DESIGN OF A UNIVERSAL PHANTOM FOR QUALITY ASSURANCE IN DIAGNOSTIC RADIOLOGY X-RAY IMAGING

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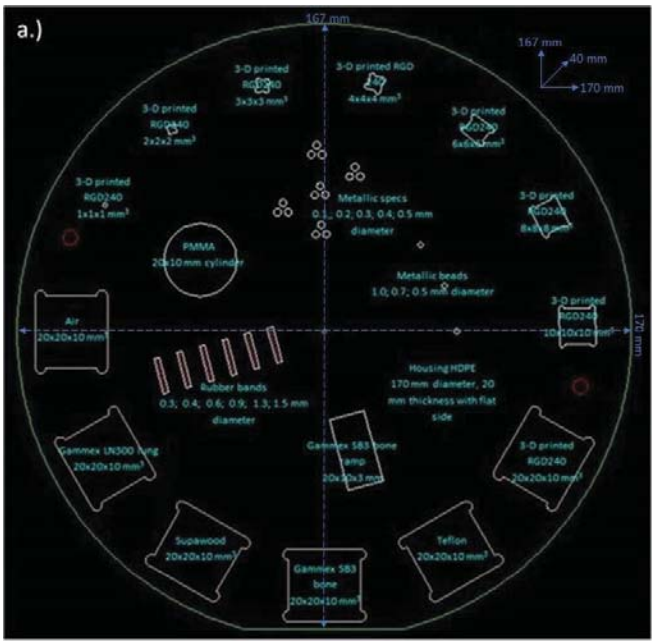
Abstract— **Background:** In medical X-ray imaging several diagnostic x-ray imaging modalities are applied to enable disease diagnosis, i.e. general projection radiography, fluoroscopy, mammography and Computed Tomography (CT) scanning. X-ray images must be of sufficient quality to enable accurate diagnosis. Image quality is quantified using suitable phantoms to ensure that equipment failure is detected before patient care is affected.

A variety of phantoms are commercially available. However, these are modality specific, expensive and often complicated to use. In resource limited institutions, like many in Africa including South Africa, three problems are identified in the field of diagnostic radiology X-ray image quality control (QC). These are cost, man power and expertise and time constraints. A gap thus exists in the market for a single universal image quality assurance (QA) phantom, capable of doing all required QC tests for all X-ray imaging modalities. A phantom, answering to this requirement, in addition must be user-friendly and cost- and time-efficient.

The aim of this study is to design, develop, manufacture, test and validate a universal image QA phantom (U-QA phantom) for diagnostic radiology X-ray imaging. The phantom must be compact, unique, universal (i.e. not modality specific), easy and quick to use and manufactured at a substantially reduced cost compared to the commercially available options.

Methods: Using literature studies on existing commercial phantoms for guidance, a prototype universal phantom was designed, manufactured and tested for all X-ray imaging modalities. From the prototype results, adjustments were made and the universal image quality phantom was developed and manufactured. The phantom is made from high density polyethylene and houses several inserts of different materials (Figure 1) to asses sensitometry, image uniformity, limiting resolution, image noise, i.e. signal-to-noise (SNR) and contrast-to-noise (CNR) ratios, geometry and measurement tools, standard signal, low contrast detectability, positioning and alignment, artefacts and visual image quality inspection. For CT scanning the phantom measures slice thickness and for mammography masses, fibres and micro-calcifications are evaluated.



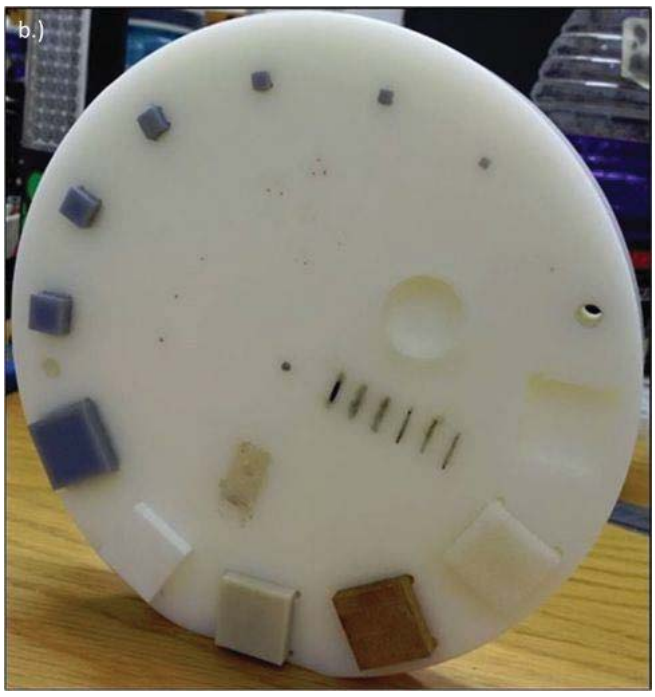


Fig. 1. A) The composition of the U-QA phantom showing the dimensions of the different inserts and the phantom. B) The bottom half of the U-QA phantom showing the different inserts in place.

Data analysis software was developed for analysis of obtained images and a complete step-by-step user's manual was prepared. Reproducibility testing was performed on the phantom, using Department of Health (DoH) specified limits. Independent validation of the phantom package (Figure 2) (i.e. phantom, software and manual) was done by three independent medical physicists. They compared the phantom to the commercial phantoms in general use in their institutes.

Fig. 2. The U-QA phantom package showing the phantom, user's manual and data analysis software in a travel case.

Results: The universal image QA phantom and accompanying data analysis software produced reproducible results for all imaging modalities, within the accepted DoH tolerance levels. The independent validation results proofed that the phantom package was easy to transport, light weight and compact, easy to set-up and use, versatile, cost effective and user friendly.

Conclusion: From the reproducibility testing and independent validation results it may be concluded that the universal image QA phantom, with accompanying data analysis software and user's manual, offers an acceptable single phantom solution for medical X-ray imaging. The universal phantom is a cost and time saver and as such could fill a gap in the existing market. In addition, the phantom could also be used by radiographers in resource limited institutions.

Keywords — QA/QC. Physics. Mammography. Fluoroscopy. CT. Conventional radiography. Image quality.