Development and implementation of optimized chest CT protocol in COVID-19: A clinical audit

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ABSTRACT

Background: Several studies have justified use of chest computed tomography (CT) in diagnosis, evaluation of severity, treatment response, and complications of coronavirus disease 2019 (COVID-19) pneumonia. Increased utilization of CT in patients with known or suspected COVID-19 pneumonia has resulted in concerns of overuse, lack of protocol optimization, and radiation exposure. Aims: The study was conducted to develop and implement optimized protocol for chest CT for reducing radiation dose in adult patients suspected or diagnosed to have COVID-19 infection. Setting and Design: The study was conducted in the department of radiology of a rural tertiary care teaching hospital in western India. Clinical audit was used as a tool to impart and assess the impact of optimized chest CT protocol. Methods and Material: The pre-intervention audit included radiation dosimetry data, number of phases and length of scan of 50 adult patients, undergoing non-contrast chest CT scans in March 2021. A brief educational intervention outlining the parameters of optimized protocol was conducted on April 1, 2021. The post-intervention audit consisted of two cycles for 109 and 67 chest CT scans in the months April and May 2021. Results: The optimized protocol was found clinically adequate with a good inter-rater reliability. The compliance to the optimized protocol was weak in audit cycle 2, which improved significantly in audit cycle 3 after reinforcement. The mean (SD) per scan Computed Tomography Dose Index-Volume (CTDI-vol) reduced significantly across audit cycles [22.06 (12.31) Vs. 10.58 (7.58) Vs. 4.51 (2.90) milli Gray, respectively, P < 0.001]. Similar findings were noted for Dose Length Product (DLP). Conclusion: Clinical audit of chest CT protocol and resultant radiation doses provided adequate feedback for dose optimization. A simple educational intervention helped achieve dose optimization.

Keywords: Chest computed tomography, clinical audit, COVID-19, educational intervention

Introduction

The emergence of severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2), still remains an unprecedented challenge for the world since its first case emerged in 2019 in the Hubei province of China. Widespread testing of the individuals with suspected COVID-19, infection is considered one of the key steps in control of spread of the infection.[9]

Although reverse transcription-polymerase chain reaction (RT-PCR) assay is the preferred method of diagnosis of COVID-19 infection, chest computed tomography (CT) is often used in patients with known or suspected COVID-19 due to clinician preferences, initial shortage in availability of RT-PCR tests and false-negative RT-PCR assays. Several studies have examined and justified use of chest CT in diagnosis as well as evaluation of severity, treatment response, and complications.

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of COVID-19 pneumonia. It has also been noted that chest CT in suspected COVID-19 infection has a higher sensitivity for detection of the pneumonia in RT–PCR negative individuals. Chest CT also provides scope to differentiate infective etiology other than COVID-19 pneumonia.[1]

Increased utilization of CT in patients with known or suspected COVID-19 pneumonia has brought with it growing concerns of overuse, lack of protocol optimization, and radiation exposure. Hence, developing strategies incorporating dose optimization while retaining the diagnostic accuracy is warranted. There is lack of protocol optimization in significant number of CT examinations around the world.[1–3] Surveys conducted for evaluating use of chest CT examinations in patients with known or suspected COVID-19 pneumonia between April and July 2020 showed variability in protocols used in chest CT examinations with several fold variations in number of scan phases, CT examinations per patient, and associated radiation dose descriptors.[1,3,4] Although there has been remarkable progress in the field of Radiology in terms of technological advancement, there is a high prevalence of inappropriate or unnecessary examinations ranging from 20% to 77%.[5]

Clinical audit is a time-tested tool applied in various disciplines of healthcare for quality improvement. A complete audit cycle includes selection of standard of good practice, comparing it with local practice, implementing change when necessary and re-auditing. This tool allows scrutiny of prevailing practices and paves way for better patient care, effective use of resources, enhanced clinical services, and contributes to professional education and training.[6]

Clinical audits are not sufficiently adopted in diagnostic radiology despite significant initiatives to introduce the concept of audits for the assessment of radiological practices. This might be due to lack of well-trained auditors, lack of knowledge and guidance on audit methodology, financial support, and lack of motivation.[6,4]

A significant variability in chest CT protocol for individuals with diagnosed and suspected COVID-19 infection as well as resultant high radiation doses was noted by the consultants at the study site. There was a felt need to optimize for chest CT in suspected/known COVID-19 patients. The clinical audit was conducted to develop optimized protocol for chest CT in suspected/known COVID-19 patient with a goal of minimizing radiation without compromising diagnostic accuracy.

Methods

The study was conducted in the Department of Radiodiagnosis at tertiary care rural teaching hospital in western India, with facilities of Multidetector Computed Tomography (MDCT), Magnetic Resonance Imaging (MRI), Ultrasound, and X-ray facilities. The hospital is National Accreditation Board for Hospitals and Healthcare Providers (NABH) accredited and a Designated COVID Hospital. The chest CT scans were performed on GE Optima CT660 that was commissioned in 2012. The study was approved by institutional ethics committee.

Pre intervention audit

The pre-intervention audit (Audit cycle 1) included radiation dosimetry data from 50 adult patients, suspected or known to have COVID-19 infection, and who underwent non-contrast chest CT scans during the period of March 1, 2021 to March 31, 2021. The dose reports of patients undergoing chest CT were retrieved from Picture Archiving and Communication System (PACS) and Radiology Information Systems (RIS). Computed Tomography Dose Index-Volume (CTDI-vol) measured in milli Gray, Dose length product (DLP) measured in milliGray.cm were recorded to estimate absorbed dose. Number of phases and length of scan were documented for each patient undergoing CT examination. In case of multiphase scan, the reasons to undertake multiple phases such as motion artefacts or pathology requiring multiphase scan were noted to evaluate rationality.

Optimization of chest CT protocol

During pre-intervention audit, it was found that the radiation doses exceeded bench mark of CTDI-vol < 3 mGy recommended by Kalra MK et al.[1] in most patients with suspected and known COVID-19 infection undergoing chest CT examinations. Modifiable parameters that could help in dose optimization based on recommendations by Kalra MK et al.[1] were identified. Considering feasibility and technical specifications of the machine, the consultants developed a protocol based on recommendations by Kalra MK et al.[1] with minor modifications in rotation time, pitch, slice interval and slice thickness. The scanning parameters adopted in addition to emphasis on adequate breath holding by patients are presented in Table 1. A pilot study of 10 chest CT examinations using optimized protocol was conducted to evaluate the diagnostic accuracy and efficacy in reduction of radiation dose. Two radiologists analysed diagnostic quality of chest CT images and reported them independently. The observations on diagnostic quality of images and final impression of report were matched for inter-rater reliability. Adequate quality scans were achieved with use of the optimized chest CT

| Table 1: Parameters of optimized chest CT protocol |
|-----------------------------------------------|
| **Scan type** | **Helical** |
| Tube potential | 120 KV |
| mAs | 30-100 |
| Rotation time | 0.5 sec |
| Pitch | 1.375:1 |
| Speed (mm/rotation) | 55 |
| Scan type | 0.625 |
| Detector coverage | 40.0 mm |
| Automatic exposure control | On (SmartMa) |
| Phases | Single |
| Length of scan | Apex to base of lung |
| Reconstruction | Adaptive Statistical Iterative Reconstruction (ASiR) setup ss30 slice 30% |
protocol and CTDI-vol <4 mGy. The consultants agreed upon implementation of the new optimized protocol in suspected/known COVID-19 patients.

Educational intervention

The observations of the pre-intervention audit were shared in a meeting attended by faculty, residents, technicians, and trainee technicians to explain the need for protocol optimization. The educational intervention was conducted on April 1, 2021 consisted of a brief didactic presentation of 30 min duration, outlining the parameters of optimized protocol as described in Table 1 for chest CT that could help achieve uniformly lower radiation doses. The technicians and the residents were unaware to the plan of post-intervention audit.

Post intervention audit

After the educational intervention, the audit (Audit Cycle 2) was repeated in the same manner from April 1, 2021 to April 30, 2021 for 109 chest CT examinations. The data from this audit showed that mean and median CTDI-vol were much higher than our bench mark (CTDI-vol <4 mGy). It was observed that all technicians did not uniformly adapt the optimized chest CT protocol in the month April. A consultant conducted a Focus Group Discussion with the technical team to understand the barriers in adopting the optimized protocol. Two main themes emerged from the discussion:

Lack of Motivation due to lack of personal incentive: A general tendency to maintain status quo was difficult to change especially as the technical team did not find any motivation and personal incentive.

Fear of failure: The technical team was nervous due to fear of unacceptable quality of scans using the optimized protocol.

A consultant repeated the educational intervention to reinforce the message of the earlier intervention along with two additional components on May 1, 2021. The consultant stressed on societal incentive pertaining to minimal radiation dose especially in view of the growing paediatric patients during the second wave. Further, the consultant performed few CT scans with the technical team to show that the quality of scans is acceptable. The technical team was assured a blame free supportive supervision and at least one consultant was made available round the clock for any issues faced by the technical team in using optimized protocol.

Another cycle of audit (Audit Cycle 3) was conducted in the month of May including 67 chest CT scans to assess compliance as well as impact of the optimized protocol.

Statistical analysis

Descriptive statistics [Mean (SD), Median [Q1, Q3], frequency (%), etc.] were used to describe important characteristics across audit cycles. Analysis of variance (ANOVA) was applied to assess change in mean cumulative as well as per scan CTDI-vol and DLP values across audit cycles. Post hoc tests with Scheffe’s method were employed to check which pair of differences are significant wherever applicable. Chi-square test was performed to look for association between change in proportion of chest CT scans performed with low dose protocol, scan length from apex to base of lung and rationality of multiple scans across audit cycles. A P value of less than 0.05 was considered significant. The statistical analysis was performed using STATA (14.2) software.

Results

Two independent consultants examined 10 scans for quality of the scans and impression. Both consultants reported adequate quality of all the 10 scans for reporting. Further, the consultants have 100% agreement in impression of the scans as assessed by COVID-19 reporting and data system (CO-RADS) classification used for level of suspicion of COVID-19 infection.

The Audit Cycles 1, 2, and 3 consisted of 50, 109, and 67 scans, respectively. The mean (SD) age of the participants was similar across the audit cycles [51.33 (15.59) vs 54.93 (15.88) vs 49.25 (15.09), respectively, P = 0.06]. Similarly, the frequency (%) of males was similar across audit cycles [32 (64) vs 74 (67.89) vs 45 (67.16), P = 0.89].

The percentage of chest CT scans with optimal scan length from apex to base was similar [38% to 43.5%, P = 0.051] from audit cycle 1 to audit cycle 2. It increased significantly [43.2% to 89%, P < 0.001] from audit cycle 2 to cycle 3. The utilization of multiphase scans declined significantly [82% to 29.36%, P < 0.001] from audit cycle 1 to 2, but not significantly [29.36% to 16.42%, P = 0.052] during cycle 2 to 3. The percentage of multiple scans without rationality decreased significantly [53.6% to 9.38%, P < 0.001] from audit cycle 1 to 2. However, it was reduced further [9.38% to 0%] but could not attain statistical significance due to small numbers [Table 2].

There was a statistically significant difference in cumulative and per scan CTDI-vol values across three audit cycles (p < 0.001). Post hoc tests with Scheffe’s method revealed that mean (SD) cumulative CTDI-vol was statistically significantly lower in audit cycle 2 compared to audit cycle 1 [10.58 (7.58) vs 22.06 (12.31), P < 0.001]. It was significantly lower in audit cycle 3 compared to audit cycle 2 [4.51 (2.90) vs 10.58 (7.58), P < 0.001]. Similarly, mean (SD) per scan CTDI-vol was statistically significantly lower in audit cycle 2 compared to audit cycle 1 (7.84 ± 4.18 vs 9.69 ± 4.83, P = 0.02) and also it was significantly lower in audit cycle 3 compared to audit cycle 2 (7.84 ± 4. vs 3.86 ± 2.13, P < 0.001). A similar trend was noted with dose length product (DLP) values [Table 2, Figures 1 and 2].

Discussion

Radiation protection in medicine stands on two pillars, justification, or appropriateness of the examinations and dose...
optimization. Published literature suggests that, in clinical settings, both referring physicians and radiologists often have limited awareness of the actual doses and risks involved in CT examinations.[5,7] There have been attempts to reduce the radiation during CT scan with a notable one by Prasad et al.[8] who documented that chest CT image quality obtained with modification of CT scanning parameters is acceptable for evaluating normal anatomic structures with 50% reduced radiation dose. In order to achieve and maintain good practices in the field of Radiology, continuous efforts are required and clinical audit is a potentially valuable tool to achieve targeted good practices.[9]

Table 2: Comparison of performance indicators across audit cycles

| Month   | March n=50 | April n=109 | May n=67 | Overall P value |
|---------|------------|-------------|----------|----------------|
| Length of scan from apex to base | 19 (38%) | 47 (43.52%) | 60 (89.55%) | <0.001 |
| more than apex to base | 31 (62%) | 61 (56.48%) | 7 (10.45%) | <0.001 |
| Number of scan | 1 | 9 (18%) | 77 (70.64%) | 56 (83.58%) | <0.001 |
| >1 | 41 (82%) | 32 (29.36%) | 11 (16.42%) | <0.001 |
| Reasons for multiple scan | Not rational | 22 (53.66%) | 3 (9.38%) | 0 | <0.001 |
| Motion artefact | 13 (31.71%) | 20 (62.50%) | 5 (45.45%) | <0.001 |
| Pathology that requires multiphase scan | 6 (14.63%) | 9 (28.13%) | 6 (54.55%) | <0.001 |
| Cumulative DLP Mean (SD) | 754.83 (433.72) | 346.98 (238.83) | 141.50 (100.55) | <0.001 |
| Median [IQR] | 706.33 [417.64, 974.02] | 321.48 [114.21,453.63] | 104.72 [96.41,126.47] |
| Per scan DLP Mean (SD) | 329.02 (153.82) | 261.67 (148.95) | 122.33 (82.94) | <0.001 |
| Median [IQR] | 330.4 [201.9, 441.1] | 250.9 [108.5, 393.8] | 100.6 [93.9, 109.4] |
| Cumulative CTDI-vol Mean (SD) | 22.06 (12.31) | 10.58 (7.58) | 4.51 (2.90) | <0.001 |
| Median [IQR] | 22.02 [12.66,25.26] | 9.49 [3.39, 12.66] | 3.39 [3.16,3.39] |
| Per scan CTDI-vol Mean (SD) | 9.69 (4.83) | 7.84 (4.18) | 3.86 (2.13) | <0.001 |
| Median [IQR] | 8.8 [6.24,12.6] | 7.48 [3.39,11.88] | 3.39 [3.16,3.39] |

Figure 1: Box plots depicting reduction in per-scan CTDI-vol across audit cycles

Figure 2: Box plots depicting reduction in per-scan DLP across audit cycles

Literature on CT chest in suspected or known COVID-19 pneumonia recommend a single phase, non-contrast chest CT without the need for contrast injection in uncomplicated COVID-19 pneumonia. Direct post-contrast arterial phase CT can be performed in individuals suspected to have pulmonary embolism or necrotizing pneumonia from superimposed bacterial infection. Multiphase scan need not be performed routinely and should be usedrationally based on sound clinical suspicion and radiologist’s decision.[8]

High-resolution CT used for diffuse lung disease with scanning in inspiratory and expiratory phases, has no significant advantage.
in patients with suspected COVID-19.\textsuperscript{[3]} Chest CT should be preferably performed with an inspiratory breath-hold, extending from the lung apex to the lung base without covering the adrenals. In patients who are either short of breath or coughing, protocols with faster scanning should be preferred with the use of faster gantry rotation time (0.5 s or less) and higher pitch values (greater than 1:1) to avoid motion artifacts and need for repeat scanning. Although the choice of specific scan parameters depends on the type of CT scanner, in general, most low-dose chest CT can be acquired at less than or equal to 100 kV and low tube current. Moreover, use of automatic tube current modulation technique should be preferred since it allows automatic adjustment of tube current based on patient body habitus, considering factors that enable faster scanning. CTDI-vol of 3 mGy or less can be considered as target for radiation dose for small or average size patients (up to 80 kg), while selecting the tube potential and tube current on most scanners. The choice of section thickness may affect scan time as well as the radiation dose and thin sections (less than or equal to 1.5 mm) are optimal for assessing pulmonary opacities. While scanning individuals having trouble holding the breath, thicker sections may be optimal, especially in older scanners. Use of reconstruction methods, with iterative reconstruction being the preferred choice is recommended.\textsuperscript{[3]} Similar innovative approach was presented by Agostini A et al.\textsuperscript{[9]} and obtained high-quality image with reduced dose and reduced motion artifacts. At a broader level, Azadbakht J et al.\textsuperscript{[10]} deliberated on various parameters that affect the dose and provided general framework for radiation dose reduction without compromising image quality.

Despite the availability of frameworks to reduce radiation dose especially in COVID-19 patients, significant variability was noted in the chest CT protocols resulting in variability in radiation doses.\textsuperscript{[4]} It appears that the imaging departments have not adapted the recommendations sufficiently. The present study is the first of its kind with regards to highlighting significant variability noted in the chest CT protocols COVID-19 patients in India and use of a clinical audit to address it.

Almost a decade ago, Demb J et al.\textsuperscript{[11]} achieved significant reduction in radiation dose across institutions with effective use of clinical audits. Specific to COVID-19 scenario, Tabatabaei SM et al.\textsuperscript{[12]} attained significant reduction in radiation dose with low dose protocol. However, Tabatabaei SM et al.\textsuperscript{[12]} conducted the study as experiment where compliance to protocol is almost 100% and hence this study proves the efficacy of low dose protocol. Thieß HM et al.\textsuperscript{[13]} demonstrated appropriate image quality with good inter-reader and intra-reader agreement in patients undergoing low-dose chest CT for detection of SARS-CoV-2 infection.

The present study employed clinical audit as a tool to initiate change and hence confirms effectiveness of low dose chest CT protocol in reducing radiation dose without compromising image quality.

Changing behaviour needs diligent efforts. Many different approaches are suggested for sustainable behaviour change.\textsuperscript{[14,15]} It is prudent to note that the behaviour change was achieved using empowerment, feedback and supportive supervision without any restriction/punitive mechanisms in the present study. Primary care providers, policymakers, health care administrators, public health specialists, community leaders must assert for rational imaging and radiation dose optimization.

Limitations of the study lies in the lack of focus on audit of justification of chest CT referrals in patients with known or suspected COVID-19 pneumonias and evaluation of long-term adherence to optimized CT protocol and resultant radiation doses.

Conclusion

Increased utilization of chest CT for patients with suspected or known COVID-19 infection in the light of universal problem of variable chest CT protocols and resultant radiation doses necessitates strategies for chest CT protocol optimization. Clinical audit of chest CT protocol and resultant radiation doses can help provide adequate feedback for dose optimization. A short and simple targeted educational intervention aimed at technicians and residents who usually oversee and conduct CT scans at academic centers can help achieve dose optimization. Moreover, adaptation of a standard optimized protocol can lead to uniform reduction in radiation doses. Similar strategies can be applied for all CT examinations at imaging centers across the globe for the purpose of dose optimization.

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Conflicts of interest

There are no conflicts of interest.

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