Investigating Factors Relevant to Calcium Decomposition in Dual-Energy CT Imaging

Ruben Mellon, UHB; Michael Katsidzira, UHB

Abstract

The aim of this study was to identify an optimal beam pair for calcium removal in virtual non-calcium reconstructions, with the goal of informing bone marrow oedema imaging protocols. To assess the effect of patient size, two phantom sizes were scanned using a Siemens SOMATOM Force and a Gammex multi-energy phantom with calcium concentrations of 50, 100, and 300 mg/ml. The 80/140 kV pair, lacking tin filtration, showed increased variance and was excluded from further analyses. While Friedman tests revealed no statistically significant differences (head: $\chi^2(3)=6.6$, p=0.09; body: $\chi^2(3)=3.4$, p=0.33), observed trends indicate that greater spectral separation may improve reconstruction accuracy, warranting further investigation.

Aims & Objectives

Dual Energy CT (DECT) offers the benefits of 3D imaging from conventional CT with the benefits of material differentiation available from dual energy imaging [1].

In cases of bone marrow oedema (BME), or bone swelling, it can be useful to identify the calcium (i.e. the bone) in the images. Once identified, removing the calcium from the images can make it easier to examine the extent of swelling that is present [1] [2]. This type of image is a called a “virtual non calcium” (VNCa) image.

The accuracy of material identification can be improved by increasing the difference between the two x-ray spectra used - this is called having a high spectral separation [1] [2]. However, if too low an energy is used then the image will be noisy which is exacerbated for larger patients [3].

The study investigated the effect of x-ray energy pair and patient size on accuracy of calcium removal. No patients were scanned in this study and instead a phantom was used to simulate a patient.

Methods

A dual-source Siemens SOMATOM Force was used for the purposes of this investigation. The scanner offers improved spectral separation by utilising a tin filter and a higher maximum tube voltage.

The kV pairs available are as follows: 80/140 kV, 70/150 Sn kV, 80/150 Sn kV, 90/150 Sn kV and 100/150 Sn kV where “Sn” denotes the use of the tin filter.

The Gammex Multi-Energy phantom (Figure 1) consists of a smaller circular head phantom and an annular ring that, when combined, form an elliptical body phantom. Both configurations were imaged to simulate small and large body habitus.

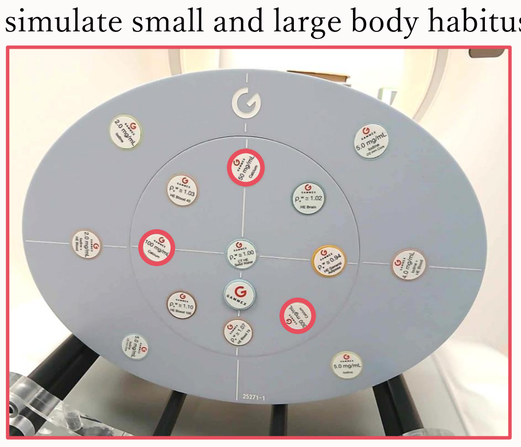


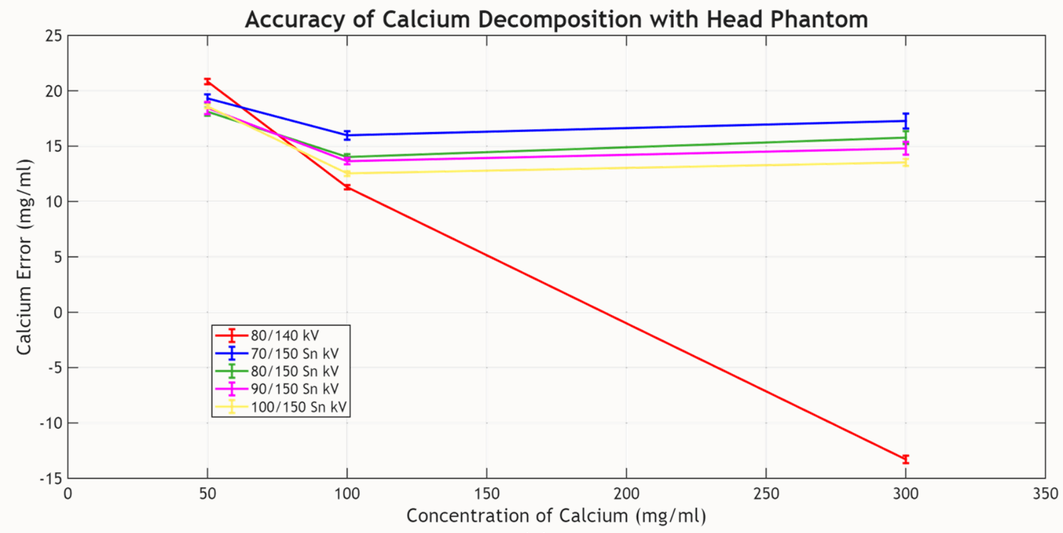
Figure 1: The Gammex Multi-Energy Phantom used in this study. The three calcium inserts of various Calcium concentrations (50,100, 300 mg/ml) used to test the accuracy of VNCa reconstructions are circled in red. A solid water insert was positioned centrally and was used to measure an equivalence of noise within the images.

“LiverVNC” is an application available on the Siemens syngo.via platform. The application is designed to remove iodine from images but can be adapted to facilitate the removal of other materials. To adapt the protocol required inputting the Dual Energy Ratio (DER) for calcium.

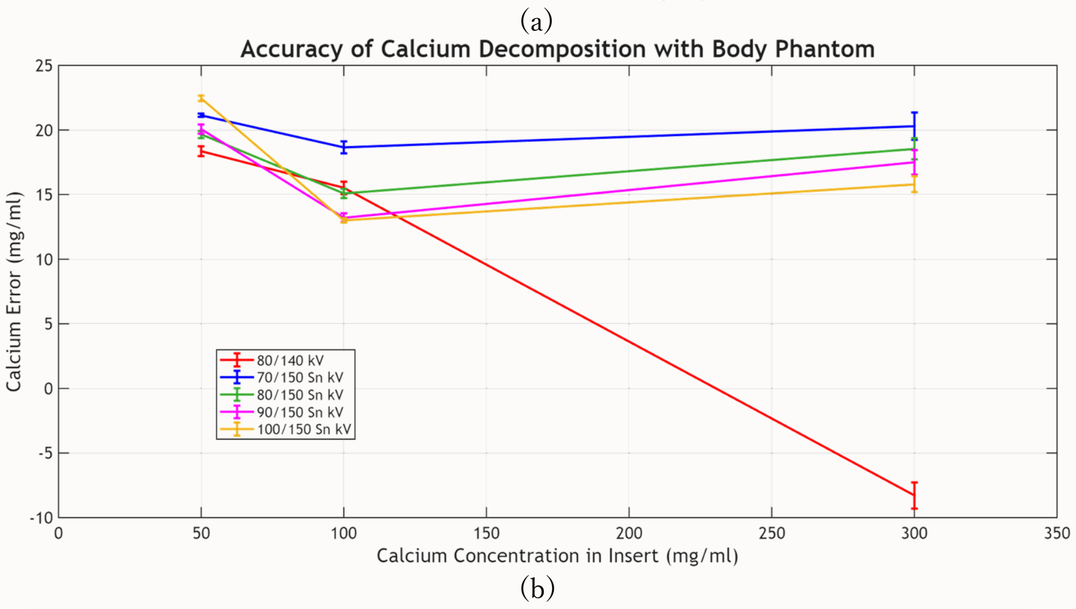
VNCa images were created for each kV pair and phantom size at a $CTDI_{vol}$ of 10 mGy. All images were reconstructed using the same parameters including kernel. The CT numbers of the calcium inserts were averaged using the three central slices.

Results & Evaluation

The obtained CT numbers were converted to a concentration of calcium (mg/ml) by applying the CT a calibration curve derived from a standard reconstruction. The accuracy of calcium removal of the VNCa reconstruction are shown for the head and body phantom in Figures 2a and 2b respectively.



(a)



(b)

Figure 2: Two plots of the accuracy of calcium removal of VNCa reconstructions where (a) is obtained using the head phantom and (b) is obtained using the body phantom. Both graphs show similar behaviour for each kV pair.

Figures 2a and 2b demonstrate that the presence of tin filtration plays a key role in consistently removing calcium across all concentrations as the dataset from 80/140kV significantly differs from all other beam pairs. For both phantom sizes, the average measured calcium concentration increases with spectral separation, while the variance decreases.

The results obtained with the 80/140 kV beam were excluded from the analyses and a Friedmann test performed on the remaining datasets. For the head phantom $\chi^2(3)=6.6$, $p=0.09$; for the body phantom $\chi^2(3)=3.4$, $p=0.33$. No statistically significant differences were observed in either case, but it is important to note that the small sample size of three (three inserts) reduces the statistical power. However, trends shown in Figure 2 indicate that further research, including image quality analysis, is necessary to identify the optimal kV pair.

References

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[3] B. Gosangi et al. Bone marrow edema at dual-energy CT: A game changer in the emergency department. *Radiographics*, 40, 2020