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.
Cardiothoracic Imaging

Detection of COVID-19 pulmonary manifestations with radiotherapy simulation CT imaging☆

Abraham J. Wu a,*, Andrew Plodkowski b, Michelle Ginsberg b, Jacob Shin a, Quincey LaPlant a, Annemarie Shepherd a, Narek Shaverdian a, Victor Ng a, Daphna Gelblum a, Lior Braunstein a, Andreas Rimner a

a Department of Radiation Oncology, Memorial Sloan Kettering Cancer Center, New York, NY, United States of America
b Department of Radiology, Memorial Sloan Kettering Cancer Center, New York, NY, United States of America

ARTICLE INFO

Keywords:
COVID-19
Radiotherapy
CT
Simulation
Screening
Pneumonia

ABSTRACT

COVID-19 is associated with characteristic lung CT findings. Radiotherapy simulation CT scans may reveal characteristic COVID-19 findings and identify patients with active or prior infection. We reviewed patients undergoing CT simulation at a major cancer center in an early epicenter of the COVID-19 pandemic in the United States. Scans were reviewed by radiation oncologists using established radiographic criteria for COVID-19 pneumonia. Radiographic classifications were compared with available COVID-19 PCR test results. A one-tailed t-test was used to compare the rate of positive COVID-19 tests in radiographically suspicious vs. non-suspicious groups. Scans deemed suspicious were re-reviewed by expert diagnostic radiologists. 414 CT simulation scans were performed on 400 patients. 119 patients had COVID-19 PCR test results available. Radiation oncologists considered 71 scans (17.1%) suspicious for COVID-19. Of these, 23 had corresponding COVID-19 PCR tests, and 3/23 (15.7%) were positive for COVID. 107 non-suspicious scans had corresponding COVID-19 test results, and 9 were positive (8.4%). The difference in positive test results between suspicious and non-suspicious groups was not significant (p = 0.23). Upon re-review by a diagnostic radiologist, 25 (35%) scans deemed suspicious by radiation oncologists were confirmed to meet criteria, while the rest were re-classified as “atypical” for COVID-19. We conclude that radiotherapy simulation CT scans can be reviewed for signs of COVID-19 pneumonia by radiation oncologists. However, suspicious CT simulation was not associated with a higher incidence of COVID infection compared with non-suspicious CT simulation, and there was low concordance between radiation oncologist and diagnostic radiologist classification of scans.

1. Introduction

The COVID-19 pandemic has caused massive illness, loss of life, and disruption to virtually all aspects of life worldwide. Despite significant advances in understanding and prevention, such as vaccines, SARS-CoV-2 and its variants continue to spread and sicken, and are becoming endemic. Identifying COVID-19 infection is particularly important in cancer patients, who not only are at higher risk due to older age and immunocompromise, but are in close contact with other patients and healthcare workers within healthcare facilities.

SARS-CoV-2, as a respiratory virus, often causes characteristic lung changes that are identifiable on CT scans.1,2 Many cancer patients receive radiation therapy, a treatment that typically requires the acquisition of CT imaging to design radiation therapy fields (simulation). Our center is a major tertiary cancer center located in early American epicenter of the COVID-19 pandemic when it unfolded in the United States in early 2020. We hypothesized that simulation CT scans obtained on patients during this time might show characteristic findings of COVID-19 pneumonia, and that this in turn may represent a tool to identify patients with active or recent COVID-19 infection prior to starting a course of radiotherapy. Because CT simulation images are not typically reviewed by diagnostic radiologists, we also wished to investigate whether trained radiation oncologists could identify COVID-19 pneumonia with accuracy comparable to diagnostic radiologists.

☆ The authors report no pertinent conflicts of interest. Details can be found on each author’s individual COI form.

* Corresponding author.
E-mail address: wua@mskcc.org (A.J. Wu).

https://doi.org/10.1016/j.clinimag.2022.11.008
Received 7 July 2022; Received in revised form 20 October 2022; Accepted 8 November 2022
Available online 17 November 2022
0899-7071/© 2022 Elsevier Inc. All rights reserved.
2. Methods

All patients undergoing CT simulation during a six-week period were reviewed between March 1 and April 13, 2020. Patients only underwent simulation if they were without symptoms or clinical suspicion for COVID-19. Most scans were done under free-breathing conditions, with slice thickness \( \leq 3 \text{ mm} \) and without IV contrast. Only patients whose scans included the majority of the bilateral lungs were included.

All scans were reviewed by one of 10 academic radiation oncologists with specialization in thoracic malignancies. These radiation oncologists underwent a one-time interactive training session with expert thoracic diagnostic radiologists to identify COVID-19 pneumonia findings and classify them according to consensus criteria published by the Radiological Society of North America. These criteria comprise four categories from most suspicious to least: “typical” appearance for COVID-19 pneumonia, “indeterminate,” “atypical,” and “negative.” For the purposes of this study, any patient considered “typical” or “indeterminate” was considered suspicious for COVID-19 infection.

These radiographic classifications were then compared with available COVID-19 PCR test results. (At the time of this study, COVID-19 PCR testing was not routinely performed on all radiation oncology patients.) A one-tailed t-test was used to compare the rate of positive COVID-19 tests in the radiographically suspicious vs. non-suspicious groups. All scans deemed suspicious by the radiation oncologists were then re-reviewed by an expert thoracic diagnostic radiologist to assess concordance of radiographic classification between radiation oncologists and diagnostic radiologists.

3. Results

During the study period, a total of 414 CT simulation scans included the lungs were performed at our center, comprising 400 patients total. The most common cancer types were breast (37%), lung/thoracic (23%), and spine (21%). On initial review by radiation oncologists, 17 scans (4.1%) were deemed “typical” for COVID-19 pneumonia, 54 (13%) were “indeterminate,” 85 (21%) were “atypical,” and 258 (62.3%) were “negative” (See Figs. 1 and 2).

COVID-19 PCR test results were available for 119 patients (corresponding to 130 scans, or 31.4%). Of the 71 scans deemed “typical” or “indeterminate” for COVID-19 pneumonia, 23 had corresponding COVID-19 PCR test results, and of these, 3 (15.7%) were positive for infection. All three positive cases had been deemed “indeterminate” by the reviewing radiation oncologist. Of the 343 scans deemed “atypical” or “negative” for COVID-19 pneumonia, 107 (31.2%) had corresponding COVID-19 test results, and of these, 9 (8.4%) were positive, 3/9 deemed “atypical” and 6/9 deemed “negative.” This difference in positive COVID-19 PCR results between suspicious and non-suspicious groups was not statistically significant when using a one-tailed t-test \((p = 0.23)\) to compare patients with PCR test results.

The 71 scans initially deemed suspicious by radiation oncologists were re-reviewed by diagnostic radiologists. Of these, 25 (35.2%) were still deemed “typical” or “indeterminate” by diagnostic radiology, while the remaining 46 (64.8%) were deemed “atypical.” Of the three suspicious simulation CT scans with positive COVID test results, one was deemed “indeterminate” by the reviewing diagnostic radiologist while the other two were deemed “atypical.”

4. Discussion

In this report, we compared radiation oncologist and diagnostic radiologist assessments of potential COVID-19 pneumonia in simulation CT imaging for radiation therapy patients. Anecdotally, radiotherapy-associated CT imaging has been reported to contribute to the identification of otherwise occult COVID-19 infection, but it is uncertain whether mass screening of radiotherapy patients is a worthwhile strategy. A unique aspect of our study was that we relied on radiation oncologists to do the initial radiographic screening, then had their interpretations reviewed by diagnostic radiologists. Since nearly every radiotherapy patient undergoes CT simulation and simulation imaging is not generally reviewed by diagnostic radiologists, our study represents the most realistic scenario for screening CT simulation images for signs of COVID-19 infection. This also gave us an opportunity to evaluate the concordance between radiation oncologist and diagnostic radiologist interpretations.

Our findings indicate that a substantial number of patients simulated for radiotherapy during the COVID pandemic did, indeed, have lung CT findings that were potentially consistent with COVID infection based on radiation oncologist review. However, relatively few of these patients proved to have confirmed COVID infection based on PCR testing. Moreover, having a suspicious CT simulation scan was not associated with a higher rate of positive COVID-19 PCR test compared to having a non-suspicious CT simulation scan. This suggests that routine screening
of CT simulation scans is of limited value in diagnosing COVID-19. This finding is consistent with a French study in which all scans were reviewed by diagnostic radiologist, in which review of CT simulation scans also did not prove very efficacious in identifying COVID-19 infection.5

Anecdotally and in principle, screening of CT simulation images may identify some patients with otherwise-unsuspected COVID-19 infection who are about to undergo radiation therapy. However, our results suggest that incorporating routine review of simulation CT images for signs COVID-19 pneumonia is unlikely to identify a substantial number of positive cases. This is likely due to limited sensitivity and specificity of screening CT simulation images in this population. Technically, while CT simulation images are typically acquired on diagnostic-quality CT scanners, they are generally not being acquired using diagnostic CT protocols. For example, they are usually performed under free-breathing rather than breath-hold conditions, and using parameters optimized for radiotherapy target delineation rather than diagnosis of occult medical conditions, and therefore not necessarily comparable to the diagnostic chest CT images for which the COVID-19 radiographic criteria were defined.

Many radiotherapy patients also have comorbid conditions affecting the lungs that can confound the identification of COVID-19 pneumonia, reducing the specificity of CT imaging for this purpose. In particular, many lung cancer patients have lung abnormalities related to the malignancy itself, and/or have other underlying lung pathologies (e.g. COPD) that can obscure or masquerade as COVID-19 pneumonia.

A secondary aim of this study was to determine the feasibility and accuracy of radiation oncologists’ review of CT simulation images for signs of COVID-19 pneumonia. Radiation oncologists are not formally trained in diagnostic CT interpretation and utilize simulation CT images for the exclusive purpose of accurate tumor and normal tissue delineation, not for identification of occult pathophysiologic processes. Though all investigators used the same standardized criteria for reviewing scans, and the radiation oncologists all participated in a training session led by diagnostic radiologists, the rate of concordance in classification between radiation oncologists and diagnostic radiologists was low. However, it is hardly surprising that a one-time training session would not allow radiation oncologists to achieve the diagnostic accuracy of expert, board-certified diagnostic radiologists. Given the results of this and similar studies, it is difficult to justify having all CT simulation scans reviewed by a diagnostic radiologist.

A major limitation of this study is that only a minority of study patients had corresponding COVID-19 PCR test results, diminishing the power of our study to identify smaller benefits and distinctions in the diagnosis of COVID-19 pneumonia. COVID-19 testing is now more widely available and performed, including at our center. However, we feel it is unlikely that repeating this analysis in a more recent cohort of patients with PCR test results would yield a substantially different result. In addition to PCR testing, rapid antigen testing is widely available and provides a practical and rapid way to screen radiotherapy patients for COVID-19 infection if needed. The advent of COVID-19 vaccination also presumably has reduced the incidence of occult COVID-19 infection in cancer patients, particularly infection that would lead to identifiable COVID-19 pneumonia on CT imaging. Therefore, we conclude that although it is feasible to review simulation CT scans for signs of COVID-19, implementing such a practice is unlikely to identify a meaningful number of patients with otherwise occult or pre-symptomatic infection.

Funding statement

This research was partially supported by NIH Cancer Center Support Grant P30 CA008748.

Data statement

Research data are stored in an institutional repository and may be available upon request from the corresponding author.

References

1. Caruso D, Zerunian M, Polici M, et al. Chest CT features of COVID-19 in Rome, Italy. Radiology 2020;201237.
2. Dangis A, Girodts C, De Bruecker Y, et al. Accuracy and reproducibility of low-dose submillisievert chest CT for the diagnosis of COVID-19. Radiol Cardiothorac Imaging 2020;2(2):e200196.
3. Simpson S, Kay FU, Abbara S, et al. Radiological Society of North America expert consensus statement on reporting chest CT findings related to COVID-19. Endorsed by the Society of Thoracic Radiology, the American College of Radiology, and RSNA - secondary publication. J Thorac Imaging 2020;35(4):219–27.
4. Younes J, Donahue B, Flyer M, Thompson S, Huang A, Gallant F. Covert COVID-19: cone beam computed tomography lung changes in an asymptomatic patient receiving radiation therapy. Adv Radiat Oncol 2020;5(4):715–21.
5. Sun R, Achkar S, Ammari S, et al. Systematic screening of COVID-19 disease based on chest CT and RT-PCR for cancer patients undergoing radiation therapy in a coronavirus French hotspot. Int J Radiat Oncol Biol Phys 2021;110(4):947–56.