Routine computed tomography scanning protocols for head, chest and abdomen

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The most direct method of reducing the radiation dose reduction is that of decreasing the tube voltage and tube potential. However, the use of other techniques including Automatic Emission Control, Imaging Filters and Noise-Reducing Filters also aid in the reduction of radiation dosage without diminishing the image quality.

The machines used for routine CT at KSMC are the General Electronics system, the Philips system and the Siemens Somatome Sensation 16 Slice. For this evaluation, I would focus on the Siemens system as my experience is confined to the same. The CT scanning protocols for head, chest and abdomen will be covered in this paper. CT can be performed with or without contrast and the procedure essentially depends on the physician performing the imaging procedure.

Routine CT Scanning Protocols for the Head

Table 1 shows the numerous parameters and dimensions for the CT scan of the human skull using KSMC's protocol. Skull imaginative view, reconnoitre vision of the brain SOM (supra orbit meatal) line are the baselines for this assessment. This protocol does not use IV contrast or oral contrast. The second protocol used is for mass lesion or tumour. The second protocol is similar to the first one but uses IV contrast that is set between 100cc to 120cc of Omnipaque 350. Patient preparation and training vary for protocols with and without contrast.

Abbreviations used:

RT = Rotation time , DC = Detector Collimation , ST= Slice Thickness FR=

Feed / Rotation , OC= Oral Contrast, IR= Injection Rate , SD= Scan Delay

In protocols using no contrast, patient training is not necessary, while procedures using contrast require that the four elementary steps be completed, the steps being; only one CT scan contrast must be planned for patient within any agreed 48 hour period, secondly, in next 72 hours of the test BUN and Creatinine procedures must be allowed, thirdly, after midnight and before the test the patient must take only clear liquids and lastly, patient should not eat or drink 4 hours prior to the test.

The dose optimization study of Udayasankar et al. (2008) has used a significant reduction of radiation dose as follows. Children with a shunt for hydrocephalus, who undergo multiple scanning procedures, were chosen for the study and both standard dose of 220 mA and a low dose of 80 mA were performed simultaneously. All low-dose CT scans were of acceptable quality and the radiation dose was reduced effectively. This conclusion that low dose CT scan of the head does provide acceptable image quality can be extended to our current dose reduction protocols at KSMC.

Similarly, Smith et al. (2008) studied dose modulation in four types of CT studies, including, brain CT performed without contrast material (unenhanced CT) in adult patients, unenhanced brain CT in paediatric patients, adult cervical spine CT, and adult cervical and intracranial CT angiography. The researchers found that use of dose-reduction techniques for these CT examinations produces significant dose reduction while image quality is maintained. For each examination, the weighted volume CT dose index (CTDIvol) and dose-length product (DLP) were reduced by 60. 9% and

60. 3%, respectively, by using z-axis dose modulation and by 50. 4% and 22. 4% by using x-y-z–axis dose modulation. With the 16-section scanner, both CTDIvol and DLP were lowered by up to 60. 9% for unenhanced brain CT in adults performed by using dose reduction compared with these values for unenhanced brain CT performed without dose reduction. The dose was reduced drastically from an average of 233. 1 mA to 91. 1 mA.

Head, with and without contrast: Helical Computed Tomography

Table 2 shows the examination requirements for 16 slice machine to perform the test.

In comparing the protocols, we find that at KSMC we have successfully reduced the radiation dose. Haplin (2004) demonstrates that tube voltage (kV) of 140 and tube potential (mA) of 380 is required to reconstruct the data into high-quality slices. KMSC uses a tube voltage of 120 kV and tube potential of 240 mA for the same purpose. The images have been defined and sharp at such optimization and are of good and acceptable quality. Also, patient risk factors are reduced considerably due to exposure to lower radiation.

Routine CT Scanning Protocols for the Chest

High-resolution CT (HRCT)

For high-resolution CT, all areas of the lung field of any patient should be plastered/ covered. Table 3 shows the parameters related to KSMC’s protocol used for CT scanning of the chest. The standard procedure for high-resolution CT utilizes a kV of 120, mA of 130 and a rotation of 0. 5 seconds. The range of these parameters is similar for both HRCT and Pulmonary

Embolism (PE). No oral or IV contrast is used for this procedure.

Table 3: Parameters and dimensions for the CT scan of the chest using KSMC's protocol

Real-time thin slab VRT or MIP

Source: taken from KSMC

Studies by Diederich and Lenzen (2000), show that reducing the tube voltage is the most direct method to achieve radiation dose reduction. They demonstrated that the radiation can be reduced from the standard 200 mA that is commonly used to 110-140 mA without any significant reduction in the image quality.

Ravenal et al. (2001) compared the images obtained with a range of doses from 40 to 280 mA and based on their study, recommended that the radiation dose could be optimized at 120 mA without compromising the image quality.

Schueller-Weidekamm et al. (2006) achieved a radiation dose reduction of 67% by reducing the standard protocol dose from 140 kV/175mA to 100kV/125mA. On comparison of the images produced in both cases, there seemed no obvious deterioration in the image quality and the image of peripheral pulmonary artery was improved.

Automatic Exposure control techniques can be used effectively to control and reduce radiation dose as shown by Greess et al. (2000). In their study, they showed a radiation dose reduction of 22% with angular modulation. Similarly, Kalra et al. (2005) reported radiation dose reduction of 26% without any deterioration or significant changes in image quality.

Kalra et al. (2003) also demonstrated the use of imaging filters to improve the image quality by removing noise and artefacts. The use of these filters can effectively reduce the radiation dose. However, the role of these imaging filters is lung parenchymal interpretation.

Reduction in the radiation dosage is the key here in routine HRCT at KSMC in comparison with the findings of Gianluigi et. al. (2009). The findings suggest that the tube voltage and tube potential employed by Smart-mA in the study were set at 120 kV and 350 mA, while at KSMC the tube potential has been standardised to 130 mA. This again reiterates the idea of using low dose with an increased pitch to obtain the quicker image from the patient.

Pulmonary embolism (PE)

During the application of this protocol, IV contrast is mandatory. The contrast used normally is 100-120 cc of Omnipaque 350. The imagery effects can be obtained in a caudal/cranial path to bound motion-related artefact and artefact related to contrast in SVC and right surface of the heart of the patient.

In the studies by Wang et. al (2008) for CT pulmonary Angiography (CTPA), we find that CTPA can evaluate pulmonary artery obstruction disease and right ventricular function dynamically in patients presenting with massive pulmonary embolism. At KSMC, we analysed the pulmonary vein barriers and ventricular role parameters using CTPA. Comparing both the studies revealed differences in delay timing and use of contrast. The contrast used by Wang et. al. (2008) is through the use of intravenous administration of 80-100 ml. of Omnipaque while at KSMC, 100- 120 ml of Omnipaque 350 was used. The tube potential was slightly reduced in the KSMC protocol at 130 in comparison to 150 mA used by the other study. Thereby, it is shown that the radiation dose is consistently low for routine CTPA in KSMC. The reduction of milliamperage does not show any drastic effect on the visualization of the parenchymal structure. On the contrary, it eludes the possibility of potential lung cancer due to overexposure to high radiation.

Routine CT Scanning Protocols for the Abdomen

CT images in the abdomen from the diaphragm to the symphysis pubis were acquired at KSMC. Table 4 shows the parameters and dimensions included in the protocol for CT scanning of the abdomen.

Studies by Funama et al. (2005) have efficiently used a low voltage of 90 kV in abdominal CT without compromising low-contrast detection. The tube voltage was reduced from 120kV to 90 kV leading to radiation dose reduction of 35%.

Table 4: Parameters and dimensions for the CT scan of the abdomen using KSMC’s protocol

Exam region

1- Liver

2- pancreas

3- spleen

4-Kidney

Liver

The standard parameters for scanning the liver are given in Table 4. This scanning method is unique in that the increments are in three-dimension and are set at 0. 75 x 0. 5 (3D), along with the filming of 5 x 5. For this protocol, oral contrast and IV contrast can be used. Time dual-phase imaging is performed for assumed hepatoma, cirrhosis, alleged HCC, a brain tumour and tumour that has metastases in the vascular system. Single image scanning is sufficient where metastases are hypovascular (i. e. colon cancer) for injury recognition.

Wessling et al. (2007) assessed the reduction of radiation dose and the use of noise reduction filters in connection to the image quality in detecting liver lesions using multislice CT scan (MSCT) The image quality was assessed at the standard 120kV/180mA, followed by reduction of radiation dose to 155, 130, 105, 80, 55, 30 and 10 mAs. The detection of lesions remained sensitive and unchanged until the reduced dose of 105 mA without using a filter and up to 85 mA with the noise reduction filter, ANR-3D. Thus, this study is promising in that it proposes the use of noise-reducing filters to reduce the radiation dose in liver CT.

The concept of Multi-Detector Computing Tomography (MDCT) was proposed by Larsen et. al (2009), which uses a radiation dose of 120kV/150mA. The pitch factor in this study was 1. 25. Larsen et. al significantly concluded that MDCT detected more metastases with better sensitivity of p0. 06. The key difference with the protocol used at KSMC is that of contrast. Visipaque was used in MDCT while, KSMC resorted to Omnipaque 350 for providing contrast. We also found that the study used a tube voltage similar to the protocol at KSMC. However, KSMC uses a higher tube potential of 225 mA when compared to 150 mA used by MDCT.

Pancreas

Table 4 provides the standard protocol used for scanning R/O pancreatic collection and phase of pancreatic tumour. For this protocol, oral contrast is provided with Gastrograph. IV contrast can also be used in the range of 100 to 120 cc. Omnipaque 350 is used to provide contrast here. Scan delay timings are at 25 seconds for arterial and 50 to 60 seconds for venous scans. This test passes for an ultimate three-dimensional angiographic protocol Kalra et al. (2002) performed diagnostic contrast-enhanced abdominal CT using the standard radiation dose of 240-300 mA and at a dose reduced by 50% at 120-150 mA. The kV was kept constant at 140. The images of the pancreas were graded and it was concluded that the image quality score was significantly higher than that of the standard protocol.

A plethora of papers can be found for CT scanning procedures for the pancreas. Liu et. al. (2009) studied patients undergoing helical CT of the abdomen. The scanning parameters used here were 120 kV/260-380mA and 1. 375 beam pitch. The radiation dose used at KSMC, however, shows a contrasting decline. The tube potential employed is 200 mA against 260-380 mA used by Liu et. al. (2009). Again, we reiterate the use of a low dose of radiation for imaging purposes, thereby attempting to minimise the ill-effects of high radiation.

Spleen

The parameters given in Table 4 are for the splenic lesion scan. Increments are given using 3-dimension to be included in 5X5 filming. Contrast is provided by Omnipaque 350 and scan delay is 25 to 30 seconds.

The studies of Kalra et al. (2002) extended to the entire abdominal cavity in reducing the original radiation dosage from 240-300 mA to 120-150 mA. On rating the image quality and anatomical details of the spleen, a significantly high score of $p < 0.005$ was observed, indicating an uncompromised image quality at 50% dose reduction.

The study by Fenchel et. al. (2003) uses multi-slice helical CT (MSCT) which has led to new dimensions in spatial and temporal resolution in CT imaging. The study is identical to the protocol used at KSMC in using comparable radiation dosage. The study uses 120kV/230mA comparable to our protocol at 120kV/225mA. Thus optimization for scanning protocol for the spleen is achieved at KSMC that is identical and comparable to the study proposed and conducted by Fenchel et. al. (2009).

Kidney

The standard protocol listed in Table 4 is for the scan of alleged renal mass. Contrast using Gastrograph and also IV contrast is used in this protocol. Scan delay of 25 seconds is estimated for arterial and 50 to 60 seconds for venous scans. At KSMC, the procedure is performed in three phases instead of four. This is aimed at reducing the radiation dose to the patient.

The studies at Department of Radiology, Massachusetts General Hospital and Harvard Medical School, using a multidetector CT scanner, used a dose reduction of 50 % while keeping the tube voltage at a constant 140 kV (Kalra et al. 2002). The dose was reduced to 120-150 mA in contrast to the standard dose of 240-300 mA. The scans obtained were scored using a five-point scale from unacceptable, substandard, acceptable, above-average to superior. There was no statistically significant difference observed in the protocol using a reduced dose in comparison to the standard protocol. There were no inter-observer disputes among the radiologists involved in the study.

The study by Yoon et. al. (2006) uses the recommended procedures for Somatom plus S scanner from Siemens. The findings from the CT scan in this study can be considered in the differential diagnosis. The parameters of the test are 120kV/100-210 mA, which is very much equivalent to the protocol used at KSMC. This further ratifies the use of low dose radiation for scanning patients presenting with renal mass.

Conclusion

In reviewing literature across sections on dose optimization and reduction protocols, there seems a positive ray of hope in reducing radiation dose up to 50% from the standard protocols (Kalra et al. 2002). The use of Automatic Emission Controls, Imaging Filters and Noise Reduction Filters further aid in a significant reduction of radiation dose in varying degrees. In comparing literature for CT scan for head, chest and abdomen, the protocols followed at KSMC have shown slight variation in contrast techniques and radiation dosage. We, at KSMC, use lower dosage as compared to the standard papers and have come out successfully in doing so. The use of low radiation has also been ratified by some studies that use doses similar to ours. Further reduction in radiation dose as suggested possible by some studies can also be incorporated in the dose reduction protocols at KSMC to reduce the possible risk of exposure in patients without compromising the image resolution.

CT scanning is a very promising and futuristic technology and its contribution to medical diagnosis cannot be discounted. However, the benefits must definitely be balanced especially in case of repeated examinations or in vulnerable groups. The wise use of radiation dose is the key to this goal. Optimisation and subsequent reduction in radiation dose must be the consistent objective of the radiologist. In considering this balancing act, we at KSMC have performed individual modification and adaptation of tube voltage and potential to suit our specific needs in the best possible image resolution and lowest possible radiation dose. In conclusion, based on my experience and the suggestions from the literature reviewed in this paper, I would strongly recommend the lowering of tube potential from 200 mA to 150 mA.