Appendix 1

Supplement elaborating the workflow and techniques in the 3D printing process

Acquisition of the raw data

The area of interest is imaged with computerized axial tomography (CT) scan. A general protocol for acquisition on Seimens Somatom® Drive is listed below.

Image acquisition was on a dual source CT machine (Somatom Definition; Siemens®, Erlangen, Germany) with electrocardiographic gating in most cases. Sedation was not required in most of the cases. The heart rate in most of these patients was in the range of 90–130 bpm. Nonionic iodinated contrast was given as 1.5–2 mL/kg bodyweight using a pressure injector with a flow rate of 1–2.5 mL/s followed by a saline flush. Bolus tracking was done in the aorta or pulmonary artery based on the area of interest. Imaging parameters used for scanning include: detector collimation of 64×0.6 mm (64 sections, each with a thickness of 0.6 mm), pitch of 1.4–2, gantry rotation time of 330 ms, tube voltage of 80–120 kV and fully automated real-time anatomy-based dose regulation (CARE Dose 4D) to reduce radiation exposure. The spatial resolution was 0.3–0.45 mm with an in-plane temporal resolution of 75 ms.

Once the raw DICOM data was obtained by the CT scan, the work flow for preparation to 3-D print was as below.

Segmentation

Data acquired from CT scan is cropped to include the area of our interest. The next important process is segmentation which was done using Materialise's Mimics® Innovation suite software. The segmentation was done by the use of manual or semiautomatic methods. Thresholding, adjusting brightness, region growing and manual editing of single slice or multiple slices were the main methods use. Segmentation time could take anywhere between 30 to 90 minutes based on the intricacy and complexity of the case. Once segmentation of the desired area was achieved a mask of that area was produced. This mask was smoothed and converted to the STL (STerioLithography) format. In this file format, the object would be ready to be printed.

Choosing a material to print

Based on the hardness of the material needed to simulate the body part of interest we have used materials including Tango, Veroflex, Agilus, Bone matrix and Gel matrix resin.

We then choose parameters to decide the size and placement of the print. We choose to print the model to the exact scale. We also set up this to include support structures. Once this process is done, the next step is to convert the STL file into a code that contains instructions for the printer.

Printer used

We used a Stratasys® 750 J printer to print all our models. Once the printing process was done, post processing was done to remove the support structures manually, using waterjet and/or with a cleaning solution and finally dried. The time to print a model was between 4 to 18 hours based on the size and complexity of the model.

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