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Evaluation of low contrast resolution and radiation dose in abdominal CT protocols by a difference detail curve (DDC) method

Abstract: The use of optimised CT protocols regarding radiation exposure is a legal requirement. Since low contrast visibility is intrinsically varying within the CT slice, there is no adequate method for optimisation of dose and image quality. We developed a method to access image quality in a way that represents the situation closer to a real patient. This method is based on a novel difference detail curve (DDC) phantom with low contrast objects representing native tissue contrast and contrast media with different densities and diameters. The position of the contrast objects have been evaluated by a noise level analysis of CT slices of different manufactures. The dose – length – product can be measured within the phantom simultaneously. For all tested manufactures and CT protocols, the noise analysis revealed a similar spatial variation of the signal -to-noise ratio (SNR). For the DDC method, contrast steps of 6 (4-8) Hounsfield Units (HU) are adequate. For the different CT units, comparable low contrast detectability is associated with remarkably varying dose levels (CTDI range from 8 to 18 mGy for native contrast and 9-16 mGy for contrast media). The novel DDC phantom is sensitive to protocol optimisations and therefore suitable for rating subtle effects caused by protocol optimisation.

Keywords: Difference Detail Curve, Low Contrast Detectability, CT Protocol Optimisation, Nosie Analysis.

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1 Introduction

One of the pillars in radiological protection is the use of optimized procedures and techniques. Regarding Computer Tomography (CT) scans, this implies the use of optimized scan protocols: The exposure parameters should enable a sufficient image quality by using a dose as low as reasonably achievable (ALARA principle). For simultaneous quantification of image quality and radiation exposure during an optimisation process [1], an adequate phantom is needed.

One difficulty is the variation of the low contrast visibility across the CT slice due to the changing noise levels. An adequate method for optimisation of dose and image quality should consider this variation, especially for the case of patient – like shape. Based on a noise analysis, we developed therefore a phantom having an elliptical cross section representing a real patient, which is based on a noise analysis.

2 Materials and methods

The method is using a difference detail curve (DDC) phantom [2-4] with cylindrical low contrast objects representing native contrast and contrast media with different densities and diameters. The contrast steps of the objects are derived by a human observer study.

The objects are embedded in an elliptical PMMA phantom (30 cm x 34 cm) having the effective diameter of a body CTDI phantom (32 cm). The position of the contrast objects have been evaluated by a noise level analysis of CT slices of different manufactures reconstructed by different (including iterative) reconstruction algorithms (see **Figure 1**). Based on a human observer study with 17 observes, an adequate contrast-range of 6 to 60 HU (in steps of 6 HU) above PMMA was selected. The contrast objects are shaped by drilled holes with diameters varying between 2 and 15 mm placed in a PMMA slab with a thickness of 40 mm (see **Figure 2**). This slab can be combined with other PMMA slabs for MTF-measurements. The holes are filled with a

glucose solution. For the native contrast, the HU are adapted according the concentrations shown in **Figure 3**. For the contrast media objects, the HU are achieved by a glucose solution (adapted to the HU of PMMA; 30% by weight) and varying concentrations of Iopamidol (Iopamiro ®, Bracco).

For the measurements, two slabs (one for native and one for contrast media contrast) have been combined with 4 additional PMMA slabs, each with 4 cm thickness, resulting in a total length of 24 cm. This phantom body was scanned similar to a real patient by choosing a standard abdomen protocol.

The dose – length – product can be measured within the phantom simultaneously. For the measurement of the Dose – Length – product, we used a 30 cm chamber (PTW Unidos with CT chamber type 30017).

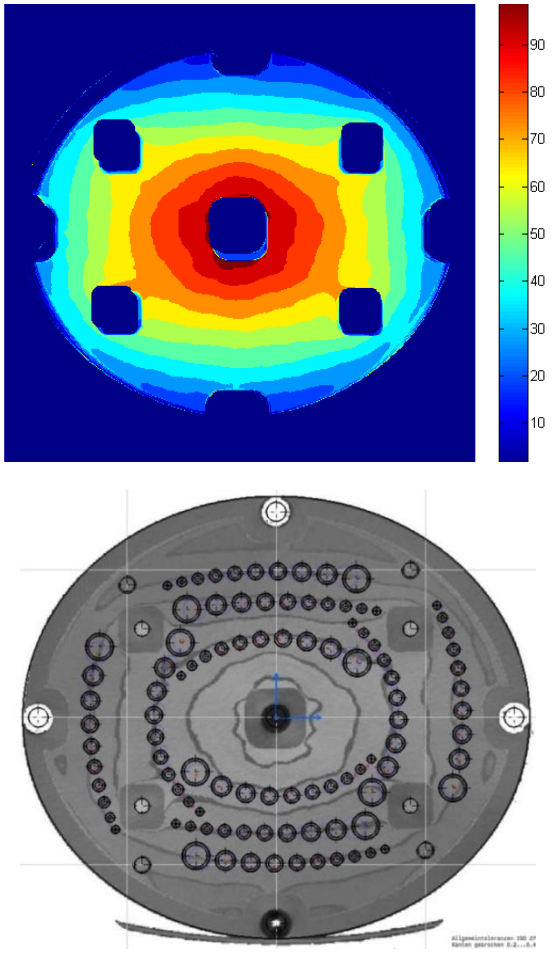

Figure 1: CT scan (slice) of elliptical PMMA slab: (A) SNR normalized to the maximum (100%) in a homogeneous slab; (B) positions of low contrast objects in respect to the noise – the objects are placed along SNR isolines.

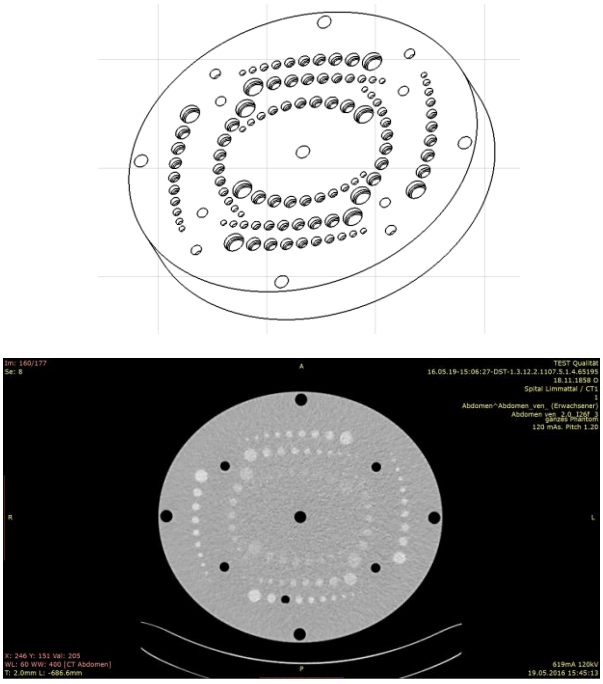

Figure 2: Realisation of the elliptical DDC phantom, upper image: 3D view of the PMMA slab with the holes for the low contrast objects fillings; lower image: CT scan of the DDC phantom. The objects with the lowest contrast are lying in the centre, where the SNR has the highest values.

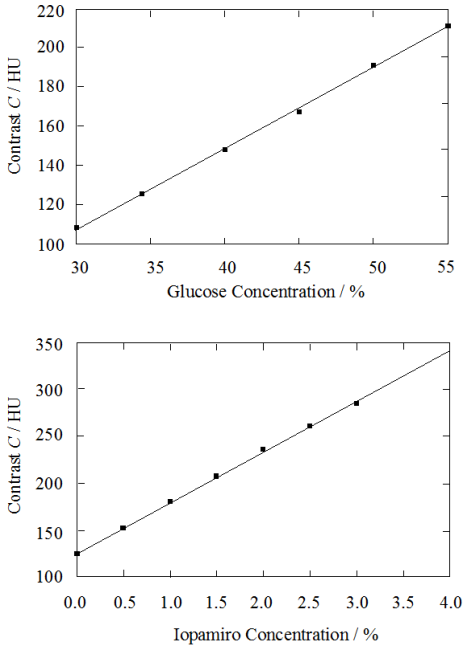

Figure 3: Relation between the HU and the liquid composition: Upper diagram shows the native contrast, lower diagram the contrast media. Measurements have been performed at a Siemens Definition AS 64 with a tube voltage of 120 kV.

3 Results

For all tested manufactures and protocols, the noise analysis revealed a similar spatial variation of the signal -to-noise ratio SNR (see **Figure 1**, A). For the DDC method, contrast steps of 6 (4-6) Hounsfield Units are adequate. For the different CT units, comparable low contrast detectability is associated with remarkably varying dose levels (CTDI range from 8 to 18 mGy for native contrast and 9-16 mGy for contrast media).

A detailed analysis of the visibility of contrast objects by a human observer rating exhibit a logarithmic behaviour when plotting the DDC as a function of the object (cross-section) areas *x* (see **Figure 4**). The limit contrast C = C(x) can be described as:

$$C(x) = a\ln(x) + b \qquad (1)$$

In **Figure 4**, the average DDC from 26 CT units (of 22 hospitals; 27 protocols) including 15 Siemens - , 6 Philips-, 4 GE- and 1 Toshiba- CT is shown. Since the HU are known from a calibration measurement at a Siemens Definition AS 64 CT by applying high tube current (516 mA) to minimize noise and subsequent uncertainty of the HU-values, the main contribution of scatter in Figure 4 is given by the variability of the low contrast visibility of the different protocols and CT units. The fit parameters *a* and *b* in Eq.1 are sensitive to the exposition parameters such as tube current or to the reconstruction algorithm.

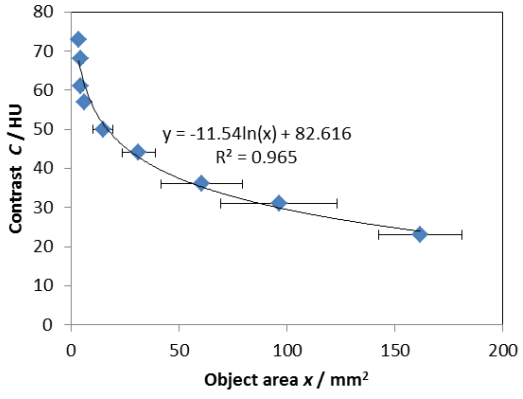

Figure 4: Average DDC for contrast media objects: The measurement and analysis of 27 abdominal protocols relevels a high variability of low contrast visibility especially for contrasts below 50 HU (above PMMA).

4 Discussion and conclusions

The novel DDC phantom is sensitive to protocol optimisations and therefore suitable for rating subtle effects of optimisation. Due to non-linear changes of contrast when modifying tube voltage, it is important to monitor iodine and normal tissue contrast simultaneously.

The method is designed for human observer - rating since it is intended to cover the whole radiological chain from the interaction of the radiation with the patient to the visual perception of the radiologist reading the CT images. This is a different goal compared to the use of a CatPhan phantom for annual QA testing as investigated by Gulliksrud et al. [5]. It could be discussed if a model observer would be beneficial because of the fact that this supports automatized analysis. In contrast to this aspect, the use of non-cylindrical contrast objects mimicking a diversity of lesions would be interesting since model- and human observer often are expecting cylindrical (circular) objects. In addition, the contrast objects in the novel DDC phantoms are aligned along SNR iso-lines, resulting in a more or less ordered pattern. This facilitates the recognition of the objects by human observers. Therefore, a random-like structure considering the intra-slice - SNR variation combined with a dedicated graphical user interface would be a clear improvement.

Author's Statement

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References

[1] Heads of the European Radiological Protection Competent Authorities (HERCA): HERCA CT position paper: The process of CT dose optimisation trough education and training and role of manufactures. HERCA 2015

[2] Hay GA, Cowen AR. Physical Aspects of Medical Imaging. Ed BM Moores, RP Parker and BP Pullan, Chichester: Wiley, 1981, pp 63-70

[3] Hasegawa BH, Cacak RK, Mulvaney JA, Hendee WR. Problems with Contrast-Detail Curves for CT Performance Evaluation. AJR, 1982; 1.

[4] Faulkner K, Moores BM. Contrast-detail assessment of computed tomography scanners. Phys Med Biol 1986, 31(9): 993-1003

[5] Gulliksrud K, Stokke C, Traegde Martinsen AC. How to measure CT image Quality: Variations in CT-numbers uniformity and low contrast resolution for a CT quality assurance phantom. Physica Medica, 2014; 30: 13