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ORIGINAL ARTICLE

Working from home: Changes in radiologist reporting behavior in response to the COVID-19 pandemic

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Abstract

Background: Remote reporting is an important preventive measure against coronavirus disease 2019 (COVID-19) for radiology departments; it reduces the chance of cross-infections between coworkers. The purpose of this study was to evaluate how the preferred locations that radiologists filed reports from changed in response to COVID-19 by measuring the use of internal teleradiology workstations.

Methods: Data were obtained from the radiological information system (RIS) database at our institution, which recorded the reporting workstation for each radiological examination. The reporting activities in 2021 were divided into computed radiography (CR) and computed tomography (CT)/magnetic resonance imaging (MRI) groups. The Wilcoxon signed-rank test was used to measure differences in the use of off-site workstations in prepandemic, midpandemic, and postpandemic periods.

Results: There were statistically significant increases in the number of reports filed from off-site workstations for each attending physician from the prepandemic period to the midpandemic period in both the CR (15.1%-25.4%, $p = 0.041$) and CT/MRI (18.9%-28.7%, $p = 0.006$) groups. There was no significant difference noted between the prepandemic and postpandemic periods for either the CR (15.1% vs 18.4%, $p = 0.727$) or CT/MRI group (18.9% vs 23.3%, $p = 0.236$).

Conclusion: In response to the COVID-19 outbreak, radiologists used internal teleradiology to report CR and CT/MRI examinations significantly more frequently. In contrast to the predictions of previous studies, the use of internal teleradiology returned to baseline levels after the pandemic was under control.

Keywords: COVID-19 Pandemic; Radiology; Teleradiology

1. INTRODUCTION

Coronavirus disease 2019 (COVID-19) seriously affects all aspects of people's lives around the world, and the healthcare environment is one of the most severely affected areas. To reduce human contact and maintain social distance, many companies are encouraging their employees to work-from home, accelerating the spread of remote work. For radiology departments, teleradiology (remote reporting) is an important preventive measure against COVID-19. By adopting teleradiology, it enables only a small number of radiologists to remain in the facility, reducing the chance of cross-infections between coworkers.[1]

1.1. Teleradiology and the COVID-19 pandemic

Teleradiology is a subset of telemedicine, which means interpreting images at a location physically remote from where the images were acquired.[2] There are two main types of teleradiology, internal teleradiology and external teleradiology, also known as intramural teleradiology and extramural teleradiology, respectively. Internal teleradiology means that the off-site reading is performed by a radiologist employed by the practice while external teleradiology is performed by radiology services providers.[3] With the development of computer technology and the internet and the increasing market demand, teleradiology has been booming since the mid-1990s.[4] A 2016 study of members of the European Society of Radiology (ESR) found that nearly 90% of the respondents had internal teleradiology at their institutions, and nearly 50% of them had external teleradiology.[5] A 2019 survey targeting members of the American College of Radiology also showed that more than 80% of the respondents were using internal teleradiology, and nearly half of them were

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using external teleradiology.[6] It is fair to say that telemedicine was already a part of radiologists' work before the COVID-19 pandemic.

1.2. Previous studies showed increases in teleradiology use during the pandemic

During the COVID-19 pandemic, many radiology departments began to implement or increase their use of teleradiology to reduce the risk of exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[3,7] For example, a study by Quraishi et al[3] found that nearly two-thirds of medical facilities in the United States had increased the number of home-based workstations for radiologists; nearly three-fourths of them transferred daytime work to internal radiology. The studies mentioned above were conducted via questionnaire.

We hypothesized that (1) the radiologists changed their reporting habits with an increased frequency of working from home by using internal teleradiology in response to the COVID-19 outbreak and (2) the tendency might persist after the rate of newly diagnosed cases returned to the level before the outbreak and would be determined by analyzing log data from our radiology information system (RIS).

2. METHODS

2.1. Study setting and approval

This Institutional Review Board-approved retrospective study was performed at a tertiary referral medical center with 2800 beds located in Taipei, Taiwan. The radiology department has approximately 32 board-certified full-time radiologists and issues more than 750 000 reports annually.

2.2. Internal teleradiology in our department

Our institution has adopted internal teleradiology since 2013. Attendings can work remotely by logging into servers of virtual desktop infrastructure providers via the software VMware Horizon Client (version 8, VMware, Inc., California, CA, USA) on their home-based workstations with two-factor authentication. The server returns a virtual operating system environment where all the applications needed for reporting are prepared and installed, including a Digital Imaging and Communications in Medicine (DICOM) viewer (SmartIris, version 2.1.0.11, The Taiwan Electronic Data Processing Co., Taichung, ROC), RIS, and hospital information system (HIS). The workstations are equipped with 3-megapixel (MP) medical monitors for displaying images. When connected to a stable internet connection, such as a reliable 30 Mbps, radiologists can view images without compromising their resolution or quality, and with minimal delay.

The use of internal teleradiology in our department has been on the rise since its introduction. In 2013, 6.8% of computed tomography (CT) and magnetic resonance imaging (MRI) exams were reported via VMware, and this number had increased to 18.6% by 2020.

2.3. Study time periods and definitions

In the year 2021, there was a significant surge in domestic COVID-19 cases diagnosed in Taiwan between May and August, in comparison to the periods of January to April and September to December.[8] Therefore, we defined these months as the midpandemic period. The periods before and after the midpandemic period exhibited relatively low numbers of newly diagnosed cases. Consequently, the time span between January 2021 and April 2021 is defined as the prepandemic period, while the period from September 2021 to December 2021 is defined as the remission period (Fig. 1).

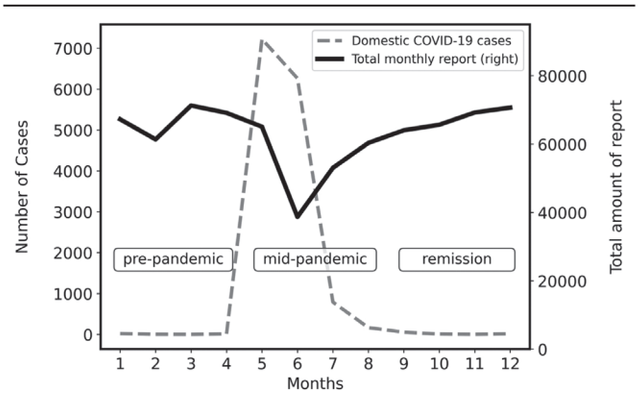

Fig. 1 Monthly domestic COVID-19 cases and change in total report volume in 2021 at our institution. The prepandemic period covered January to April 2021; the midpandemic period covered May to August 2021; the remission period covered September to December 2021. COVID-19 = coronavirus disease 2019.

2.4. Data selection

Data were obtained from the RIS database at our institution. The database contained information about the study title, study modality, reporting physicians (including residents and attending physicians involved in the study), number of modifications, and reporting workstations.

Using the records generated by the reporting workstations, we can determine which reports were performed on an off-site machine.

All reported data in 2021 were searched and collected. To reduce heterogenicity, the data were filtered and processed in the following steps (Fig. 2):

1. Resident-mediated reports and reports were excluded by part-time radiologists.
2. Sonograms, mammograms, and interventional exams were excluded.
3. All reports from attendings who did not report during any of the above three study time periods were excluded.
4. Revised reports were excluded.

5./6. The remaining reports were separated into a computed radiography (CR) group and a CT/MRI group.

To analyze trends in remote work, we compared the proportion of reports generated on off-site workstations for each radiologist in the prepandemic, midpandemic, and remission periods in the CR group and the CT/MRI group. Note that the number of modifications and reporting workstations are updated when the report content changes, for example, when the report is temporarily saved or later revised. Consequently, reports with a number of modifications >1 were excluded to prevent any unwanted confounders.

2.5. Statistical analysis

Changes in report volume each month during the prepandemic, midpandemic, and remission periods were evaluated by ordinary linear regression with adjusted Newey-West standard errors. The Wilcoxon signed-rank test was used to measure the differences in the use of off-site workstations during the three periods, as the Shapiro–Wilk test showed that the distribution of all datasets departed significantly from normal ($p < 0.01$). Statistical analyses were performed using Python programming language and statistical packages such as SciPy (version 1.6.2) and statsmodels (version 0.12.2). Figures were created by Python programming language and packages such as SchemDraw (version 0.14) and matplotlib (version 3.3.4). All statistical tests

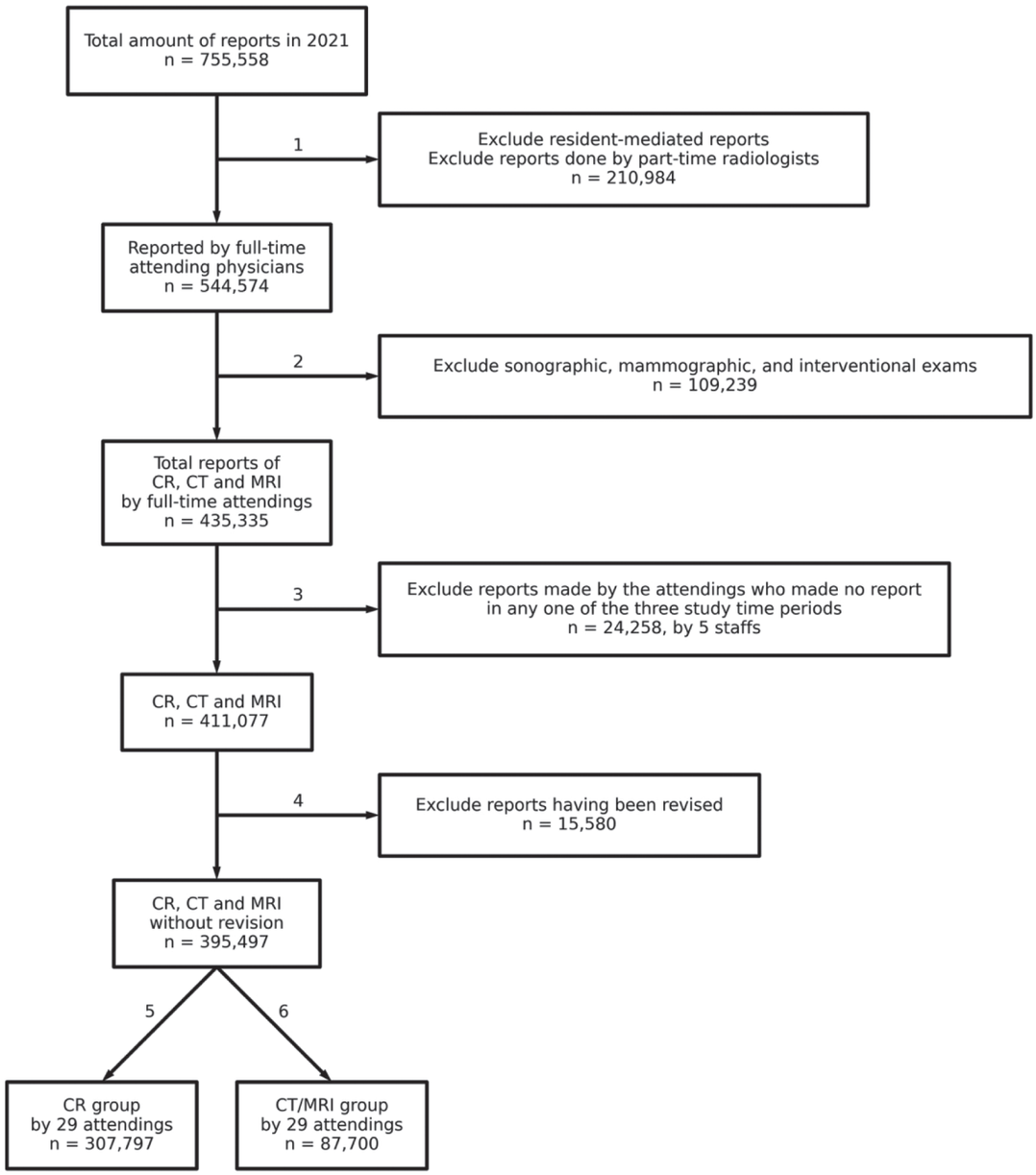

Fig. 2 Flow chart for the selection and exclusion of data. CR = computed radiography; CT = computed tomography; MRI = magnetic resonance imaging.

were two-tailed, and p values of 0.05 or less were considered statistically significant.

3. RESULTS

There were 755 558 reports produced by the radiology department in 2021. On average, 67 239, 54 273, and 67 378 reports were generated monthly in the prepandemic, midpandemic, and remission periods, respectively.

There was a statistically significant decrease in monthly reporting in the transition from the prepandemic period to the midpandemic period (Fig. 1, b = –2283; 95% CI, –4221.502 to –345; p = 0.021). From the midpandemic period transitioning to the remission period, there was a statistically significant increase in monthly reporting (Fig. 1, b = 2778; 95% CI, 576-4980; p = 0.013). There was no significant difference in the reporting volume between the prepandemic and remission periods (Fig. 1, b = 491; 95% CI, –66 to 1048; p = 0.084).

There were 411 077 reports after excluding resident-mediated reports, reports made by part-time radiologists, interventional examinations, sonography, and mammography exams, and reports made by attendings who were absent in any of the three study time periods. The remaining imaging modalities were CR, CT, and MRI. Further exclusion of reports that were revised brought the final total number of included reports to 395 497. CR studies were treated as a separate group; CT and MRI studies were combined as the CT/MRI group. The numbers of studies in the CR group and CT/MRI group were 307 797 and 87 700, respectively (Fig. 2). These reports were all performed by 29 full-time physicians.

The relationships between newly diagnosed weekly domestic COVID-19 cases in 2021 and the usage of off-site workstations are illustrated in Figs. 3 and 4. There were observable increases

in the usage of off-site workstations for reporting both CR and CT/MRI images during the peak of domestic COVID-19 cases.

In the CR group, an average of 15.1% (SD 20.9%, median 7.0%, interquartile range [IQR] 20.7%) of reports were made from off-site workstations for each attending physician during the prepandemic period (Table 1). In the midpandemic period, the average use of off-site workstations for CR image reporting increased by 68.2% to 25.4% (SD = 27.1%, median = 20.1%, IQR = 42.1%), which was statistically significant ($Z = -2.04$, $p = 0.041$). In the remission period, the average usage of off-site workstations for reporting CR images decreased to 18.4% (SD = 25%, median = 9.5%, IQR = 28.0%), which was significant ($Z = 2.19$, $p = 0.029$). There was no significant difference between the prepandemic period and remission period ($Z = -0.35$, $p = 0.727$). The results are summarized in Table 2 and Fig. 5.

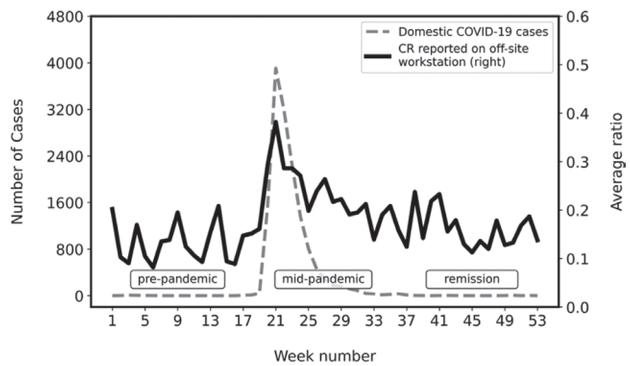

Fig. 3 Weekly number of newly diagnosed domestic COVID-19 cases in Taiwan and average percentage of CRs reported on an off-site workstation for each attending physician in 2021. The prepandemic period included January to April (week 1-17); the midpandemic period included May to August (week 17-35); and the remission period included September to December (week 35-53). COVID-19 = coronavirus disease 2019; CR = computed radiography.

In the CT/MRI group, the average percentage of the reports performed on off-site workstations by each attending physician during the prepandemic period was 18.9% (Table 1, SD = 20.8%, median = 9.2%, IQR = 34.2%), which increased significantly by 52.9% to 28.7% (SD = 28.5%, median = 18.4%, IQR = 51.0%) in the midpandemic period ($Z = -2.77$, $p = 0.006$). In the remission period, the average usage of off-site workstations for reporting CT/MRI images decreased slightly to 23.3% (SD = 25.2%, median = 16.4%, IQR = 38.2%). There was no

Table 2

Comparison of the average percentage of reports issued on an off-site workstation by each attending in the prepandemic, midpandemic, and remission periods

	Prepandemic vs midpandemic	Midpandemic vs remission	Prepandemic vs remission
CR group	$Z = -2.04$, $p = 0.041$[a]	$Z = 2.19$, $p = 0.029$[a]	$Z = -0.35$, $p = 0.727$
CT/MRI group	$Z = -2.77$, $p = 0.006$[a]	$Z = 1.35$, $p = 0.178$	$Z = -1.17$, $p = 0.236$

CR = computed radiography; CT = computed tomography; MRI = magnetic resonance imaging.
[a]Statistically significant, $p < 0.05$.

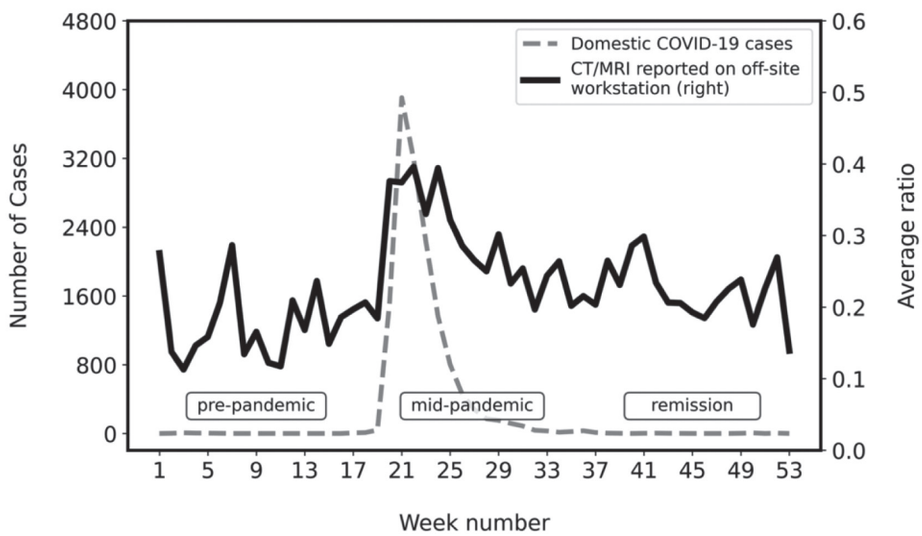

Fig. 4 Weekly number of newly diagnosed domestic COVID-19 cases in Taiwan and average percentage of CTs/MRIs reported on an off-site workstation for each attending physician in 2021. The prepandemic period included January to April (week 1-17); the midpandemic period included May to August (week 17-35); and the remission period included September to December (week 35-53). COVID-19 = coronavirus disease 2019; CT = computed tomography; MRI = magnetic resonance imaging.

Table 1

Comparison of off-site workstation use between the CR and CT/MRI groups during each period

	CR group	CT/MRI group	CR group vs CT/MRI group
Prepandemic	15.1% (SD = 20.9%, median = 7.0%, IQR = 20.7%)	18.9% (SD = 20.8%, median = 9.2%, IQR = 34.2%)	$Z = -1.33$, $p = 0.184$
Midpandemic	25.4% (SD = 27.1%, median = 20.1%, IQR = 42.1%)	28.7% (SD = 28.5%, median = 18.4%, IQR = 51.0%)	$Z = -1.30$, $p = 0.194$
Remission	18.4% (SD = 25%, median = 9.5%, IQR = 28.0%)	23.3% (SD = 25.2%, median = 16.4%, IQR = 38.2%)	$Z = -1.53$, $p = 0.126$

Average proportions of reports issued on off-site workstations by each attending during the prepandemic, midpandemic, and remission periods in the CR and CT/MRI groups.
CR = computed radiography; CT = computed tomography; MRI = magnetic resonance imaging; IQR = interquartile range.

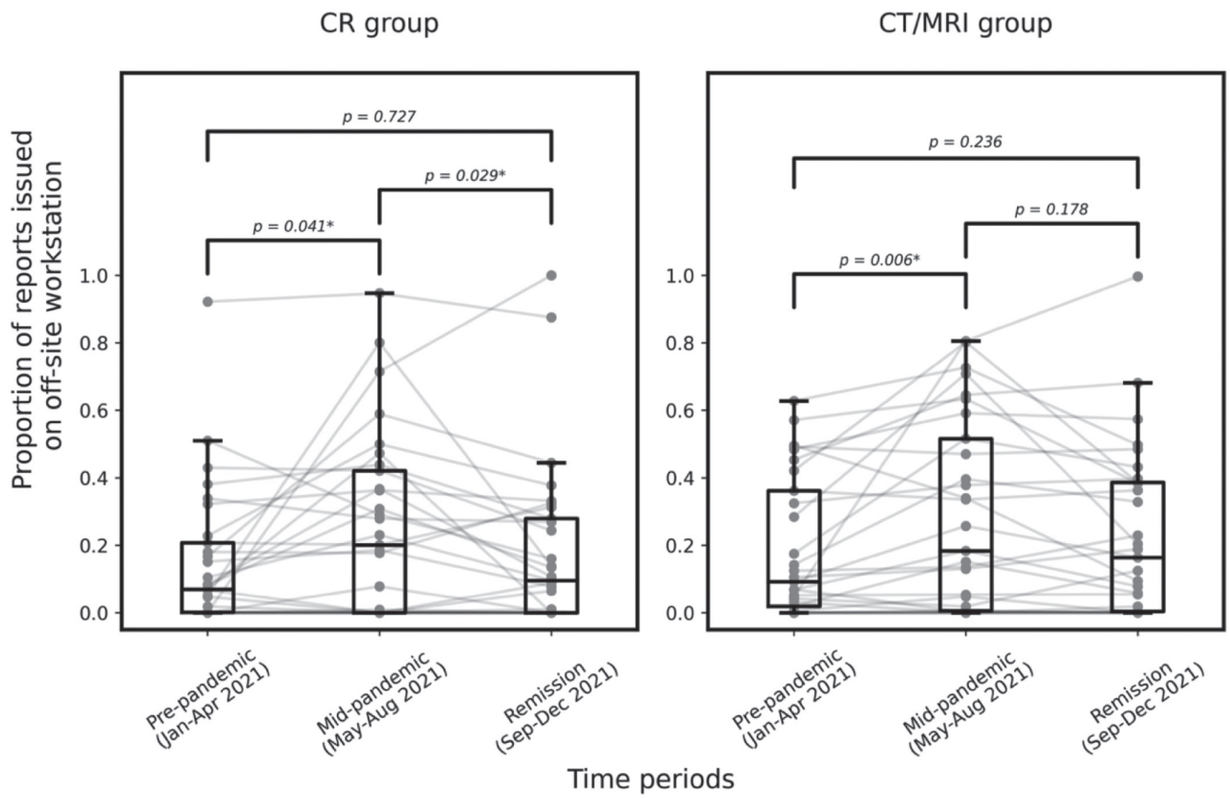

Fig. 5 Boxplot and Wilcoxon rank-sum test of the different proportions of reports issued on an off-site workstation by each attending physician during the prepandemic (Jan-Apr 2021), midpandemic (May-Aug 2021), and remission (Sep-Dec 2021) periods in the CR group and the CT/MRI group. *Statistical significance, $p < 0.05$. CT = computed tomography; MRI = magnetic resonance imaging.

statistical significance between midpandemic and remission (Z = 1.35, p = 0.178) or prepandemic and remission (Z = –1.17, p = 0.236). The results are summarized in Table 2 and Fig. 5.

No statistically significant differences in the usage of off-site workstations between the CR group and the CT/MRI group were found in any of the prepandemic (p = 0.184), midpandemic (p = 0.194), and remission (p = 0.126) periods (Table 1).

4. DISCUSSION

Our literature review indicated that this is the first study to evaluate the relationships between the COVID-19 outbreak and behavioral changes among radiologists leaning toward working from home on off-site workstations, as indicated by log records on the RIS rather than surveys. As a result, our study provided a better assessment of the need for internal teleradiology in response to a pandemic outbreak.

4.1. COVID-19 outbreak in Taiwan during year 2021 and 2022

The spread of COVID-19 has been well controlled in Taiwan since the first positive case was diagnosed on January 21, 2021.[9] The number of daily confirmed domestic COVID-19 cases was consistently below 5 until May 11, 2021. In response, the Central Epidemic Command Center (CECC) declared Alert Level 3 for COVID-19 in Taipei City and New Taipei City, with instructions to conduct schools online, mask in public spaces, limit group meetings, avoid unnecessary travel, etc. In 2021, domestic COVID-19 cases peaked at 720 cases on May 22. During Alert Level 3, our department followed institutional guidelines and implemented standard operating procedures. All meetings and teaching programs were held online. Social distancing was also advised. In 2021, the majority of domestic COVID-19 cases in Taiwan were diagnosed between May and August. Following that period, Taiwan experienced relatively low numbers of newly diagnosed cases from September 2021 until April 2022. However, waves of outbreaks occurred throughout the remainder of the year 2022.[8]

4.2. The effects of COVID-19 on our department

Previous publications have consistently indicated that radiology departments would experience a significant decrease in examinations during a pandemic outbreak,[7,10–12] especially during the first wave.[13] As predicted, our data also showed a similar result (Fig. 1). There was a statistically significant decrease in the monthly reporting volume during the midpandemic period ($p < 0.05$). On average, the monthly reporting volume decreased by 19.3%. In our experience, the reporting volume recovered to prepandemic levels once domestic COVID-19 cases were under control.

4.3. *The increased usage of internal teleradiology during the* mid*pandemic period*

The percentage of reports issued on off-site workstations increased substantially with the increase in newly diagnosed domestic COVID-19 cases. An increase of 68.2% was observed in the CR group and 52.9% in the CT/MRI group (Figs. 3 and 4). These changes were not as pronounced as the results from an earlier study by Callaway et al[14] that showed a nearly 150% increase in the use of remote workstations during the height of the pandemic. This finding could be due to two main reasons. First, internal teleradiology has been in

place for a long time in our institution and has already gained popularity among attendings. By our internal data, there were 18.6% reports of CTs and MRIs issued via internal teleradiology in 2020 before COVID-19 was discovered in Taiwan. Internal teleradiology at that time was used mainly when individuals were on call, working overtime, and obtaining expert opinions from other colleagues. Second, our department did not have a work-from-home policy or a public endorsement of making reports from off-site locations. Therefore, there were fewer external forces keeping attendings away from the office. The observed behavioral changes were mainly due to self-motivation.

4.4. Use of internal teleradiology has returned to prepandemic levels

According to a study by Quraishi et al,[3] nearly half of the radiologists surveyed had positive experiences with internal teleradiology and intended to maintain a similar work pattern after the pandemic ends. Other studies also showed similar results.[10,14,15] However, our data showed a different result. Once the pandemic was under control, activity on the off-site workstations returned to prepandemic levels ($p > 0.05$). However, attendings returned to the office to report CRs and CTs/MRIs on site at different rates (Table 1).

In the CR group, the average reporting activity on off-site workstations decreased by 27.6%, from 25.4% in the midpandemic period to 18.4% in the remission period, with statistical significance ($p = 0.029$). In contrast, in the CT/MRI group, the number decreased by only 18.8%, from 28.7% to 23.3%, without statistical significance ($p = 0.178$). It is noteworthy that no statistically significant difference in the use of off-site workstations was found between the CR and CT/MRI groups in either time period (Table 1). We speculated that this small varying degree of change might be influenced both by the continuing tendency to work-from home and by the different time and energy requirements for reporting CRs and CTs/MRIs. To minimize contact with other colleagues, it would be reasonable to report CRs in fragmented time in the hospital and allocate larger blocks of time for reporting CTs/MRIs from home.

This study has several limitations. It is a single-institution study. The generalizability of this study is unclear. There are several factors that could lead to different results, including differences in pandemic severity; differences in departmental, institutional, regional, and national strategies related to the pandemic; and differences in personal attitudes toward the pandemic. The definitions of the prepandemic, midpandemic, and remission periods are arbitrary. Therefore, the preemptive or latent responses of radiologists to the outbreak may not be entirely included in the midpandemic period. The data show only radiologists' responses to the first wave of the domestic COVID-19 outbreak. These results cannot be directly applied to subsequent outbreak waves. More data and a longer observation period are needed to determine the long-term impact of the pandemic on teleradiology utilization.

Due to the anonymity of the information and the lack of a questionnaire survey, the motive and reasoning behind the behaviors could not be elucidated.

In this article, the positive effects and negative effects of working from home are not evaluated. Future research may analyze the difference in efficiency or accuracy in reporting from an on-site vs an off-site workstation.

In conclusion, in response to the pandemic outbreak, radiologists significantly increased their utilization of the internal teleradiology system to work remotely for both CR and CT/MRI reporting. Contrary to the predictions of previous survey studies, this heightened activity returned to baseline levels as the pandemic entered a remission status. These findings can provide valuable insights for department administrators in effectively managing resources during future pandemic situations.

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