

The impact of pitch values on image quality and radiation dose in an abdominal adult phantom using CT

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Aims and objectives

Different parameters on CT can be used to reduce the patient radiation dose. One of these parameters is pitch, which is defined as the table movement per 360 degrees rotation time divided by the beam width (1). The use of a high pitch can reduce the radiation dose and the scan time (1). When the CT scan is acquired within a shorter time, possible motion artefacts can be reduced. This is useful when scanning areas in which there is a lot of involuntary movement, such as the cardiac and lung regions. However, it is important to consider the effect of a higher pitch on image quality, particularly on the spatial resolution (2).

On the other hand, a low pitch might be chosen when high image quality is needed. Consideration has to be made when deciding whether the effective radiation dose counterbalances the image quality.

This study aims to identify the impact of pitch on image quality and effective dose for axial and coronal planes in abdominal adult CT.

Methods and materials

Image acquisition

This study was performed at the University of Salford. An adult-sized, abdomen anthropomorphic phantom [Fig. 1](#) on page 3 (PH-5 CT Abdomen Phantom, Kyoto Kagaku Company, Japan) was scanned on a Toshiba Aquilion 16 MDCT scanner [Fig. 2](#) on page 4 (Toshiba Medical Systems, Minato-ku, Japan), configured according to commonly used parameters in clinical practice. To keep the results relevant to a clinical setting, automatic tube current was used. The tube voltage was fixed to 120 kV and a rotation time of 0.5 s was set. Three different pitch values were used; fast (1.438), standard (0.938) and detail (0.688).

The scan range was 261 mm and covered the entire upper abdomen. Images were acquired with a thickness of 1 mm and reconstructed to 3 mm thick slices, resulting in 88 images.

Perceptual image quality evaluation

Anatomical structures were assessed visually using two-alternative forced-choice (2AFC) with 8 observers. The selected images were then scored against images acquired with

a different pitch but within the same slice region at the same plane (axial [Fig. 3](#) on page 5 and coronal [Fig. 4](#) on page 6). This method allowed the observers to rate the evaluated image as worse, equal or better compared to the control image.

Physical image quality evaluation

The signal-to-noise ratio (SNR) was calculated using the mean attenuation value (S) and dividing it by the standard deviation (#), as the equation below (3), using the ImageJ software.

$$\text{SNR}=\text{S}/\# \text{ (1)}$$

Calculation of CTDI_{vol}, DLP and effective dose

To estimate effective dose CT Expo softwareTM was used.

Statistical analysis

A *p*-value with a significance level of 0.05 was used for all the undertaken statistical analysis.

Images for this section:



Fig. 1: Adult-sized, abdomen anthropomorphic phantom (PH-5 CT Abdomen Phantom, Kyoto Kagaku Company, Japan).

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Fig. 2: Toshiba Aquilion 16 MDCT scanner.

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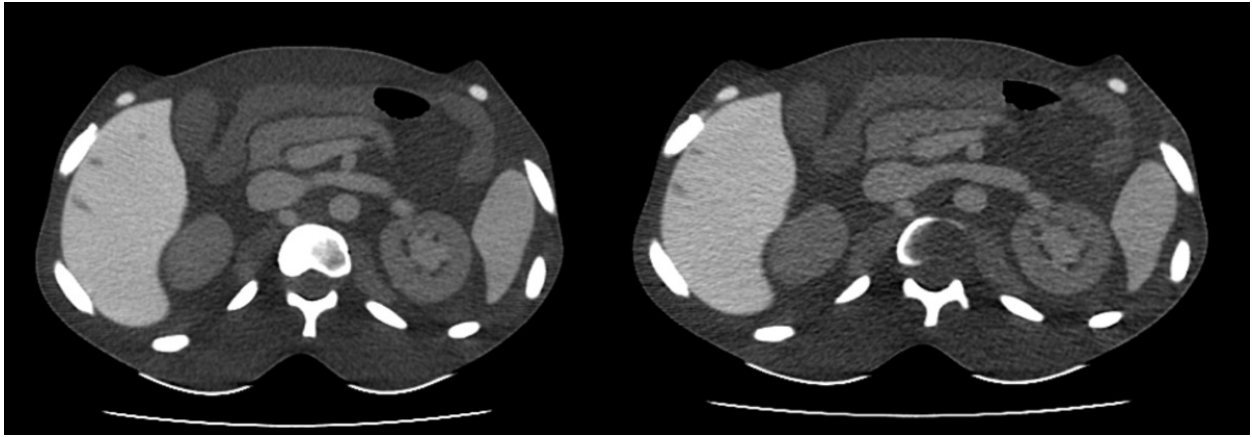


Fig. 3: Two-alternative forced-choice (2AFC) method. The selected images were scored against images acquired with a different pitch but within the same slice region. In this case axial plane.

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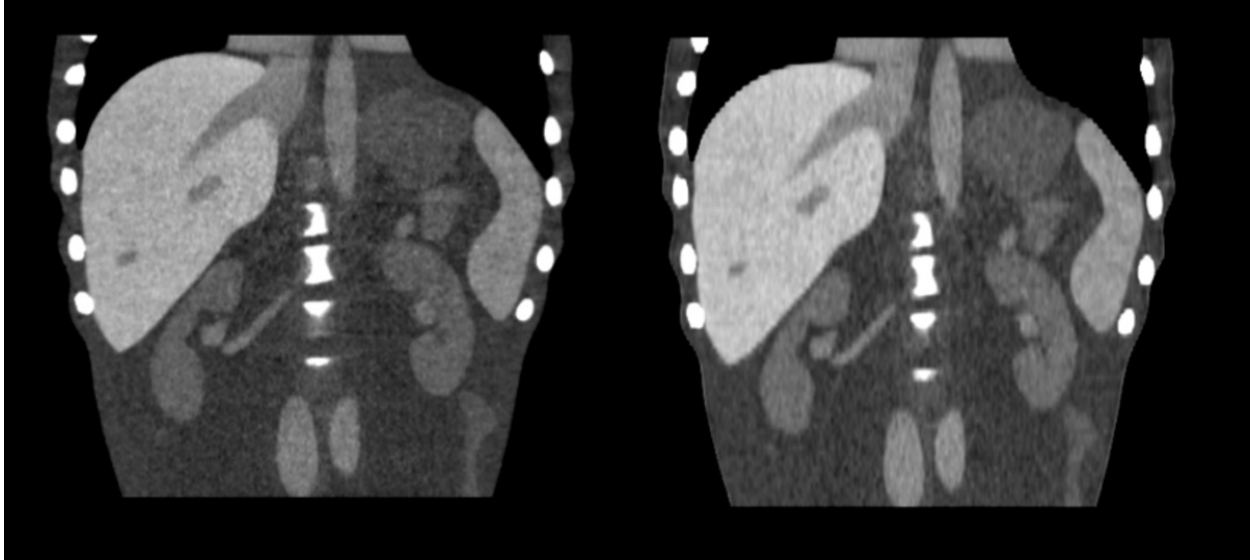


Fig. 4: Two-alternative forced-choice (2AFC) method. The selected images were scored against images acquired with a different pitch but within the same slice region. In this case coronal plane reconstruction.

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Results

Perceptual image quality evaluation

The overall ratings obtained for 2AFC image quality evaluation showed that there was no statistically significant differences ($p=0.42$) between the overall abdomen images obtained with standard and detail pitch acquisition modes in the axial plane Fig. 5 on page 9 . In spite of that, after analysing each criteria separately, detail pitch performed better for liver parenchyma, vessels image and pancreatic contours as well. These results are shown in Table 1.

Table 1. Subjective image scoring.

Visually sharp reproduction of the following structures	Standard vs. Detail		Detail vs. Fast		Fast vs. Standard	
	Axial	Coronal	Axial	Coronal	Axial	Coronal
Liver parenchyma and vessels	-0.750	1.000	1.000	0.125	-0.625	-1.000
Spleen parenchyma	-0.375	0.875	1.000	0.000	-0.250	-1.000
Pancreatic contours	-0.875	1.000	1.000	0.875	-1.000	-1.000
Kidneys and renal vessels	0.500	1.000	0.750	0.875	-0.875	-1.000
Retroperitoneum	0.000	0.750	0.625	0.625	-0.875	-0.625
Aorta and vena cava	0.325	0.750	0.750	0.375	-0.750	-0.625
Mean	-0.208	0.896	0.854	0.479	-0.729	-0.875
± Standard Deviation	± 0.552	± 0.123	± 0.166	± 0.374	± 0.267	± 0.194

p-value $p=0.42$ $p= 0.03$ $p= 0.03$ $p = 0.04$ $p= 0.00$ $p = 0.02$

However, detail pitch provides superior 2AFC image quality compared to standard in axial plane when evaluating the liver ($p<0.034$) and pancreas ($p=0.008$) Table 2.

Table 2. Standard vs. Detail (axial) p -values.

Visually sharp reproduction of the p-Value following structures

Liver parenchyma and vessels	0.03
Spleen parenchyma	0.18
Pancreatic contours	0.00
Kidneys and renal vessels	0.10
Retroperitoneum	0.96
Aorta and vena cava	0.35

The results for spleen, kidney, renal vessels, retroperitoneum, aorta and vena cava are not significant for detail vs standard.

For the coronal reconstruction [Fig. 6](#) on page 9 , standard pitch mode generated images with better quality than both detail and fast modes ($p=0.03$ and $p=0.02$), respectively). Detail was slightly better than fast and although there was a high standard deviation for the scores, the p -value showed a statistically significant difference.

Physical image quality evaluation

Mean SNR values for the three pitch factors are shown in table 3. No difference amongs the SNR values for axial images was found, considering that all calculated p -values were higher than 0.05. However, for coronal images there was a significant difference in SNR between standard and detail pitch acquisition modes ($p=0.03$).

Table 3. Mean SNR values for the three pitch modes.

Slice Group	Axial			Coronal		
	Standard	Detail	Fast	Standard	Detail	Fast
Upper	7.36	11.00	7.64	9.38	13.22	8.38
Middle	6.32	5.57	4.59	7.66	14.33	6.00

Lower 5.37 3.95 3.65 3.37 4.72 3.20

CTDIvol, DLP and effective dose

Standard provides a 26.3% reduction in effective dose (mSv) compared to detail. Fast had the worst image quality in axial and coronal planes but the lowest dose. In the coronal plane, standard was superior to both detail ($p=0.026$) and fast ($p=0.023$) in terms of image quality. The differences in SNR results were not significant except in standard vs detail in the coronal plane ($p=0.03$).

Images for this section:

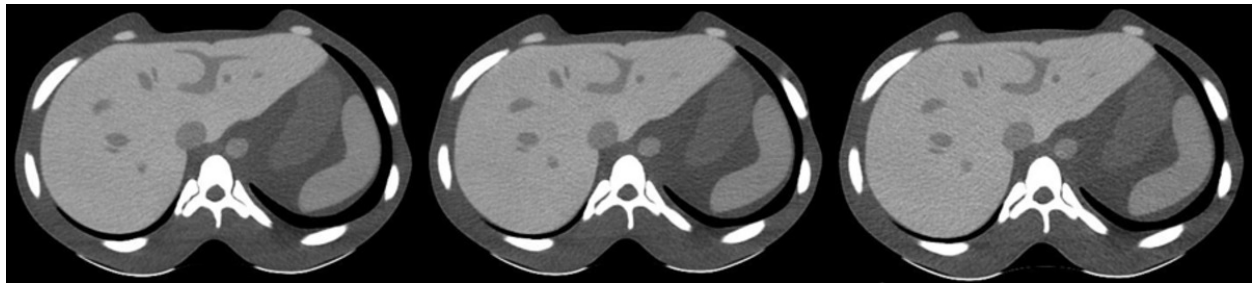


Fig. 5: Axial images for Detail, Standard and Fast pitches, respectively.

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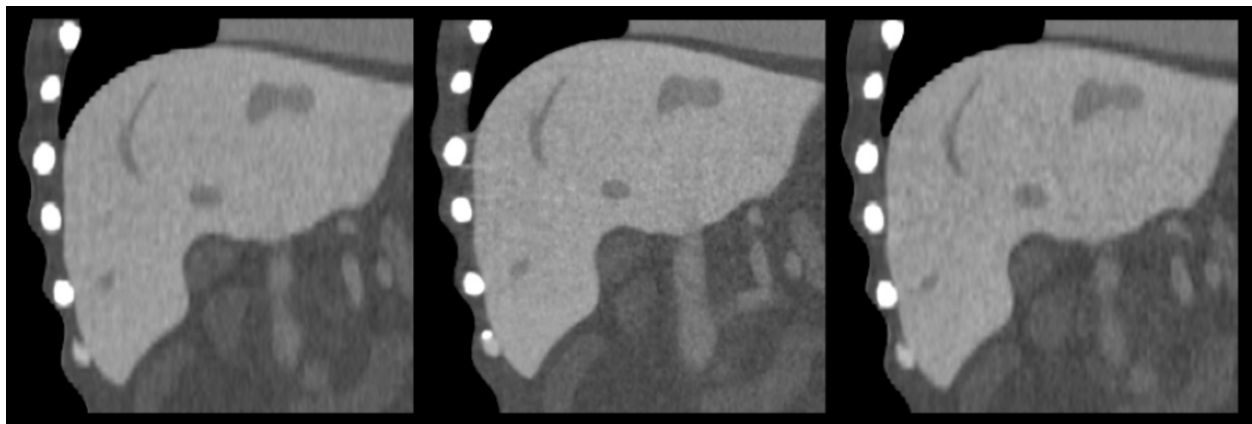


Fig. 6: Coronal images for Detail, Standard and Fast pitches, respectively.

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Conclusion

Detail pitch provides superior image quality to standard and fast in the axial plane. Standard had superior image quality to both detail and fast in the coronal plane. Effective dose is inversely proportional to the pitch factors. The most irradiant pitch mode was detail and the less was fast.

In the coronal plane standard was superior to both detail and fast in terms of image quality and fast was worse than detail. No significant difference was noted between SNR values in the axial plane, except between standard and detail in the coronal plane.

Personal information

Luís Lança has been teaching radiography subjects since 2000 at Lisbon School of Health Technology (ESTeSL/Portugal). His teaching and research activities involve expertise, knowledge and practical skills in contemporary diagnostic radiography practice (such as plain digital radiography, Computed Tomography and radiation protection). Luís is also an Affiliated Senior Research Specialist in Radiography at Karolinska Institutet/ Sweden.

This work was undertaken during the radiography research summer school OPTIMAX 2016, held in the University of Salford/UK. All the co-authors are participants in the 4th OPTIMAX edition representing several higher education institutions across Europe and Brazil.

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