Identification of Ferromagnetic Materials of Medical Devices in Patients by Using Dual Energy CT

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Introduction

It is imperative for clinicians to identify if medical implants in patients contain ferromagnetic components before patients undergo MRI exams, because ferromagnetic materials in the environment of MRI can potentially introduce detrimental hazards on patients. Conventional single energy CT images (SECT) have ambiguity in differentiating material types. Since CT images from dual energy CT (DECT) can provide more accurate CT number quantification, they have the potential for better material identification.

This study aims to develop a technique to differentiate ferromagnetic/non-ferromagnetic material types by using DECT technique.

Methods

Experiments were performed on a GE Revolution Apex CT scanner with GSI (Gemstone Spectral Imaging) profiles.

Both SECT and DECT protocols were selected from routine head protocols with the same pitch = 0.516, tube current= 335 mA, tube rotation time = 0.8 s, slice thickness = 2.5 mm, AR% = 50, and collimation width 64*0.625 = 40 mm, but with different kVp (SECT images were acquired at 140 kVp while the DECT images were acquired at fast 80/140 kVp switching).

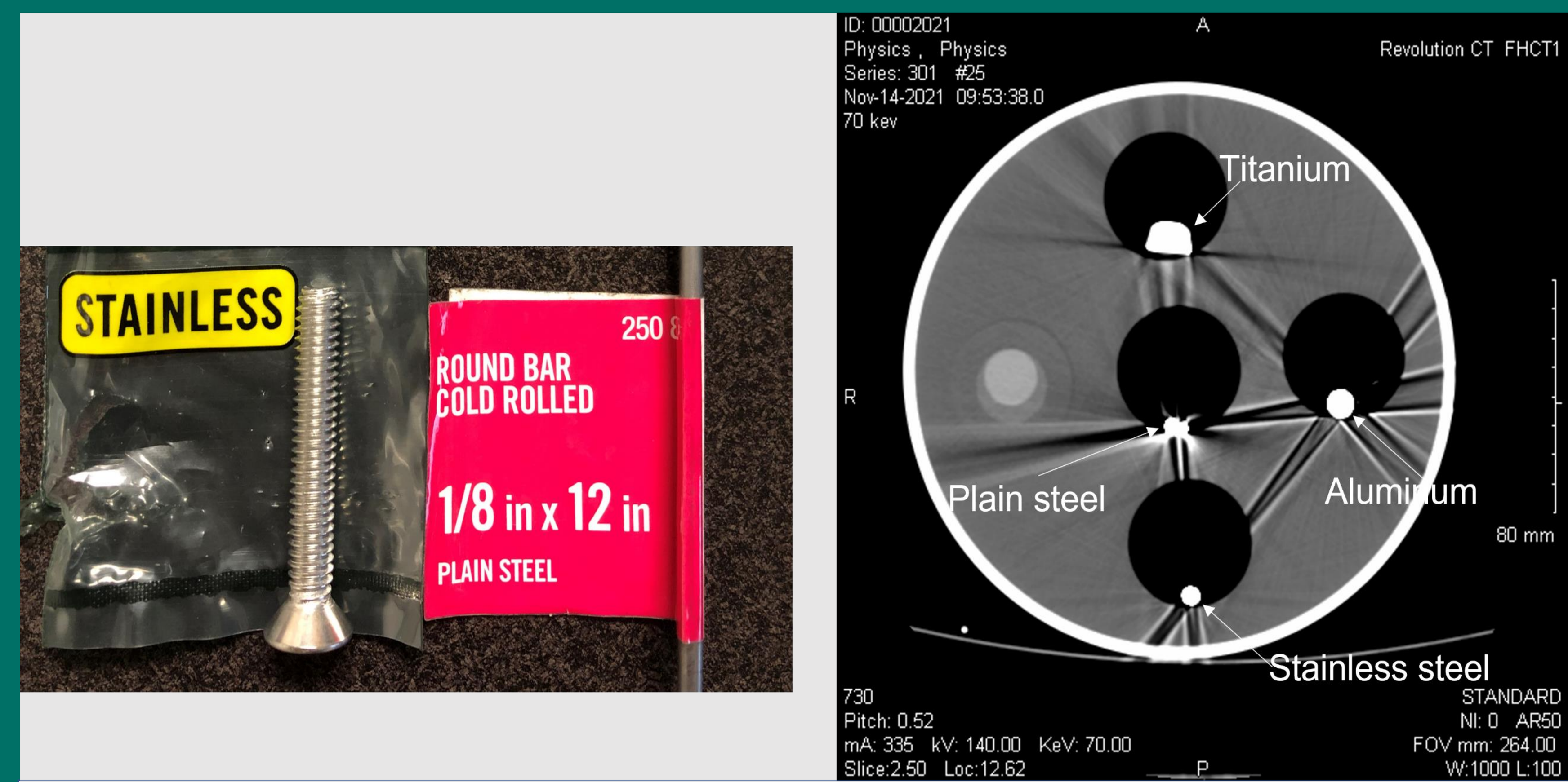
To prevent CT number saturation, the mode of extended CT number scale was activated which extended the CT number range from [-1024, 3071] (12-bit mode) to [-31743, 31743] (16-bit mode) (1).

Monochromatic images at different energy levels (70, 80, 90, 100, 110, 120, 130, 140 keV) were reconstructed from acquired DECT images.

A ferromagnetic steel rod, a SAE 304 non-ferromagnetic stainless steel screw (Everbilt®), an aluminum rod and a titanium rod were placed as inserts in an anthropomorphic phantom which has 21 cm diameter and 15 cm length (Figure 1).

Regions of interest (ROI) were manually selected on CT images for each material with its mean value as the CT number (HU).

To compare the difference of CT numbers between the two types of steel, a paired Student's t-test was performed.



(a) (b)

Figure 1. (a). The stainless steel screw and plain steel rod, (b). A DECT image of the phantom with inserts at 70 keV.

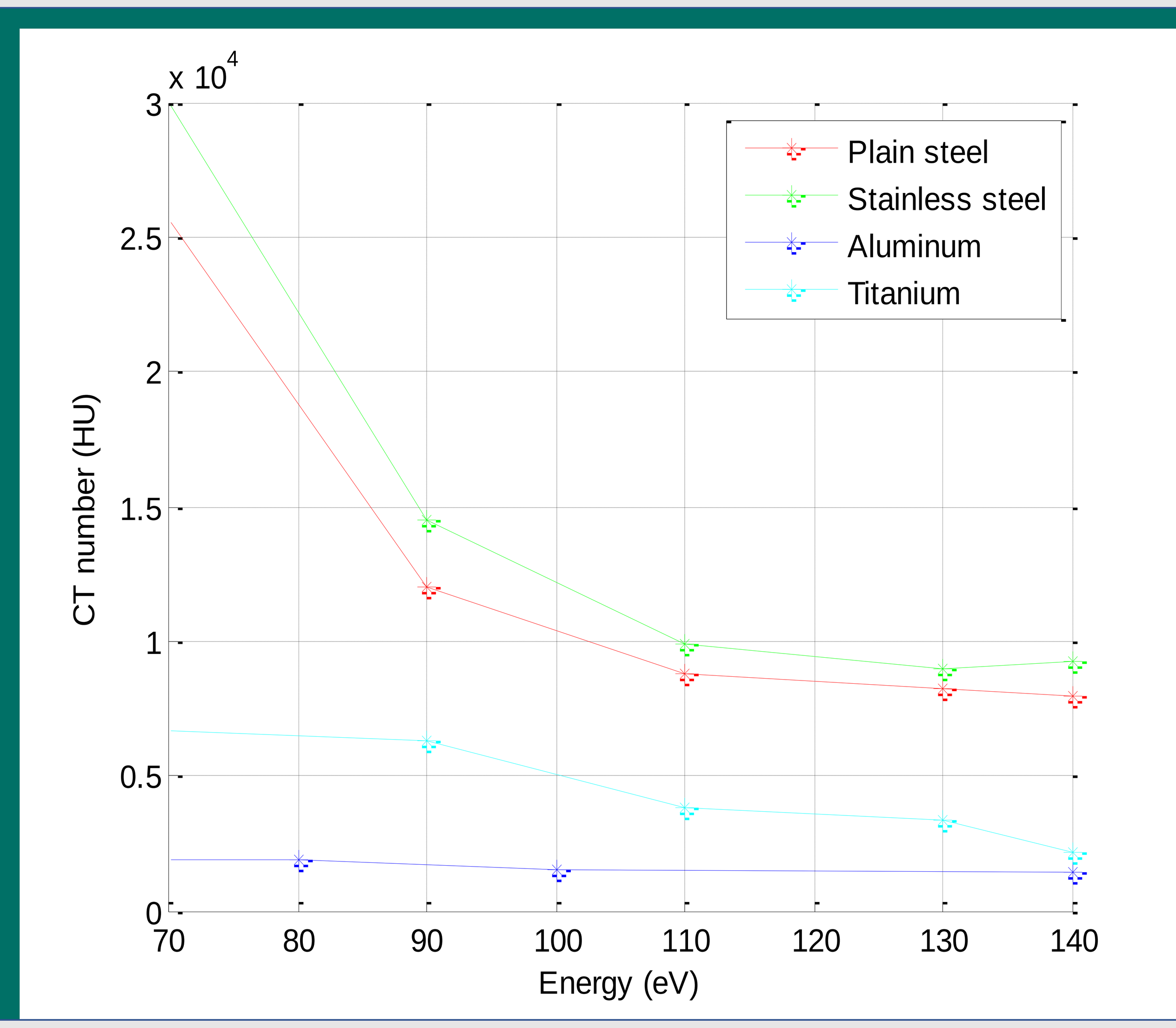


Figure 2. The CT numbers of the metallic rods at different energy levels.

Table 1. CT numbers (HU) from SECT and DECT.

	CT number (HU) (SECT @ 140 kVp)	CT number (HU) (DECT @70 keV)
The plain steel rod	16103.31±1033.84	27940.26±1190.41
The stainless steel screw	16662.46±1884.98 HU	22438.98±1314.49
	p=0.35	p<0.01

Results

Measured CT numbers from SECT images at 140 kVp for these two steels with 10 measurements indicate there is no significant difference between these two steels (16103.31±1033.84 (plain steel) vs 16662.46±1884.98 HU (stainless steel), p=0.35)(Table 1). However, DECT images of these two types of steel have significant different CT numbers at all energy levels, as shown in Figure 2. As an example, CT numbers of these two types of steel at 70 keV show the non-ferromagnetic stainless steel has a significantly higher CT number than the ferromagnetic plain steel (27940.26±1190.41 vs 22438.98±1314.49 HU, respectively, p<0.01). Measured CT numbers of other two metallic materials are much lower than these two types of steel (6634.12 for titanium and 1897.45 for aluminum at 70 keV).

Discussion

It is challenging to identify ferromagnetic and non-ferromagnetic steels, since the major composition of the two types of steel is iron. The plain steel which is a ferromagnetic material is a metal alloy with iron as its major composition and carbon as minor content (up to 0.30%) (2). The SAE 304 stainless steel is a metal alloy with iron still as its major composition, but with several metal additions such as chromium, nickel, magnesium, and molybdenum, presenting non-ferromagnetic. In SECT images, the CT number is ambiguous in differentiating these two types of steel with such subtle composition difference due to the polychromatic x ray source and its resulted beam hardening and metal artifacts (3). Using DECT, monochromatic images at different energy levels are not susceptible to these artifacts theoretically, thus enabling precise differentiation of subtle difference of linear attenuation coefficients between these two types of steel.

Conclusion

This preliminary phantom study presents the potential of using DECT in differentiating ferromagnetic and non-ferromagnetic steels. Future studies will be conducted using more representative ferromagnetic/non-ferromagnetic materials and medical devices in phantoms and patients.

Reference

1. GE. Revolution Apex™, Revolution™ CT with Apex edition, Technical Reference Manual. 2021.
2. https://en.wikipedia.org/wiki/Stainless_steel#cite_note-40.
3. McCollough CH, et al. Principles and applications of multi-energy CT: Report of AAPM Task Group 291. Med Phys 2020;47(7):881-912