research article

Does low dose computed tomography compromise the detection of hepatic metastases?

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Abstract
The increase in the application of computed tomography (CT) has resulted in an increase in radiation dose to the population. Recent research studies have shown that lowering the radiation dose in CT examinations has resulted in images of similar quality compared to that of the standard dose. The aim of this study was to determine whether lowering the radiation dose during CT examination of the abdomen compromises the detection of hepatic metastases.

Materials and methods: A sample of 16 patients was subjected to a CT examination of the abdomen during which a routine portal venous examination and an additional low dose sequence through the liver were performed. Two reviewers, who were blinded as to which images were acquired with low or standard dose, rated the quality of the images in terms of conspicuity, sharpness of the margins of the hepatic metastases, anatomical detail of the liver as well as image noise.

Results: Conspicuity of the hepatic metastases was not compromised by the low dose sequence but margins of the hepatic metastases and anatomical detail were rated less favorable compared to the standard dose sequences. Noise levels on the low dose images were also rated higher than those obtained with standard dose.

Conclusion: Lowering the radiation dose to patients does not compromise conspicuity of hepatic metastases. It is recommended that low dose CT should be used in especially patients being followed up with confirmed hepatic metastases in order to reduce the dose delivered to patients.

Keywords: Radiation dose, conspicuity, metastatic margins, noise levels.

Introduction

Computed tomography (CT) imaging is known to be a major contributor of medical exposure to the collective radiation dose received by patients and is considered to be on the rise [1]. This is largely due to a sharp increase in the application of this imaging modality, especially since the introduction of multi-detector computed tomography (MDCT) [2].

The increased use and advanced applications, such as CT angiography and perfusion CT with MDCT, have concomitantly seen an increase in the awareness of the radiation dose delivered by this modality [3]. This has led to various research projects aimed at reducing the dose delivered to patients on whom CT examinations are being undertaken. Recent studies have shown that the radiation dose delivered to patients can be lowered by lowering the exposure parameters such as tube potential measured in kilo-voltage (kV) or tube current (mA) during image acquisition [4]. These studies have found no significant difference in the image quality obtained with either a lowered tube potential or tube current [5 - 6]. Even though the use of lowered exposure parameters have not seen a substantial lowering of the image quality obtained with low dose CT, the effect thereof on diagnosis of pathologies is yet to be determined [6].

The purpose of this study was to ascertain whether low dose CT of the abdomen has a profound influence on the detection of hepatic metastases in adults. The research methods employed such as data collection, the analysis thereof as well as the discussion of the results are reflected in this article.

Materials and methods

A prospective quantitative study comprising 16 participants was done to ascertain to what extent low dose CT compromises the detection of hepatic metastases. This study further aimed to ascertain whether there was a significant difference in image quality, with reference to conspicuity, sharpness of margins of hepatic metastases, and image noise of standard and low dose CT.

Ethics approval for this study was obtained from the ethics review committees of both Charles Sturt University, Wagga Wagga, New South Wales, Australia and University of Cape Town, Cape Town, South Africa as well as the medical superintendent responsible for medical research at Groote Schuur Hospital, Cape Town South Africa, where the study was conducted. Ethics approval was also obtained as required, from the radiation safety committee of Charles Sturt University. All ethics requirements within this project were in compliance with the Helsinki Declaration of 2000 [7].

Informed consent was obtained prior to commencement of the CT examination from all participants. Confidentiality and anonymity was ensured by the fact that the participants' names and hospital numbers were not used for publication of results or reflected on the images when reviewed by the radiologists.

All participants were subjected to two sequences. One study involved the standard portal-venous phase using a 70 second delayed after contrast administration. A low dose sequence was performed immediately after the portal venous phase, on average 5 seconds after the portal venous phase.

The tube current measured in milli-ampere (mA) for all participants examined during the portal-venous phase was kept at 120 kV and 400 mA with a 0,5 tube rotation with, 3mm tube collimation. All other parameters such as the kernels were kept the same. A pitch of 5,5 was employed for all sequences. For the low dose sequence the mA was reduced to 50%, in other words to 200 mA. For the portal-venous sequence participants were scanned from the diaphragm to the symphysis pubis, which represented the standard dose examination. The low dose sequence was acquired starting at the diaphragm and ending at the inferior part of the liver. The effective mAs applied therefore for the standard dose sequence was 200 mAs and 100 mAs for the low dose sequence. A sample of 16 adults, 10 females with age range 46 - 79, (mean age 61 years), and six males, age range 59 - 75, (mean age 66) years was included. The inclusion criteria for the study were all participants referred to the CT department with a confirmed cancer history, irrespective of the primary and a strong clinical suspicion of liver metastases.

All participants were injected intravenously with 100 ml of non-ionic contrast media, at 3 ml per second using a Mallinkrodt power injector. Contrast enhancement of hepatic metastases in this study was thought not to be affected by the low dose sequence because this sequence was performed approximately 5 seconds after the portal-venous phase. All CT examinations were performed on a Toshiba Acquilion TSX 101 A, a four slice multi-slice system. The study was conducted over eight weeks and all participants were scanned on the same multi-slice unit.

Hard copy images of both the standard and low dose sequences of the liver only were taken. Images were reconstructed at 7 mm, which is the standard increment for reviewing and reporting CT images in this department. Two radiologists who are experienced in abdominal CT, reviewed both image sets. These reviewers were blinded as to which images were taken with standard dose and which were taken with low dose. This was done by removing the names of participants and other technical criteria from the images so as to prevent reader bias. Films of both sets, namely the standard and low dose of the same participant, were assigned a randomly selected numerical number in order to strengthen randomness of image analysis.

This number was used to identify participants and to cross correlate with the data when performing the data analysis. Demographic details such as participant's age, sex and type of primary cancer were recorded from the hospital folder.

Individual analysis of each image set was performed by the two reviewers in order to assess each image set independently. Aspects considered were:

- Conspicuity of hepatic metastases, which were rated as either vague, intermediate or sharp. For statistical calculation of this data, the variable vague was rated as 1, intermediate as 2 and sharp as 3.
- Margins of metastatic lesions were rated as either vague, intermediate or sharp using the same criteria as above.
- Reviewers were also asked to rate the anatomical detail of the liver as either poor, moderate or good where poor was rated as 1, moderate as 2 and good as 3.
- Image noise was rated as either low, moderate or high where low was rated as 1, moderate as 2 and high as 3.
- Where applicable, other hepatic lesions and extra-hepatic lesions were rated as either vague, intermediate or sharp, where vague was rated as 1, intermediate as 2 and sharp as 3.
- Reviewers were then asked to compare the two sets of images overall and indicate on which of the two images sets, metastases were best seen.

Data analysis

Statistical analysis was performed to evaluate image quality scores between the two sets of data using the Wilcoxon matched pairs test. This non-parametric test is ideal to measure data that is not normally distributed and being ordinal of nature. Results were considered as statistically significant when a p-value < 0,05 was found. All measurements with p > than 0,05 were considered as not significant.

Results

Table 1(a-d) is a summary of the responses of the reviewers in terms of their impression of the conspicuity, sharpness of margins of metastatic lesions, anatomical detail of the liver and the image noise observed on the films.

It is evident from the data that there was not a marked difference between the reviewer's impression of the conspicuity of the metastatic lesions between the low dose and standard dose image sets (Table 1a). The Wilcoxon matched pairs test reflected in Table 2 confirmed this finding.

Conspicuity of metastatic lesions	
Reviewer 1	**Reviewer 2**
LD	**LD**
12 Sharp 3 Intermediate 1 Vague	12 Sharp 2 Intermediate 1 Vague 1 Lesion not observed
SD	**SD**
14 Sharp 1 Intermediate 1 Vague	14 Sharp 1 Intermediate 1 Lesion not observed

Table 1(a) LD: Low dose; SD: Standard dose; n = 16

Sharpness of metastatic margins	
Reviewer 1	**Reviewer 2**
LD	**LD**
3 Sharp 10 Intermediate 3 Vague	7 Sharp 7 Intermediate 1 Vague 1 Lesion not observed
SD	**SD**
13 Sharp 3 Intermediate	13 Sharp 2 Intermediate 1 Lesion not observed

Table 1(b)

Anatomical detail of liver	
Reviewer 1	**Reviewer 2**
LD	**LD**
12 Moderate 4 Poor	4 Good 11 Moderate 1 poor
SD	**SD**
16 Good	16 Good

Table 1(c)

Image noise	
Reviewer 1	**Reviewer 2**
LD	**LD**
4 High 12 Moderate	15 Moderate 1 Low
SD	**SD**
1 Moderate 15 Low	1 Moderate 15 Low

Table 1(d)

Pair of Variables	Wilcoxon Matched Pairs Test (EXCEL REVIEWERS DATA 20051209. Marked tests are significant at p <.05000 Valid N	T	Z	p-level
Conspicuity LD & Conspicuity SD	16	5.500000	1.048285	0.294508

Table 2. Wilcoxon matched pairs test of the conspicuity of metastases of the standard and low dose images.

Pair of Variables	Wilcoxon Matched Pairs Test (EXCEL REVIEWERS DATA 20051209.sta) Marked tests are significant at p <.05000 Valid N	T	Z	p-level
Margins LD & Margins SD	16	0.00	3.179797	0.001474

Table 3. Wilcoxon matched pairs test of the margins of metastases of the standard dose and low dose images.

Table 2 reflects the Wilcoxon matched pairs test for scores of the variables between the conspicuity of metastases of the low dose and standard dose set of images. The p-value was calculated as 0,294508. The difference in observation between the low and standard dose image sets was therefore found to be non significant.

In terms of the sharpness of the margins of the metastatic lesions (see Table 1b) it was clear that the standard dose was rated to be better on 13 images as scored by both reviewers and 3 and 7 by the reviewer 1 and 2 respectively.

Table 3 reflects the Wilcoxon matched pairs test done for the reviewer's observation in terms of depiction of the margins of metastatic lesions of the 16 subjects. The p-value (0,0015) indicates that there was a significant difference in their observations between the low and standard dose image sets.

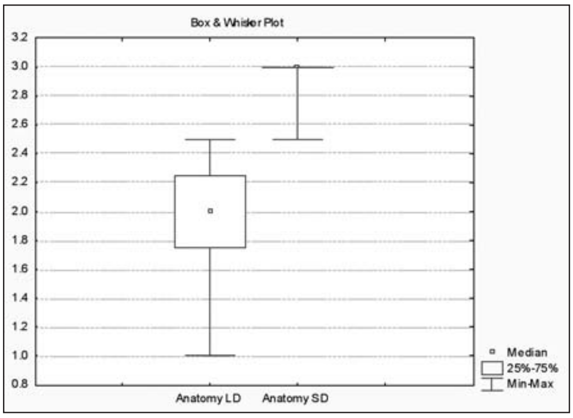

Table 4. Box & whisker plot of the anatomic detail of the liver of the standard and low dose images.

The box and whisker plot reflected in Table 4 indicates the reviewers' rating of the anatomic detail of the liver between the low and standard dose images. The standard dose images were generally rated better than that of the low dose images as shown in Table 1. Anatomical detail for 16 of the images were rated as good by both reviewers compare to 4 as good (reviewer 2) and 12 as moderate (reviewer 1). It is evident

Pair of Variables	Wilcoxon Matched Pairs Test (EXCEL REVIEWERS DATA 20051209.sta) Marked tests are significant at p <.05000 Valid N	T	Z	p-level
Noise LD & Noise SD	16	0.00	3.516196	0.000438

Table 5. Wilcoxon matched pairs test of the noise levels of the standard and low dose images.

that with a median of 3 (25th percentile of the distribution was 1,8, and 75th percentile at 2,2.) The median of the low dose images was found to be 2 (25th percentile at 1 and a 75th percentile at 2,5), which is lower than that of the standard dose with a median of 3.

Noise levels were rated lower on the standard dose compared to the low dose images. Both reviewers rated the noise levels on 15 of the standard dose image sets as low, 1 as moderate compare to 4 as high on the low dose image sets and 15 as moderate by reviewer 1 and 2 respectively.

The Wilcoxon matched pairs test in Table 5 confirmed this finding as the p-value was found to be 0,0004, indicating that there was a significant difference in their observation of the noise levels between the standard and low dose images.

Table 6 is the corresponding box and whisker plots of the measurements of the noise levels between the standard and low dose images. The median for the standard dose images was calculated as 1, which is fairly low (25 percentile and 75 percentile as 1). The measurements for the noise levels of the low dose images were found therefore found to be higher than the standard dose images (median of 2, 25 percentile 2 and the 75 percentile 2,2).

Table 7 represents a two-way summary table of the observed frequency of the reviewer's opinion as to which image sets demonstrated metastases better. Both reviewers indicated that the standard dose images, overall, demonstrated the metastases better (16 reviewer 1 and 15 reviewer 2). Reviewer 2 was with one image set, indecisive as to which image set portrayed metastases better.

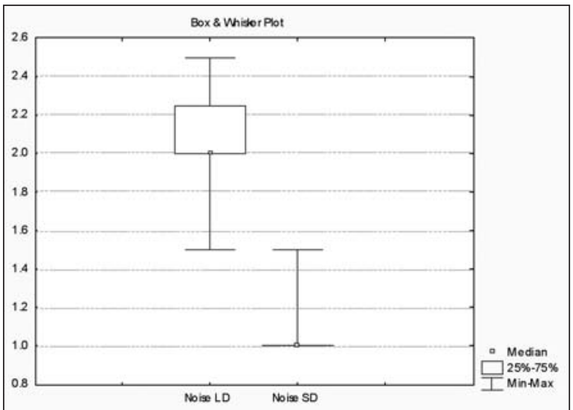

Table 6. Box & whisker plot of the noise levels of the standard and low dose images.

Discussion

The average dose estimate for a single CT examination is postulated between 10 - 30 mSv. CT further amounts to about 67% of all medical exposures and can therefore be considered as the single largest source of radiation after background radiation [8]. This study was therefore useful as it aimed to ascertain whether low dose CT compromises the detection of hepatic metastases in view of the high radiation dose delivered by CT.

Of the four variables tested, except for conspicuity of metastatic lesions, margins of metastases, anatomical detail of the liver and image noise were generally better demonstrated by the standard dose image sets. However cognizance must be taken of the conspicuity of metastatic lesions that was found not to be different between the low dose and standard dose images. It is known that hepatic metastases are the most common malignant lesion of the liver, far more common than primary liver tumours, and is the most challenging entity to rule out in a patient with a known history of cancer [9].

Successful detection therefore relies on conspicuity of such metastases [10]. If hepatic metastases are diagnosed successfully, the sensitivity and specificity of cancer staging would be improved and subsequently instigate appropriate treatment such as chemotherapy or local liver resection, which aid in patient management [11]. As CT is the primary imaging modality for hepatic metastases, low dose CT must be equally sensitive to that of standard dose CT for the detection of hepatic metastases. This study indicated that low dose CT is equally sensitive for the detection of hepatic metastases. As this was a relatively small study, larger studies should be done to validate this finding.

Exposure to radiation dose may induce cancer in the exposed individual after a latent period of up to a few decades [12]. It is for this reason that the radiation dose applied to patients should be as low as reasonable achievable (ALARA principle). CT accounts for 4 - 10% of all radiological examinations [13]. It is in view of the latter that many practitioners are becoming more and more sensitized about the dose received by patients when undergoing CT examinations. Low dose CT examinations are helpful in lowering the dose received by patients. As stated earlier, however, its sensitivity and specificity to detect hepatic metastases are of vital importance especially in the clinical work up of those suitable for surgical removal.

The reduction in the tube current is the most practical means of reducing CT radiation dose [14]. A 50% reduction in tube current was found to reduce radiation dose by half. Any decrease in tube current should be considered carefully because such reduction causes an increase in image noise, which may affect the diagnostic outcome of the examination. Reducing the dose delivered in CT leads to a reduction in the number of photons to which the patient is exposed, which results in an increase in noise, impeding the diagnostic quality of such images [12]. This was confirmed in this study as reviewers rated the noise levels to be higher on the low dose images. One aspect however not determined in this study, was whether the noise levels on these low dose images, affected their ability to detect such metastatic lesions. This aspect can be tested in further studies.

Studies done recently found that images obtained with low-dose CT were comparable to those of standard dose CT, even though the clinical outcome of low dose CT has not yet established [6].

Figure 1 (a) represents the standard dose obtained at 120 kV, 200 mAs (400 mA x 0,5 tube rotation) whilst Figure 1 (b) represents the low dose examination performed at 120 kV, 100 mAs (200 mA x 0,5 sec tube rotation). Note that there is no major difference in image quality between the two images even though the low dose was acquired at 50% of the standard dose. The conspicuity of the two cystic metastatic lesions appears almost similar (arrows). The only

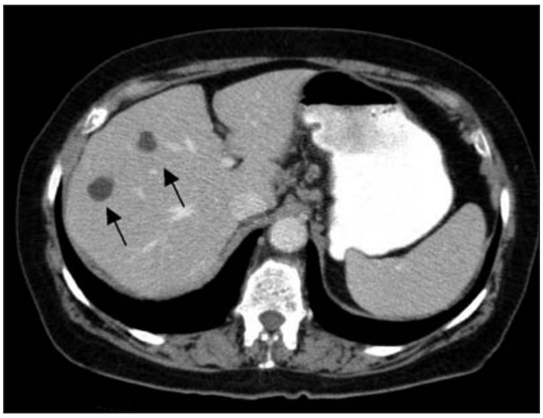

Figure 1(a). Abdominal CT of a 79-year-old female with colon cancer. Note the two cystic metastatic lesions visible in the right lobe of the liver (arrows).

Mets Better LD	2-Way Summary Table: Observed Frequencies (EXCEL REVIEWERS DATA 20051209 Marked cells have counts > 10 Mets Better SD Y	Mets Better SD Uncertain	Row Totals
N	15	1	16
Y	0	0	0
Totals	15	1	16

Table 7. Two way summary table of the observed frequencies of which images depicted the metastases better.

Figure 1(b). Slice taken with 50 % reduction in dose of the same female as Figure 1(a).

appreciable difference between the two images is the slightly higher noise levels visible on the low dose image (Figure 1b). Figures 2 (a) and (b) confirm the findings of this study that even though the conspicuity of metastatic lesions were found to be similar in nature between the low dose and standard dose images, the margins of the metastatic lesions on the low dose image sets (Figure 2b) were slightly inferior to that obtained with the standard dose seen in Figure 2 (a). (See metastatic margins). The use of radiation in diagnostic imaging, requires that images be obtained with as low as reasonably achievable radiation dose without compromising image quality [15]. In this study anatomical detail of the liver was found to be better on the standard dose images, however anatomical detail of the liver on the low dose was generally rated as moderate. It can be argued that since the anatomical detail of the liver was not considered as poor, the moderate rating indicates that it does not really have a profound negative effect on the anatomical detail of the liver.

Figure 2(a). 49 year old female with a tumour of the gastro-intestinal tract with metastases (arrow) of the liver.

Figure 2(b). Low dose image taken at the same level as the standard dose as that of Figure 2(a).

Due to the high radiation dose delivered by MDCT, it is postulated that low dose CT will become the norm in future in order to reduce the dose delivered to patients. However, as indicated earlier, the impact of low dose CT on the diagnosis of other pathologies ,including the liver, is yet to be studied empirically.

Research on dose reduction must therefore focus on image quality and standard practice identifying acceptable thresholds of image quality so that the minimum radiation dose needed to achieve acceptable CT image quality can be determined [14]. It is important to define lesions detection, namely at what level detection is acceptable or not, so that optimal dose optimization can be achieved.

This study is congruent with other studies as it has been shown that low dose CT can be used in detection of hepatic metastases. It is therefore recommended that low dose CT should be applied especially in patients being followed up with confirmed hepatic metastases, in order to reduce the dose delivered to such patients. Even though anatomical detail of the liver, sharpness of the margins of the metastatic lesions and noise levels were found to be slightly inferior to that of the standard dose, it is argued that these factors will not have a profound effect on the detection of any metastatic lesions.

Delimitations of this study

Early or late arterial phase, considered to provide precise documentation of the arterial vasculature, was not studied [16]. Inclusion of this phase would have resulted in a higher radiation dose to subjects.

Determining the contrast-to-noise ratio (image noise in Hounsfield units) was not performed which may have been able to give a more objective statistical indication of the difference in image quality. The effect that low dose CT has on obesity with respect to image noise was not studied. It is recommended that these aspects be investigated in a larger sample population in order to validate the findings of this study.

Conclusion

Due to the burgeoning application of CT, there is an emergent need for radiation dose reduction to avoid a reversal of the risk-benefit ratio associated with CT [14]. In other words, if CT dose delivered to patients is to be justified in future, careful attention should be paid to use of the imaging modality to avoid the risk of higher radiation doses outweighing the benefits associated with current state of the art MDCT applications. The authors of this study aver that research on dose reduction must focus on image quality and standard practice.

CT scanner technology has to improve further to increase scanner efficiency and enhance image quality at reduced radiation exposures [3].

This study was beneficial as it informs health professionals that patients can be satisfactorily scanned with a low dose protocol thereby reducing the radiation dose delivered to the latter especially those who are followed up for metastatic disease of the liver.

This study adds to the body of knowledge regarding the effects of low dose CT on clinical diagnoses of hepatic metastases. A practice which hopefully will come to fruition in future.

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media statement

HPCSA finally erasing defaulting practitioners

Gauteng Province could be the hardest hit when the Health Professions Council of South Africa (HPCSA) starts erasing health care practitioners for non payment of annual fees tomorrow (Friday, 6 October 2006).

The HPCSA could be forced to erase 11 057 practitioners who have failed to pay their annual dues. Annual fee deadline is 1 April of every year. At 3 286, Gauteng province has the highest number of practitioners who have not yet paid and could be removed from the roll of practitioners tomorrow.

KwaZulu Natal Province could also suffer the same fate as 2 102 of its practitioners have not yet paid. This is followed by the Western Cape with 1 428 who might also be struck off the roll unless they pay their fees before end of business tomorrow.

Once a practitioner is erased, he or she will have to pay a penalty fee to be restored to the register of practitioners. Those who apply for restoration of their names to the register within six months after erasure will pay twice the applicable annual fee for the current year, as well as the outstanding fees.

After a period of six months, but within 12 months of the erasure date, the amount shall be equivalent to four times the applicable annual fees as well as the outstanding fees. Those who pay after 12 months will pay five times the applicable annual fees as well as the outstanding amount.

The HPCSA is a statutory body that has been established in terms of the Health Professions Act to regulate the professional conduct of health practitioners in South Africa. In order to safeguard the public and guide the professions, registration with HPCSA in terms of the Act is a prerequisite for practising any of the professions with which Council is concerned. Practising any of the professions falling under the jurisdiction of Council and for which a scope of practice has been promulgated, without being registered, constitutes a criminal offence in terms of the Act.

Practitioners who would like to find out about their registration status are urged to contact the HPCSA on (012) 338 9300. Members of the public can also find out the registration status of their practitioners by phoning the same number.

Issued by: Tendai Dhliwayo, Communications Officer, Health Professions Council of South Africa, www.hpcsa.co.za
tel: 012 338 9368, cell: 082 801 6685
Released: 05 October 2006

letter to the president

PO Box 1435
Wandsbeck 3631
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6 October 2006

The President
Society of Radiographers of SA
PO Box 6014
Roggebaai 8012
Cape Province

Dear Mr Speelman

Acknowledgement in Respect of Merit Award

It was indeed an honor to be conferred with the prestigious 'Merit Award' for outstanding service to the profession of Radiography and to the Society in particular.

In my opinion I would be failing in my duty if I did not acknowledge the Society. I sincerely believe that what I have achieved would not have been possible if it were not for my involvement with Society matters. I have gained tremendous experience and exposure while dealing with Society issues. Also, at this juncture it is fitting for me to thank all those in the profession for their help and support - with a special thanks to Leonie Munro who has been a stalwart in my career.

As I approach my 'sell-by date', I would like to urge younger professionals to get involved in the Society. It is definitely one way of fostering professional unity.

Sincerely
Fozy Peer