Implementation of Copper Filtration in Adult and Pediatric Chest Radiography: A Clinical Phantom Study

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INTRODUCTION

A 2025 best practices in digital radiography white paper was released by the American Society of Radiologic Technologists (ASRT)[1] claiming that literature supports the use of copper (Cu) filtration in routine chest radiography and pediatric radiography with digital image receptors. We wanted to test their claim that **contrast and spatial resolution**, from here on referred to as image quality (IQ), **would remain consistent with Cu filtration increase as well as with changes in phantom size.**

METHODS AND MATERIALS

We evaluated entrance exposure ($K_{entrance}$) and IQ on contrast-detail (C-D) (Figure 1,3), Lung Man (Figure 2) and radiography IQ (Figure 4) phantoms using both manual and automatic exposure control (AEC) exposures while varying Cu filtration. Acrylic was utilized to simulate varying patient thickness for part of the work.

RESULTS

The C-D phantom results can be seen in Table 1. When a "Lung Man" phantom was imaged using an adult chest technique, $K_{entrance}$ to the phantom while using Cu filtration had an average value of 62.8 µGy compared to without Cu filtration (144.9 µGy). Results from using adult chest techniques on the C-D phantom with increasing acrylic thickness between the phantom and the x-ray tube is seen in Figures 5-6 for the $K_{entrance}$ and IQ. Results from imaging the C-D phantom in acrylic with age-based pediatric techniques is seen in Figure 7. Qualitative and quantitative IQ results from exposing the radiography IQ phantom to age-based pediatric techniques is seen in Figures 8-10.

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Figure 1. C-D phantom where size and depth decreases from the top left

Figure 2. Lung Man anatomical phantom

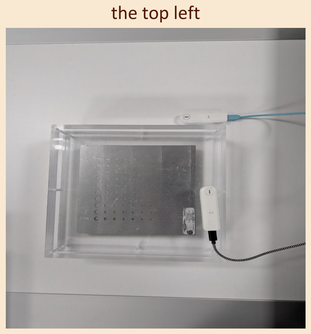

Figure 3. C-D phantom between two acrylic slabs.

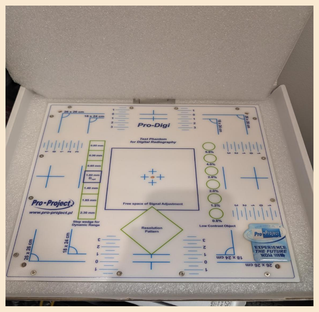

Figure 4. Radiography image quality phantom

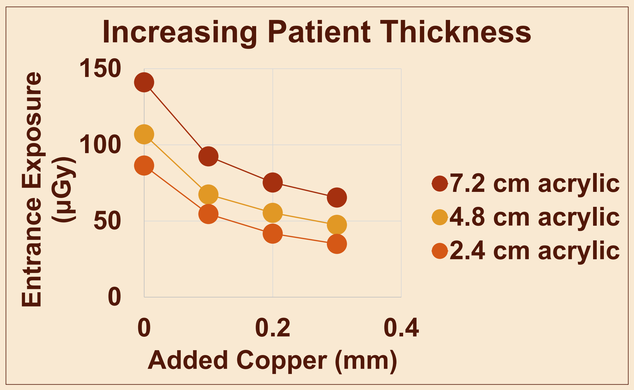

Figure 5. $K_{entrance}$ on acrylic with Cu added as acrylic thickness increased

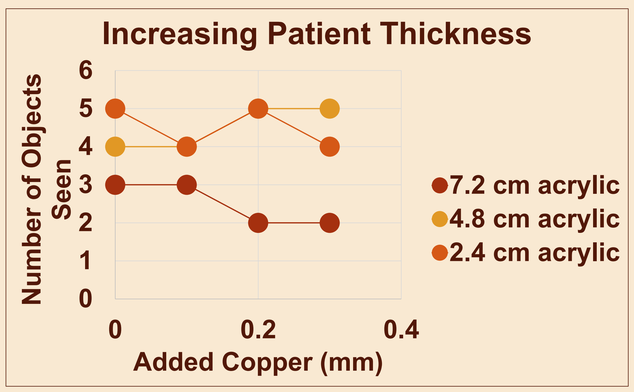

Figure 6. Lowest contrast objects counted in C-D phantom

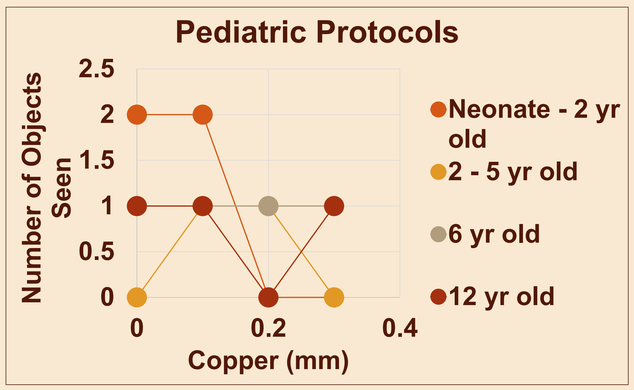

Figure 7. Lowest contrast objects counted as Cu increased

Table 1. C-D phantom results showing count of columns at lowest contrast as size decreases and rows of smallest size as contrast decreases.

Filtration (mm Cu)	EI	Lowest Contrast	Smallest Size
None	293	6	5
0.1	199	6	6
0.2	159	6	4
0.3	136	6	4

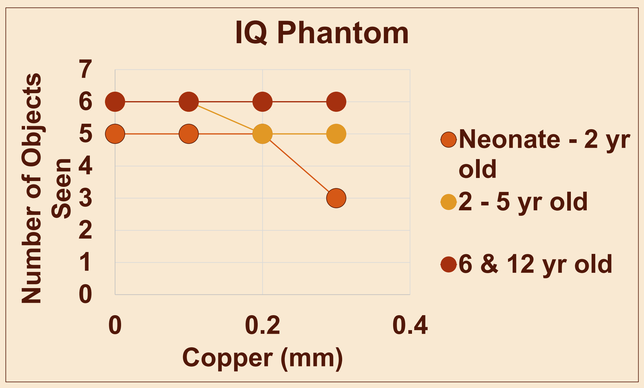

Figure 8. Lowest contrast objects counted in IQ Phantom

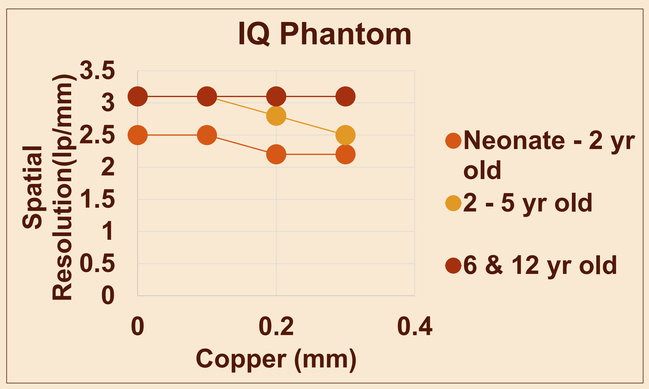

Figure 9. Spatial resolution in IQ Phantom

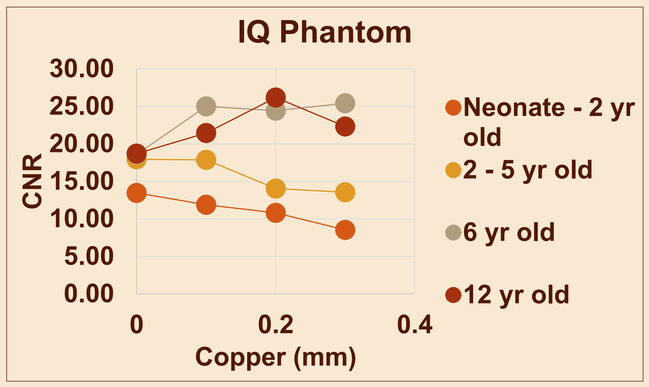

Figure 10. CNR in IQ Phantom

DISCUSSION

With increasing Cu filtration thickness, $K_{entrance}$ in all cases was reduced, with one example being illustrated in Figure 5, which aligned with results from literature.[1-3] In regards to IQ, Figure 6 demonstrates that contrast potentially has some negative correlation with patient thickness at or beyond 7.2 cm. Contrast correlation with Cu filtration increase is mixed depending on acrylic thickness; however, when comparing the result for 7.2 cm of acrylic with the IQ results of Brosi et al[2], we see a similar result of decrease in IQ at 0.2 mm Cu added filtration. This comparison is not equivalent since the techniques used for Figure 6 were for adult chest

DISCUSSION (Cont.)

(120 kV). A more equivalent comparison can be seen in Figure 7 where our clinical neonate-2 yr old technique (60 kV, 1 mAs) falls off at 0.2 mm Cu like in Brosi et al[2] (60 kV, 0.8-2 mAs). For the other three protocols (2-5 yr old, 6 yr old, 12 yr old), we see a mixed result like in Figure 6 which is most likely due to the noise of the images from which we take away a need for a less subjective IQ evaluation. One mistake that we made with regard to the IQ evaluation was to not increase the techniques of the Neonate-2 yr old and 2-5 yr old protocols to match dose to the image receptor without acrylic or Cu filtration and was mentioned as a necessity in Tugwell-Allsup.[3] The results of Figures 8-10 demonstrate this point with qualitative and quantitative IQ decreasing for both manual protocols. For the AEC-controlled pediatric protocols, we see equivalent or improved qualitative and quantitative IQ with at least 0.1 mm Cu over none. The values recorded in Figures 8-10 were based on one image at each protocol and filter combination and would statistically improve with multiple images at each combination. Nevertheless, the results in Figures 8-10 are consistent with previous literature where Cu filtration either had an insignificant or no effect on IQ while reducing $K_{entrance}$ for exams that had either automatic exposure control (AEC) or manual techniques compensated for the additional patient and Cu filtration thicknesses.[1-3] Accounting for these attenuations paired with more exposures at each combination are a part of future work. Additionally, we were limited by the acrylic available to our department and were unable to match the optimal thicknesses for various ages studied in literature.[2] Future work would require access to greater acrylic thicknesses to appropriately assess.

CONCLUSIONS

Cu filtration reduces $K_{entrance}$ while yielding equivalent or improved IQ with manual techniques that compensate for patient thickness**. AEC-controlled protocols may need an increase in kV while manual techniques need increased techniques to maintain IQ.** Next steps are to identify the optimal Cu filtration and technique combination for greater patient thickness followed by implementing these combinations clinically to evaluate IQ.

Balać V, DeMaio DN, Griswold R, et al. *Best Practices in Digital Radiography*. American Society of Radiologic Technologists; 2025.
Brosi P, Stuessi A, Verdun FR, Vock P, Wolf R. Copper filtration in pediatric digital X-ray imaging: its impact on image quality and dose. *Radiol Phys Technol*. 2011;4:148-155. doi:10.1007/s12194-011-0115-4.
Tugwell-Allsup JR, Morris RW, Thomas K, Hibbs R, England A. Neonatal digital chest radiography- should we be using additional copper filtration?. *Br J Radiol*. 2021;94:20211026. doi:10.1259/bjr.20211026.