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COVID-19 and Radiology Resident Imaging Volumes—Differential Impact by Resident Training Year and Imaging Modality

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Rationale and Objectives: The COVID-19 pandemic has greatly impacted radiology departments across the country. The pandemic has also disrupted resident education, both due to departmental social distancing efforts and reduced imaging volumes. The purpose of this study was to assess the differential impact the pandemic had on radiology resident imaging volumes by training year and imaging modality.

Materials and Methods: All signed radiology resident reports were curated during defined prepandemic and intrapandemic time periods. Imaging case volumes were analyzed on a mean per resident basis to quantify absolute and percent change by training level. Change in total volume by imaging modality was also assessed. The number of resident workdays assigned outside the normal reading room was also calculated.

Results: Overall percent decline in resident imaging interpretation volume from the prepandemic to intrapandemic time period was 62.8%. R1s and R2s had the greatest decline at 87.3% and 64.3%, respectively. Mammography, MRI and nuclear medicine had the greatest decline in resident interpretation volume at 92.0%, 73.2%, and 73.0%, respectively. During the intrapandemic time period, a total of 478 resident days (mean of 14.5 days per resident) were reassigned outside of the radiology reading room.

Conclusion: The COVID-19 pandemic caused a marked decrease in radiology resident imaging interpretation volume and has had a tremendous impact on resident education. The decrease in case interpretation, as well as in-person teaching has profound implications for resident education. Knowledge of this differential decrease by training level will help residency programs plan for the future.

Key Words: COVID-19; Education; Resident; Virtual-learning; Volume.

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INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has had an extraordinary impact on graduate medical education in all specialties including radiology. As COVID-19 cases surged, radiology departments across the country were forced to defer elective and non—time-sensitive imaging and procedures in order to curb the spread of disease and protect patients and healthcare workers. Additionally, in some pandemic “hot spots,” radiology residents were redeployed to nonradiology clinical areas, such as Emergency Departments (ED) and COVID-19 general practice units, in an effort to aid their colleagues in the direct care of patients

(1,2). In our own program, residents were also tasked with helping to lead the radiology imaging deferment team and assist in the triage of thousands of imaging studies. Even those residents not redeployed during the pandemic were affected, oftentimes being assigned to “distance learning,” both due to inadequate imaging volumes, as well as in an effort to maintain adequate social distancing in the reading room.

As the educational impact of the pandemic became apparent, residency programs across the country worked tirelessly to transition from onsite clinical learning to a virtual educational curriculum in the form of live-streamed didactics and video lecture series (3–5). Yet, despite the robust virtual learning content available to trainees, the education provided by hands-on image interpretation cannot be replaced — and as a result, resident education suffered (6). In addition to the effect on resident education, concerns have also been raised regarding the impact of the pandemic on residents achieving the fixed graduation requirements for mammography, nuclear medicine, and Early Specialization in Interventional Radiology (4,7,8). The purpose of this study was to assess the

Acad Radiol 2020; ■:1–6

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<https://doi.org/10.1016/j.acra.2020.09.010>

differential impact the pandemic had on radiology resident imaging volumes by training year and imaging modality.

MATERIAL AND METHODS

This Health Insurance Portability and Accountability Act-compliant, retrospective study was conducted within a large academic radiology practice that trains 36 radiology residents (34 diagnostic radiology residents and 2 integrated interventional radiology residents). The residency training program includes nine residents in each of the four radiology residency years (R1–R4). This study was approved by the institutional review board at our institution.

Resident Imaging Interpretation Volumes

All signed diagnostic and procedural reports were curated from January 1, 2020 to June 26, 2020. Utilizing resident rotational assignments in the institution's Radiology Information System scheduling software, resident schedules were mapped to each report to generate a sum of total resident dictated studies per week categorized by resident year and modality. In a similar fashion, faculty-only reports were mapped to generate total weekly faculty-only volumes for comparison. Emergency Radiology division faculty reports were excluded. Resident reports were then divided into non-ED weekdays and ED shifts, which includes both evenings (5 pm–9 pm) and nights (9 pm–7 am). Weekends were excluded due to the highly variable nature of the scheduling between resident year level. Weeks of the year were labeled sequentially and the sum of imaging studies was calculated within those weeks. The prepandemic time period was defined as January 6, 2020–February 28, 2020 (weeks 2–9), chosen to exclude holidays and to avoid the peripandemic time period. The intrapandemic time period was defined as

March 23, 2020–May 15, 2020 (weeks 13–20), which begins the week of the nadir in resident studies. Resident interpretation volumes by training level were calculated per resident to correct for time residents spent off service unrelated to the pandemic, including vacation days, conference days, and away rotations for pediatrics and the American Institute for Radiologic Pathology. Weekly new COVID-19 cases were obtained from the www.michigan.gov public database (9).

Resident Reassignment

The total number of resident weekdays spent reassigned outside of the radiology reading room was calculated per week and included days redeployed to a clinical floor, distance learning, or on the imaging deferment task force.

RESULTS

Resident Imaging Interpretation Volumes

Figure 1 illustrates the trend of total weekly imaging studies interpreted by all R1–R4 residents along with total weekly faculty-only imaging studies from week 2 to week 26 superimposed on weekly new COVID-19 cases in Michigan. There is a steep decline in radiology resident interpretation volume, reaching a nadir at week 13 coinciding with a sharp rise in new COVID-19 cases. There was an 82.7% decline in overall resident imaging interpretation volume from the peak of 2624 studies in week 2 to 453 studies in week 13. Similarly, faculty-only imaging interpretation volume decreased by 75.2% from its peak of 6932 in week 3 to 1721 in week 13. Radiology resident imaging interpretation volumes returned to prepandemic baseline levels at week 25 following a decline in new COVID-19 cases. During the same week

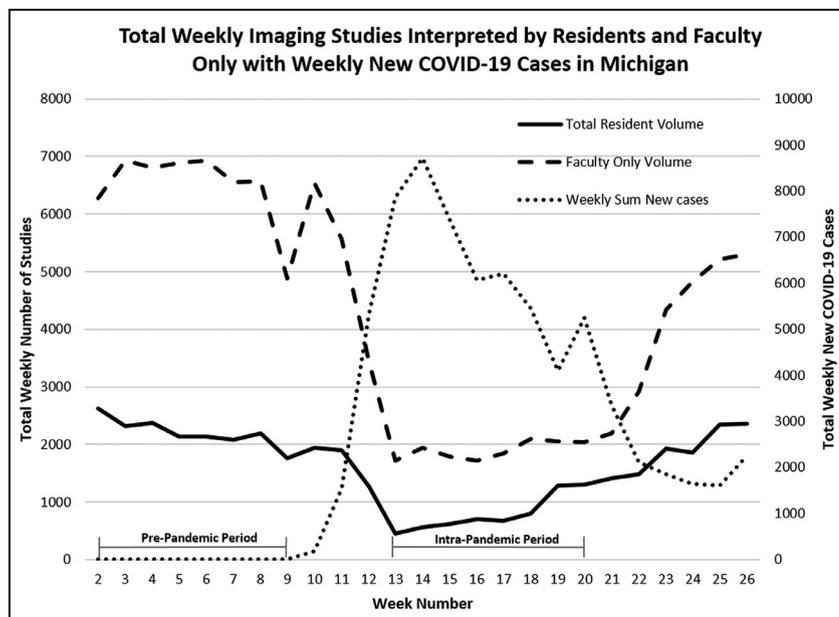


Figure 1. Plot chart demonstrating the trend of total weekly imaging studies interpreted by all R1–R4 residents and faculty only from week 2 to week 26 superimposed on weekly new COVID-19 cases in Michigan.

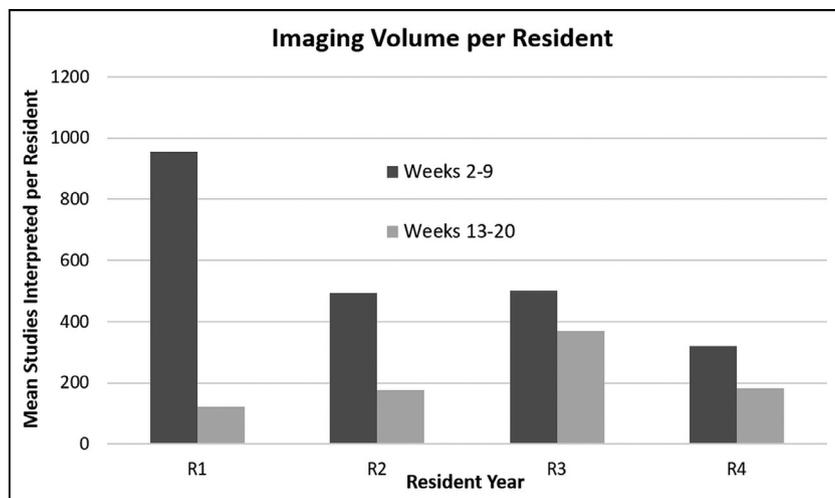


Figure 2. Bar chart demonstrating the difference in resident interpreted imaging studies between the pre-pandemic and intrapandemic time periods. Each vertical bar represents the mean number of studies interpreted by a resident in that training level over the specified time period (dark gray – weeks 2–9; light gray – weeks 13–20).

25, faculty-only imaging volumes remained 19.6% below the average during the prepandemic period.

In comparing the differential impact on per resident imaging volumes amongst resident classes between the prepandemic and intrapandemic time periods, R1s and R2s had the greatest decline at 87.3% and 64.3%, respectively. The R3 class had the lowest decline in per resident imaging volume at 26.1%. The R4s experienced a decline of 43.6%. (Fig 2, Table 1). There was a 35.2% decrease in resident imaging interpretation volume during ED shifts.

In comparing the impact on resident imaging interpretation volumes distinguished by modality, all modalities saw a decrease in resident interpretation volume compared to prepandemic levels. Mammography, MRI and non-PET/CT nuclear medicine had the greatest decline in interpretation volume at 92.0%, 73.2%, and 73.0%, respectively. PET/CT, ultrasound, and radiographs had the lowest decline at 25.3%, 58.6%, and 58.8%, respectively (Fig 3, Table 2).

Procedural and I-131 Volumes

Vascular interventional radiology, body interventional radiology and neuro-interventional radiology all experienced a decline in procedural volumes during the intrapandemic period. Total vascular interventional radiology volumes decreased by 41.3%, body interventional radiology volumes decreased by 56.6%, and neuro-interventional radiology

volumes decreased by 67.4% when compared to prepandemic volumes. During the prepandemic time period, there were nine I-131 treatment cases while during the intrapandemic time period there were only two.

Resident Reassignment

During the 8-week intrapandemic time period, a total of 478 resident days (mean of 14.5 days per resident on service) were spent in reassignment – either redeployed to a clinical floor, distance learning, or on the imaging deferment task force. The mean number of resident days per week spent in reassignment was 1.7 days per week (range 0.7–2.5 days for all intrapandemic weeks; Table 3). R1s had the highest average of reassigned days per week at 3.2 days (range 0.6–5.0 days). Fifty-two resident days were spent redeployed to a COVID-19 general practice unit and consisted of all R1s.

Discussion

The COVID-19 pandemic has had a profound impact on radiology resident education. Training a resident to become a competent radiologist requires reading and reviewing thousands of imaging studies, ideally one-on-one with staff radiologists at the workstation. As such, inadequate imaging volumes or lack of in-person teaching significantly hampers the resident educational experience (6). A recent study found a significant decrease in total imaging case volume among residents and divisions (10). Our study expands upon these findings, evaluating the differential impact by resident training year and imaging modality. During the 8 week intrapandemic period at our institution, there was a considerable decline in total radiology resident imaging interpretation volume of 62.8% for all trainee levels compared to the prepandemic time period. This decline in total volume is attributed to both a decreased number of resident workdays in the reading room along with a decrease in departmental imaging volumes.

TABLE 1. Mean Imaging Studies Interpreted Per Resident*

	Weeks 2–9	Weeks 13–20	Absolute Difference	% Change
R1	955	121	–834	–87.3
R2	493	176	–317	–64.3
R3	501	370	–131	–26.1
R4	321	181	–140	–43.6
All levels	578	215	–363	–62.8

* Interpreted studies include Monday through Friday of each week.

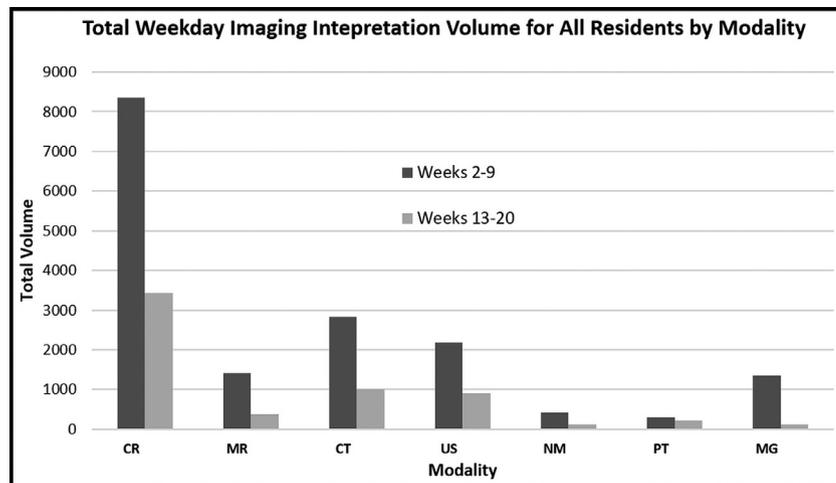


Figure 3. Bar chart demonstrating the difference in resident interpreted imaging studies by modality between the prepandemic and intrapandemic time periods. Each vertical bar represents the total number of studies interpreted by all residents for that modality over the specified time period (dark gray – weeks 2–9; light gray – weeks 13–20). CR, computed radiography; CT, computed tomography; MG, mammography; MR, magnetic resonance; NM, nuclear medicine; PT, positron emission tomography (PET); US, ultrasound.

Differential Impact by Training Level

At our institution, R1 residents experienced the greatest decline in total volumes at 87.3% compared to the prepandemic time period followed by R2s at 64.5%. R3s and R4s experienced the least overall decrease in imaging volumes at 26.1% and 43.6%, respectively. Part of this differential impact by training year is due to differences in resident rotations and the imaging modalities interpreted at that point in training. For example, during the prepandemic time period,

TABLE 2. Total Imaging Studies Interpreted by Resident by Modality*

	Weeks 2–9	Weeks 13–20	Absolute Difference	% Change
CR	8350	3442	–4908	–58.8
CT	2838	1007	–1831	–64.5
MG	1350	108	–1242	–92.0
MR	1405	377	–1028	–73.2
NM	419	113	–306	–73.0
PT	293	219	–74	–25.3
US	2188	905	–1283	–58.6

CR, computed radiography; CT, computed tomography; MG, mammography; MR, magnetic resonance; NM, nuclear medicine; PT, positron emission tomography (PET); US, ultrasound.

* Interpreted studies include Monday through Friday of each week.

TABLE 3. Average and Range of Resident Reassignment Days per Week by Resident Year*

	Average (days/week)	Range (days/week)
R1	3.2	0.6–5.0
R2	1.3	0.7–1.9
R3	1.3	0.7–2.1
R4	0.9	0.3–1.3
All	1.7	0.7–2.5

* Reassignment days only include Monday–Friday. Reassignment day includes: redeployment to COVID-19 GPU, image deferment team, or home learning assignment.

radiographs, which are performed and interpreted in higher volumes than other modalities such as MRI or CT, constituted 63% and 53% of all imaging studies interpreted by R1 and R2 residents, respectively, vs. only 15% of R3 studies and 36% of R4 studies. However, while modality-specific differences had an effect on the discordant training-level impact, pandemic-related factors also played a role. For example, whereas the R1 and R2 residents were preferentially reassigned to distance learning days, the in-house reading radiology residents consisted predominately of R3s and R4s. The R3s saw the smallest decrease in imaging interpretation volume compared to their prepandemic volumes, which may also in part be attributed to an increased coverage of nonadvanced rotations during the intrapandemic period, which include more radiographs and less advanced imaging modalities. R4 residents led the radiology imaging deferment task force, in which they were tasked with triaging pending exams as time-sensitive or not time-sensitive, thus decreasing their time in the reading room and subsequently their imaging volume in comparison to their R3 counterparts.

At the onset of the pandemic, junior residents were preferentially assigned to distance learning days for two reasons. First, senior residents have more experience and are more versatile in reading across multiple imaging modalities, thus they were better able to provide continuing coverage for the radiology department while limiting the number of people in the reading rooms. Additionally, senior residents had more experience to determine whether a study was “time-sensitive” or not, and were therefore better suited than junior residents to serve on the imaging deferment team. Second, our institution’s graduate medical education had declared a Stage 3 Pandemic Emergency Status and requested that all departments assist with the direct clinical care of COVID-19 patients. Since junior residents were closest in clinical training with respect to their intern year, they were better suited to provide that service and were thus on standby while on home assignment. As the COVID-19 pandemic continued to surge, junior residents were reintegrated into the radiology service. In retrospect, it would have been beneficial to

reintegrate junior residents into the reading room earlier in order to minimize the disruption to their education, especially since R1s were preparing to take independent call. In the future, it would be more efficient to have a “platooning” schedule with teams of residents that could alternate on the radiology service such that only half of the junior residents would be on reassignment or home learning.

Early in the pandemic, our department worked expeditiously to reallocate workstations into offices and staff homes, as well as obtain home workstations for faculty. Supplying residents with home workstations could have potentially helped with resident volumes as well, however, was not logistically possible to do during the pandemic. Faculty did staff out residents by phone and were also educated on how to staff out securely via virtual conferencing, which was frequently used and preferred to phone staffing. As with resident-interpreted studies, faculty-only interpreted studies also substantially declined during the intrapandemic period. While faculty still interpreted cases on their own, a further decrease in faculty-only interpretations would likely not have changed the number of resident interpretations as social distancing requirements and lack of resident home workstations remained the limiting factor. The fact that residents returned to prepandemic interpretation volumes during week 25 while faculty-only interpretations remained 19.6% below the prepandemic average supports the fact that faculty preferentially allowed residents to interpret studies rather than interpret on their own, which is important in a training environment.

Differential Impact by Modality and Implications for Graduation Requirements

Mammography, MRI, and non-PET/CT nuclear medicine had the greatest decline in interpretation volume while PET/CT, ultrasound, and radiographs had the lowest decline. At our institution, cancer imaging, including PET/CT, was usually considered “time-sensitive” and the imaging was not delayed. For this reason, PET/CT and non-PET/CT nuclear medicine studies were separated in order to demonstrate the discrepancy in changing volumes during the intrapandemic period.

The sharp declines observed in mammography and nuclear medicine are particularly concerning, especially for senior residents, due to potential implications for ACGME minimum graduation requirements. While our institution was fortunate not to have senior residents with unmet I-131 or breast imaging requirements, this could be an issue for senior residents at other programs. To minimize this risk, it is important that residents and program directors actively monitor graduation requirements during semiannual resident meetings. Acknowledging the potential impact that the pandemic may have on graduation requirements, the Radiology Residency Review Committee did modify these requirements for residents impacted by COVID-19. For example, in breast imaging, senior residents are allowed to review already finalized mammograms to count towards their 240 mammogram requirement (11). Additionally, for nuclear medicine, telemedicine

rotations were allowed for seniors impacted by COVID-19, as well as postgraduate documentation of supervised sodium iodine I-131 administration cases (11). Of course, the impact is not limited to R4 residents, as R1–R3 residents not on track to meet their required minimums will need to spend extra time on these rotations, potentially taking away from elective rotation time.

Procedural volumes within the department also experienced a considerable decline when compared to the prepandemic time period. This decline in procedural volumes could potentially preclude residents pursuing the Early Specialization in Interventional Radiology (ESIR) pathway from meeting minimum case volume requirements. To offset the impact of this reduced procedural volume, our program preferentially placed ESIR residents on procedural rotations in order to ensure continuity of education. The ACGME also allowed ESIR residents to enter independent interventional radiology residencies with less than 500 cases logged, although they must still log at least 1000 cases by the end of their interventional radiology residency (11).

Beyond Imaging Interpretation

The impact on resident education also extends far beyond simply measuring imaging interpretation volumes. For example, during the pandemic and peripandemic time periods, in an effort to increase social distancing, more staff radiologists worked from home, resulting in a transition from in-person read-outs to virtual or over-the-phone read-outs. In addition, in-person didactics and case-based conferences were initially halted and eventually replaced by virtual conferences for a period of time. While these virtual conferences were well-received, there is no substitute for in-person education.

The educational challenges presented by COVID-19 have also resulted in new solutions and opportunities for residents. The Association of University Radiologists accelerated the launch of their Core Curriculum Lecture Series, which offers a series of lectures by nationally renowned radiologists to help supplement resident education and could be used as a part of a distance learning curriculum (12). Likewise, the Association of Program Directors in Radiology also began offering national virtual noon conferences twice per week (13). In addition, the pandemic has increased time for resident research opportunities and allowed residents to complete various projects. Residents also had opportunities to expand the medical student curriculum and give virtual lectures.

Limitations of this study include its limitation to a single large radiology residency program and potential lack of generalizability to other programs due to variability in local prevalence of COVID-19 and stay-at-home orders. Month-to-month imaging volumes, especially modality-specific volumes, can vary greatly depending on resident rotational assignments and this could impact prepandemic reference values. As previously mentioned, modality-specific volume differences between training levels during the prepandemic period, particularly radiograph volumes, accounted for part of

the differential impact observed between training levels. Additionally, during the pandemic resident reports were sometimes signed by staff during the draft stage in which case that report would not be counted as a resident-interpreted study. However, this is felt to be a small number of exams. Finally, while this study measured the immediate impact of the COVID-19 pandemic on resident imaging interpretation volumes, the long-term effects are yet to be determined.

CONCLUSION

The COVID-19 pandemic caused a marked decrease in radiology resident imaging interpretation volume and has had a tremendous impact on resident education. The impact on resident case interpretation volume was greatest for the junior resident classes, although all classes were affected. As program directors continue to adapt to the educational challenges brought forth by the COVID-19 pandemic, knowledge of the differential effect on residents at various stages of training will help program directors and residency programs plan for the future.

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