, we believe that the impact on radiology practices' volumes will also likely vary. By focusing on key variables specific to local regions and institutions that will likely impact imaging volumes, radiology practices can better prepare to provide safe and effective care in subsequent phases of the pandemic.

We emphasize that reduction in imaging volumes represents delayed medical care. When considered for all regions across the country, the impact on the lives of patients and families is likely to be substantial, adding to already heavy impacts from the virus and from economic losses [24], and even greater for regions most heavily impacted by the disease. We encourage radiology practice leaders to work collaboratively with local health system and governmental leaders to help ensure that needed patient care is restored as quickly as the environment will safely permit.

### TAKE-HOME POINTS

- At our institution, total daily imaging volumes decreased to 46% of baseline, with a greater decrease observed in outpatient examinations compared with emergency and inpatient examinations.
- Severity of disease, lifting of social distancing restrictions, patient concern, management of pent-up demand, impact of the economic downturn, and radiology practice profile are likely key determinants of how radiology volumes will recover immediately after the acute phase of the pandemic.
- Imaging volumes have increased relatively promptly at our institution after resumption of normal scheduling 3½ weeks ago, consistent with our qualitative model.

- Rates of recovery of imaging volumes will likely vary by geography and time; conditions should be closely monitored at the local level by individual practices and institutions.

### ACKNOWLEDGMENTS

The authors acknowledge the contribution of Stacie Vilendrer, MD, MBA, and the Evaluation Sciences Unit of the Stanford School of Medicine for preliminary work on the topic.

### REFERENCES

1. ACR. States with elective medical procedures guidance in effect. Available at: <https://www.acr.org/-/media/ACR/Files/COVID19/States-With-Selective-Medical-Procedures-Guidance-in-Effect.pdf?la=en>. Updated May 1, 2020. Accessed May 6, 2020.
2. CMS. Non-emergent, elective medical services, and treatment recommendations. Available at: <https://www.cms.gov/files/document/cms-non-emergent-elective-medical-recommendations.pdf>. Updated April 7, 2020. Accessed May 6, 2020.
3. Mossa-Basha M, Medverd J, Linnau K, et al. Policies and guidelines for COVID-19 preparedness: experiences from the University of Washington [E-pub ahead of print]. *Radiology*. <https://doi.org/10.1148/radiol.2020201326>.
4. Yu J, Ding N, Chen H, et al. Infection control against COVID-19 in departments of radiology. *Acad Radiol* 2020;27:614-7.
5. CDC. CDC Covid data tracker. Available at: <https://www.cdc.gov/covid-data-tracker/>. Updated May 7, 2020. Accessed May 7, 2020.
6. Santa Clara County Public Health. Order of the health officer of the county of Santa Clara. Available at: <https://www.sccgov.org/sites/covid19/Pages/order-health-officer-031620.aspx>. Updated April 16, 2020. Accessed May 6, 2020.
7. Fuller T, Baker M, Hubler S, Fink S. A coronavirus death in early February was "probably the tip of an iceberg." *New York Times*. Available at: <https://www.nytimes.com/2020/04/22/us/santa-clara-county-coronavirus-death.html>. Published April 22, 2020. Accessed May 6, 2020.
8. Johns Hopkins University. Coronavirus resource center. Available at: <https://coronavirus.jhu.edu/>. Updated May 6, 2020. Accessed May 6, 2020.
9. Allen D, Block S, Cohen J, et al. Roadmap to pandemic resilience: massive scale testing, tracing, and supported isolation (TTSI) as the path to pandemic resilience for a free society. *Edmond J Safra Center for Ethics*. Available at: [https://ethics.harvard.edu/files/center-for-ethics/files/roadmaptopandemicresilience\\_updated\\_4.20.20\\_1.pdf](https://ethics.harvard.edu/files/center-for-ethics/files/roadmaptopandemicresilience_updated_4.20.20_1.pdf). Published April 20, 2020. Accessed May 18, 2020.
10. Mervosh S, Lee JC, Gamio L, Popovich N. See which states are reopening and which are still shut down. *New York Times*. Available at: <https://www.nytimes.com/interactive/2020/us/states-reopen-map-coronavirus.html>. Updated May 8, 2020. Accessed May 8, 2020.
11. Dance GJX, Gamio L. As coronavirus restrictions lift, millions in U.S. are leaving home again. *New York Times*. Available at: <https://www.nytimes.com/interactive/2020/05/12/us/coronavirus-reopening-shutdown.html>. Published May 12, 2020. Accessed May 18, 2020.
12. Cuebiq. COVID-19 mobility insights. Available at: <https://www.cuebiq.com/visitation-insights-covid19>. Accessed May 20, 2020.
13. CMS. Opening up America again: Centers for Medicare & Medicaid Services (CMS) Recommendations. Available at: <https://www.cms.gov/files/document/covid-flexibility-reopen-essential-non-covid-services.pdf>. Updated April 19, 2020. Accessed May 6, 2020.

14. Kwee TC, Pennings JP, Dierckx RAJO, Yakar D. The crisis after the crisis: the time is now to prepare your radiology department. *J Am Coll Radiol* 2020;17(6):749-51.
15. Lambert L. 20.5 million lose their jobs in April, sending U.S. unemployment rate to 14.7%, an 80-year high. *Fortune*. Available at: <https://fortune.com/2020/05/08/record-u-s-unemployment-rate-worst-since-1940/> Published May 8, 2020. Accessed May 8, 2020.
16. Cavallo JJ, Forman HP. The economic impact of the COVID-19 pandemic on radiology practices. *Radiology* [E-pub ahead of print]. <https://doi.org/10.1148/radiol.2020201495>. Published April 16, 2020.
17. ACR. Information related to coronavirus disease 2019—COVID-19. Available at: <https://www.acr.org/-/media/ACR/Files/Advocacy/AIA/Updated-Guidance-for-MA-and-Part-D-Plan-Sponsors-42120-FINAL.pdf>. Updated April 21, 2020. Accessed May 6, 2020.
18. ACR. Prior authorization letter. Available at: <https://www.acr.org/sitecore/-/media/ACR/Files/Advocacy/AIA/UHC-COVID-Prior-Auth-Letter-Final.pdf>. Published April 28, 2020. Accessed May 6, 2020.
19. AMA. Prior authorization (PA) policy change related to COVID-19. Available at: <https://www.ama-assn.org/system/files/2020-05/prior-auth-policy-covid-19.pdf>. Updated May 5, 2020. Accessed May 6, 2020.
20. Phillips CD, Shatzkes DR, Moonis G, Hsu KA, Doshi A, Filippi CG. From the eye of the storm: multi-institutional practical perspectives on neuroradiology from the COVID-19 outbreak in New York City. *AJNR Am J Neuroradiol* 2020;41(6):960-5.
21. Snow A, Taylor GA. Coronavirus disease (Covid-19) imaging austerity: coming back from the pandemic. *J Am Coll Radiol* 2020;17:902-4.
22. Davenport MS, Bruno MA, Iyer RS, et al. ACR statement on safe resumption of routine radiology care during the COVID-19 pandemic. *J Am Coll Radiol* 2020;17:839-43.
23. Luker GD, Boettcher AN. Transitioning to a new normal after COVID-19: preparing to get back on track for cancer imaging [E-pub ahead of print]. *Radiol Imaging Cancer*. <https://doi.org/10.1148/rycan.2020204011>. Published April 15, 2020.
24. Kansagra AP, Goyal MS, Hamilton S, Albers GW. Collateral Effect of Covid-19 on Stroke Evaluation in the United States [E-pub ahead of print]. *N Engl J Med* 2020 NEJMc2014816. Published May 8, 2020.