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Research Article

Low-Contrast Detail Phantom: Proof of Concept

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ABSTRACT

Purpose: To investigate the concept of filling the air gaps of the conventional contrast detail phantom (CDP) with various concentrations of contrast media, and to develop a variable level of attenuation-level differential phantoms that could be more appropriate for contrast measurements in some radiology cases.

Methods: Images were acquired using the digital radiography system of the traditional CDP (Perspex/air hole phantom) and the novel form of CDP where the air holes were replaced with attenuating material. In this study, two different attenuating materials were introduced, water and a 30% concentration of iodine-based contrast medium. Image quality was assessed using automated processing to calculate the image quality factor $(IQF)_{inv}$.

Results and Discussion: Phantom studies indicate that lower contrast levels are obtained when CDP holes are filled with water and a 30% concentration of iodine contrast media than those observed for air/Perspex or traditional CDP. As an example, when a 5-mAs beam is used the IQF_{inv} values are 5.32 in the case of air filling the holes; however, when these holes are filled with water under the same conditions, the value of the IQF_{inv} drops to 2.55, and to 2.83 when 30% of contrast media is used. Other concentrations were also tested. These results indicate that it is possible to extend the contrast scale in these phantoms to include ranges that are more realistic for a patient's body than just air and tissue-equivalent material.

Conclusions: These findings indicate that the proposed extension of the contrast scales allows smaller changes in contrast to be discerned. This is due to the small attenuation differences of the subject materials (e.g, 30% contrast liquid and wax) from the traditional form of CDP (material/air). This suggests that the low form of the CDP may have a useful role in assessing image quality in planar radiology as an evaluation tool to better represent low-subject contrast imaging requirements.

RÉSUMÉ

But : Étudier le concept de remplissage des espaces d'air des fantômes de contraste détaillés conventionnels (CDP) avec différentes concentrations d'agents de cont4raste et développer des fantômes différentiels présentant un niveau d'atténuation variable, qui pourraient être plus appropriés pour la mesure du contraste dans certains cas radiologiques.

Méthodologie : Des images ont été acquises à l'aide d'un système de radiographie numérique sur le modèle traditionnel de CDP (fantôme de perspex avec espaces d'air) et la nouvelle forme de CDP dans lequel l'air est remplacé par un matériau atténuant. Dans cette étude, deux matériaux atténuant ont été utilisés, l'eau et un agent de contraste à base d'iode en concentration de 30 %./La qualité d'image a été évaluée en utilisant le traitement automatisé pour calculer le facteur de qualité de l'image IQFinv.

Résultats et discussion : Les études sur fantômes indiquent que des niveaux de contraste plus faibles sont obtenus lorsque les cavités des fantômes CD sont remplis d'eau et d'une solution à 30 % d'agent de contraste iodé par rapport à ce qu'on observe pour les fantômes air/perspex ou les fantômes CDP traditionnels. Par exemple, avec l'utilisation d'un faisceau de 5 mAs, les valeurs d'IQFinv sont de 5,32 lorsque les cavités sont remplies d'air; cependant, lorsque les cavités sont remplies d'eau, dans les mêmes conditions, la valeur d'IQFinv baisse à 2,55, et à 2,83 lorsque l'agent de contraste à 30 % est utilisé pour remplir les cavités. D'autres concentrations ont aussi été testées. Ces résultats indiquent qu'il est possible d'étendre l'échelle de contraste de ces fantômes pour englober des plages plus réaliste pour le corps d'un patient que lorsqu'on utilise uniquement l'air et un matériau équivalent au tissu.

Conclusion : Ces constatations indiquent que l'extension proposée des échelles de contraste permet de discerner des variations de contraste plus faibles, en raison des petites différences d'atténuation entre les matériaux sujets (par exemple un liquide en concentration 30 % et la cire) que ce qui est possible avec la forme traditionnelle

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(matériau/air) du CDP. Ceci donne à penser que la forme basse du CDP pourrait avoir un rôle utile dans l'évaluation de la qualité de l'image en radiologie planaire, comme outil d'évaluation permettant de mieux représenter besoins d'imagerie des sujets à faible contraste.

Keywords: Digital radiography; image quality; IQF_{inv}; contrast detail phantom

Introduction

The assessment of image quality in radiologic imaging is a vital process for ensuring that high-quality images are provided, thereby enhancing diagnostic ability. Improvements in radiologic image quality commonly involve increasing patient and public dose. For example, in most cases, more x-ray photons are required to improve statistics and reduce the noise in an image, but this means an increased radiation dose [1, 2]. In accordance with the As Low As Reasonably Achievable (ALARA) principle, to keep the radiation dose as small as possible while still providing adequate image quality to enable diagnosis, the dose should be optimised with image quality [3].

The assessment of image quality can use objective or subjective methods. Objective assessments of image quality associated with diagnostic imaging systems can be equipment-based, such as noise analysis or modulation transfer functions [1]. These methods, while providing assessment of radiation detector performance, do not consider the effects of the image assessor—typically a radiologist—and the effects of the viewing system and conditions. Image quality can also be assessed subjectively. In this method, radiologists typically subjectively assess and judge the diagnostic images, with receiver-operator characteristics used to compare the performance of various imaging systems [3]. Although subjective assessment of image quality using receiver-operator characteristics analysis considers the whole imaging chain (equipment, scatter, image processing, and human observer), it is a time-consuming process and cannot be readily adopted as a quality assurance method in busy clinical practices. A commonly adopted alternative approach to assessing image quality is the use of contrast detail phantoms (CDPs) [3–5]. CDPs are designed to provide useful information on contrast detail detectability and have been shown to be one of the most reliable and commonly adopted phantoms for image quality assessments, especially in low-contrast conditions [6]. In fact, CDPs are commonly referred to as low-contrast detail phantoms. Although there are many image quality reporting tools, one commercially available CDP, the CDRAD 2.0 (Artinis Medical Systems) phantom, is the most commonly used CDP [5, 7]. The CDRAD phantom is made of acrylic (perspex-polymethyl methacrylate) 10-mm thick, in which 225 cylindrical holes of various sizes and depths are drilled in the phantom medium. The diameter of the holes varies in size from 0.3 mm to 8 mm. This range is equally distributed across 15 depths. These depths range from 8 mm (providing high contrast) to 0.3 mm (providing low contrast). Hence, the CDRAD phantom uses air–acrylic interface to create image contrast. However, the subject contrast of the CDRAD phantom is relatively high because it represents attenuation differences between Perspex and air. This research aims to replace air by filling the holes with material of a slightly different attenuating ability than that of Perspex, representing a much lower contrast measuring phantom than the conventional CPD.

The rationale for this research stems from the potential of extending the application conditions of the current type of commercially available CDP. Air and acrylic in current CDPs are the only materials used to create various amounts of image contrast for the assessment of the contrast detectability of the imaging system. In this study, the air is replaced with water, a substance equivalent to tissue. The phantom structure modification introduced in this study represents the assessment of the ability of the imaging system to discern smaller subject contrast differences with water–acrylic rather than air–acrylic.

Different scales of contrast (compared with the current air-based CDP) are also investigated in this study by filling the holes with various concentrations of contrast media. Hence, this study also examines the feasibility of including contrast media into water and using this phantom as a multiscale contrast-measuring device. This article reports on the use of this new format for the CDP with images acquired using a commercially available flat panel detector digital radiography (DR) system.

Materials and Methods

Materials

Modified CDPs were developed by adapting the commercially available CDRAD phantom: the air in the holes was replaced with a medium that has absorption characteristics similar to the base material acrylic, hence reducing the subject contrast. First, the air-filled holes within the CDRAD phantom were filled fully with distilled water. In this instance, replacing the air in the holes with water is the only physical modification of the CDRAD. By replacing air with distilled water, the CDP now represents the difference between water and Perspex rather than Perspex and air. Subject contrast in the phantom is reduced when the holes are filled with water instead of air. The 225 water-filled holes of depths and sizes varying from 0.3 mm to 8 mm will exhibit attenuation characteristics closer to that of acrylic and not exhibit the larger range of contrast in the air-filled CDRAD phantom. This modified CDP now more closely replicates the low-subject contrast commonly encountered in noncontrast radiology where attenuation between adjacent soft tissues in the human