Evaluation of Fluoroscopic Image Quality in Interventional Cardiology Using Channelized Hotelling Observer

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INTRODUCTION

- The Gabor channelized Hotelling observer (CHO) has been utilized to provide an objective and quantitative evaluation of x-ray fluoroscopic system performance[1-3]
- However, previous works utilizing CHO usually assume simple uniform background and static objects[2]
- In reality, targets of interest are located within complex anatomical background and the targets are often moving

The purpose of this work is:

- To evaluate the use of CHO to assess fluoroscopic image quality using moving vessel-mimicking test objects and anthropomorphic phantom background to simulate clinical fluoroscopy imaging conditions in interventional radiology and cardiology
- To investigate the effect of image processing on object detectability index (d') for
  - Different object sizes
  - Detector dose rates
  - Slow and fast-moving objects

METHOD

Phantom setup

- Interventional cardiology system (Siemens Artis Zee)
- Anthropomorphic chest phantom (Fig. 1)

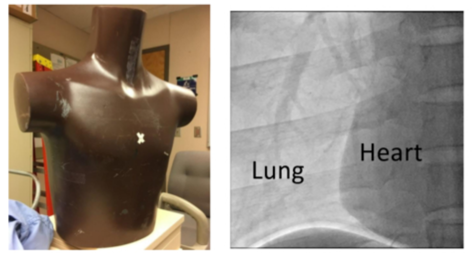

Figure 1: Anthropomorphic chest phantom used in this study (left). Fluoroscopic image showing the lung field and heart field of phantom (right)

- PMMA disk with small rods containing iodine contrast to represent vessels with diameter from 0.5 to 4 mm (Fig. 2)
- Disk mounted onto a rotation platform, which is placed on top of the chest phantom (Fig. 3)
- As the disk rotates, phantom rods pass through various anatomical backgrounds, which emulate moving objects within anatomical background (Fig. 4)

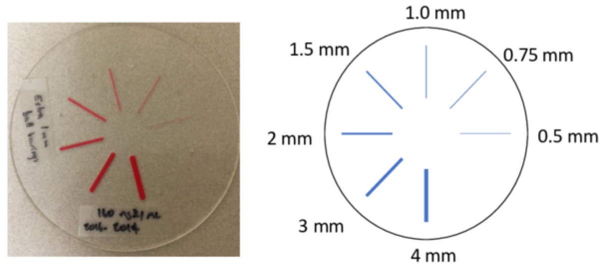

Figure 2: PMMA disk with iodine contrast rods

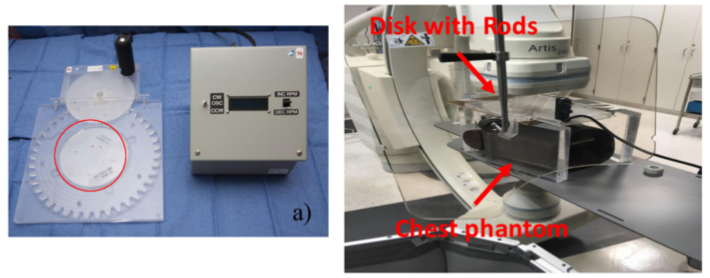

Figure 3: Disk mounted onto a rotation platform (left), which is placed on top of the chest phantom (right)

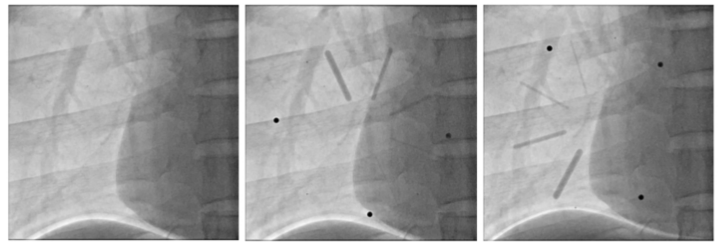

Figure 4: Phantom image with rod absent (left), and with rod rotated to different locations (middle, right)

Data acquisition

- Fluoroscopic images were acquired at a frame rate of 15 s^{-1}
- Rotation speeds of 2 and 20 cycle/min were used to create linear velocities of 5.2 and 52 mm/s
- The phantom was imaged with detector target dose (DTD) of 18, 36 and 65 nGy/frame
- Images were recorded with system's image-processing enabled and disabled

CHO analysis

- The images were analyzed to estimate d' for each rod using a framework incorporating correction of d' estimation bias[1,4] caused by finite sampling and nonstationary noise (Fig 5)

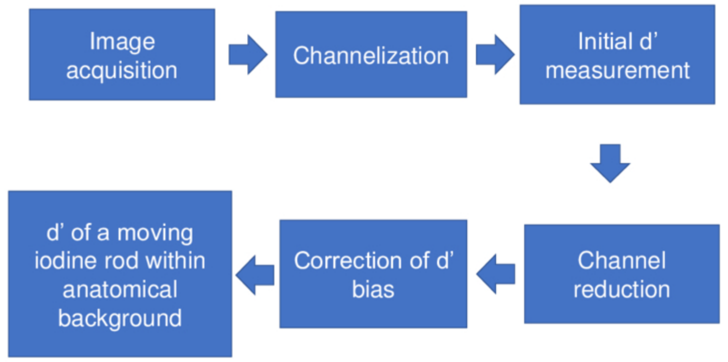

Figure 5: Framework for CHO analysis

RESULTS

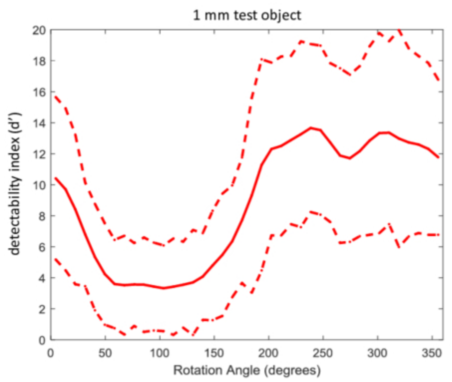

Figure 6: d' estimates for a 1 mm diameter test object as a function of rotation angles (from 0 to 360 degrees). The variation of d' with rotation angle is due to changes in quantum noise properties for various anatomical regions. Solid line: mean d' value; dashed line: standard deviation of d' estimates

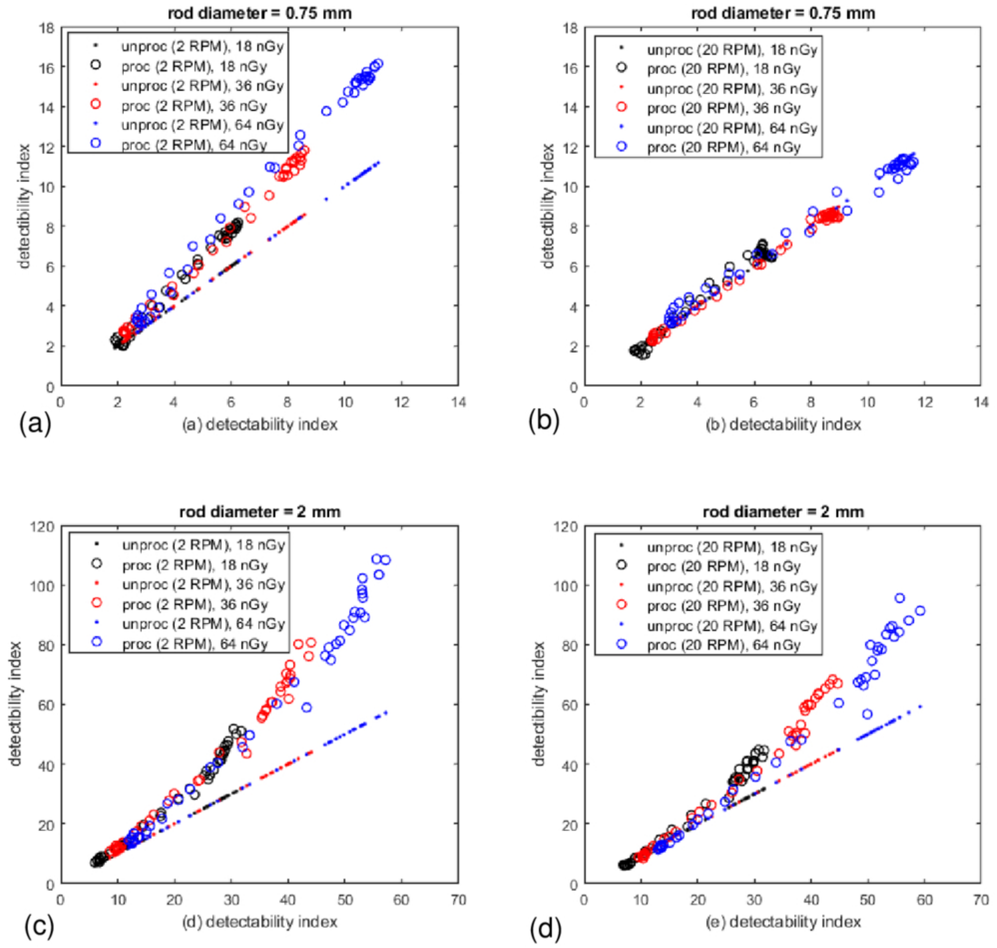

Figure 7: (a-b) comparison between d' of unprocessed images and processed images acquired at different DTD (color indication) and anatomical backgrounds for a 0.75 mm diameter object rotation at 2 rpm (a) and 20 rpm (b). The points or circles represent d' of that object when it rotated to different anatomical regions of the anthropomorphic phantom. The images acquired with different DTDs were used to generate this plot.
(c-d) comparison between d' of unprocessed images and processed images for a 2 mm diameter object rotating at 2 rpm (c) and 20 rpm (d).

Key results:

- Figure 6 shows that d' of test objects varied with rotation due to changes in quantum noise properties for various anatomical regions
- For relatively static objects test (2 rpm), Figure 7a/c shows that image processing resulted in d' enhancement compared to unprocessed images, but preferentially for larger objects and under higher DTD conditions (for which the starting d' in unprocessed image was high)
- d' enhancement due to image processing was relatively lower for low d' conditions, including small test objects and/or lower DTD conditions (Fig. 7a/c)
- Less improvement was observed in the processed images for fast-moving (20 rpm) test objects compared to slow-moving (2 rpm) objects, especially for small objects (Fig. 7)
  - For example, d' of the 0.75 mm diameter rod (at 36 and 65 nGy/frame dose rate) was significantly higher for a slow-moving object (2 rpm) than a fast-moving object (20 rpm) when image processing is applied ($p<0.05$)
- When the motion is fast, image processing improves d' for large objects but not for small objects (Fig. 7b/d)

CONCLUSION

- CHO can be used to assess X-ray fluoroscopy image processing and may provide an adjunct to qualitative assessment of image quality
- Results showed that image processing preferentially increased d' for large and slow-moving objects and this enhancement increased with increasing DTD
- However, image processing did not enhance d' for relatively low d' conditions, including small objects and low DTD

REFERENCES

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