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## Can desktop 3D printers be used to build patient specific heterogeneous phantoms for QA purposes?

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**Purpose:** To investigate the feasibility of making a heterogeneous humanoid phantom from the CT DICOM image set of actual patient using a commercially available desktop 3D printer and cost effective materials that have radiological characteristics of human tissue and bone

**Methods and Materials:** gMAX 1.5XT+ Desktop 3D printer (gCreate, NY) was used to build a 3D model reconstructed from a portion of the CT of the CIRS-Thorax phantom model 002LFC (CIRS Inc). The filament type used to print this phantom is PLA (PolyLactic Acid), which is a biodegradable plastic. The 3DSlicer (3DSlicer, MA), which is a free open source software package for visualization and image analysis, was software used to convert DICOM image CT to a Stereolithographic (STL) format, which is the format of 3D object compatible with all 3D printers. The 3DSlicer can extract or segment a specific density with specific Hounsfield Unit (HU) object from any DICOM CT image set, and then this segmented object can be imported by the 3D printing software to prepare it for printing. In this study, the bone structure of the CIRS phantom was extracted from the CT image set in order to keep only the tissue medium. There are many printing parameters that control the printing process and the filament consumption as well. In order to save the amount of filaments, we have selected very low (2%) infill ratio (defined as how much a solid model should be filled-in with material when printed), this will save us time and reduce the amount of filament consumed to print this phantom. With bone and air materials were extracted from the image and replaced by empty space. Then a silicon solid gel material was used to fill the tissue equivalent areas and left for an hour to dry. The bony area (extracted) was filled with gypsum powder (hydrated calcium sulfate  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) that was mixed with water.

**Results:** The processes of printing 4 cm thick slice of the CIRS phantom with 2% infill ratio and 100 mm/sec print speed took 3-4 hours. The infill ratio used to generate a wall that is strong enough to contain the materials added inside the phantom (i.e. silicon in tissue equivalent regions gypsum in bone equivalent regions). Figure 1 shows the axial slice of the actual CIRS phantom and that of the 3D printed one. As a last step, a CT Image set was acquired for our phantom, the HU value was ranging from -8 to 10, with relative electron density of 0.984 up to 0.998. Whereas for gypsum material, the HU value was ranging from 1070 to 1150, with relative electron density of 1.63 up to 1.72, which represents the relative electron density of cortical bones (1.65-1.7).

**Conclusions:** The process of making a portion of heterogeneous humanoid phantom from the CT image set of every specific patient is possible and can be optimized to be cost and time effective. The air gaps showing on the CT image of the 3D printed CIRS phantom (figure 2) can be avoided by using casting liquid silicon, which will fill all the space without air bubbles and without leaking outside the 3D printed phantom. By mixing water with gypsum in different proportion, we can obtain different bone type (spongy, cortical, etc.). All difficulties faced in our first trial will be avoided in our next 3D printed phantom, especially when the casting silicon liquid arrives.

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