Title: Evaluation of commercial cardiac motion phantom for dual energy chest radiography

Purpose: Mis-registration from cardiac motion causes artifacts in both the soft-tissue-only and bone-only two-exposure dual energy (DE) subtraction images. The degree of mis-registration is affected by heart rate, time interval between the low and high kVp exposures, total duration of the two exposures, and the phase of cardiac cycle at the start of the exposure sequence. Two previous investigations attempted to avoid mis-registration artifacts by cardiac gating of the first and second exposures [1, 2]. This study is to determine whether a commercial phantom with simulated beating heart can be used to investigate the factors affecting mis-registration in dual energy chest radiology.

Method and Materials: DE images of the Kyoto Kagaku cardiac motion phantom (Fig. 1) in postero-anterior orientation (Fig. 2) were made using a GE Revolution XQ/i and a GE Definium 8000 indirect DR systems. The images were acquired at 62 kVp and 125 kVp for the XQi and at 60 kVp and 125 kVp for the Definium. Fig. 3 shows one dual energy waveform. Images were acquired with a stationary heart and at rates from 50 bpm to 120 bpm without coordination of cardiac cycle with the initiation of the exposure sequence. The phantom was imaged at 70 bpm 4 times with the XQ/i and 5 times with Definium to determine variability. DICOM images were transferred to a PC where the area of the artifact on the silhouette of the heart was measured from both soft-tissue only (Fig 4c) and bone-only images (Fig 4d) using ImageJ.

Results: Table 1 shows the area of mis-registration at 70 bpm, exposure time for low energy, time interval between the end of the first exposure and the beginning of the second and total time of the exposure sequence. The duration of the low kVp pulse is longer in XQ/i than Definium for the same phantom likely due to AEC sensitivity, phantom positioning or grid differences. The time interval between the end of the first exposure and the beginning of the second exposure is relatively constant for XQ/i (0.4%), but variable for the Definium (3.5%). Fig. 5 (a) and Fig. 5 (b) are mis-registration area at different heart rates in XQ/I and Definium, respectively. The error bars in Fig. 5 (a) and Fig. 5 (b) are scaled to account for the variation for the specific imaging machine. The area of the artifact generally increases with heart rate for both machines. Variation in the area of the artifact for the Definium is twice that for the XQ/i.

Conclusion: Although designed for horizontal operation and CT, this phantom can be used upright to simulate heart motion for investigating DE mis-registration artifacts and control.

References:

[1] J. Sabol, et. al., “The Impact of Cardiac Gating on the Detection of Coronary Calcifications in Dual-Energy Chest Radiography: A Phantom study,” in *Proceedings of SPIE, Physics of Medical Imaging (SPIE, 2006),* Vol. 6142, pp. 61421F-1-61421F-12.

[2] N. A. Shkumat, et. al., “Cardiac gating with a pulse oximeter for dual-energy imaging,” Phys. Med. Biol. Vol. 53, pp. 6097-6112 (2008).

Table 1

	mis-registration at 70 bpm (mm^2)	Exposure time for low energy (ms)	Time interval (ms)	Total exposure time (ms)
XQ/i	15.6+/-2.0 (13%)	9.3+/-0.8	149.2+/-0.6	158.5+/-14.3
Definium	16.7+/-5.4 (32%)	8.8+/-0.9	155.2+/-5.4	164.0+/-16.4

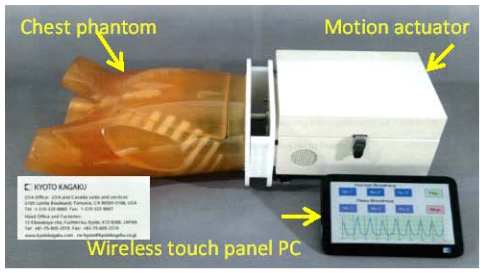


Fig. 1 Kagaku cardiac motion phantom set

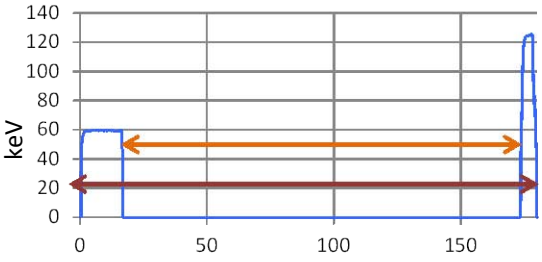


Fig. 2 Dual Energy waveform and illustrations of time interval and total exposure time.

↔ represents the time interval between the end of the first exposure and beginning of second exposure.

↔ represents the total exposure time.

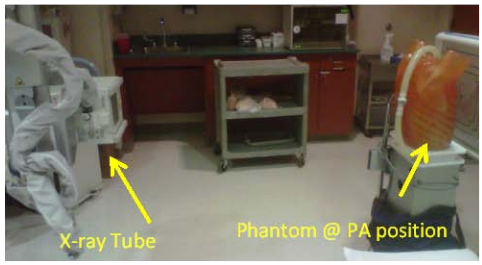
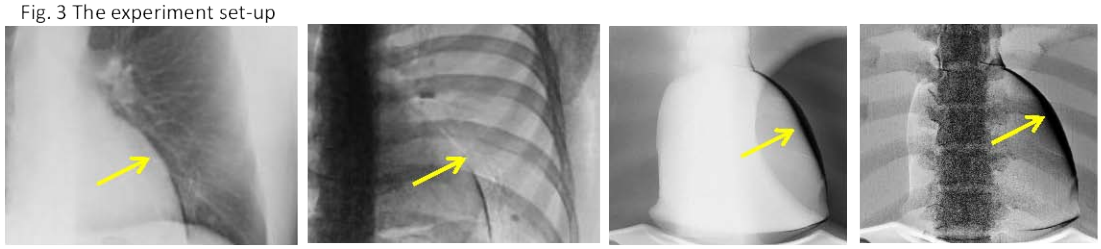


Fig. 3 The experiment set-up



(a) Soft tissue only (b) Bone only image (c) Soft tissue only (d) Bone only image

Fig. 4: (a) and (b) are human dual energy chest radiology. (c) and (d) are cardiac motion phantom dual energy radiography. The yellow arrow points the mis-registration of dual energy subtraction image.

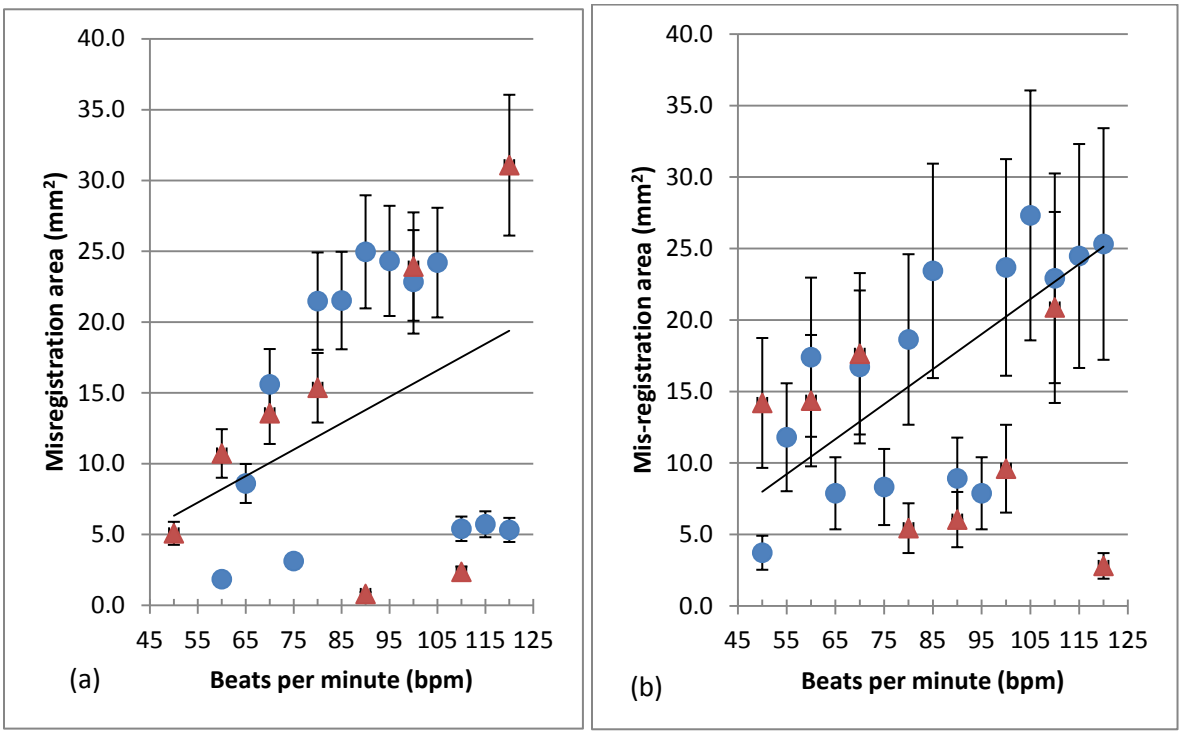


Figure 5. Misregistration vs. heart rate for a) XQ/I and b) Definium (triangles Day 1, circles Day 2)