NEW YORK INSTITUTE OF TECHNOLOGY
College of Osteopathic Medicine
at Arkansas State University

Utilizing Iodine to Enhance Radiographic 3D Visualization of Cadaveric Hearts

Monique Westley
Class of 2025, NYITCOM at A-State

Jason M. Bourke
Biomedical Sciences, NYITCOM at A-State

ABSTRACT

A functional understanding of human anatomy is essential to a successful career in medicine. However, anatomical education remains a challenging course for students in their first year of medical school. The anatomy lab is often the first time these students are exposed to complex, 3-dimensional relationships of anatomy, as well as the specialty of radiology. In radiology, students are taught how to implement radiographic images and manipulate 3D anatomical models. Unfortunately, not all medical schools have access to cadaver-based labs. These students must rely on supplementary programs for their anatomical education, and these programs are contingent on accurate 3D models of anatomy. In many instances, anatomical models are based on artistic interpretations of "textbook anatomy", which often strays far from real anatomical variants seen in life. 3D models based on real anatomy often rely on low-resolution CT scans that fail to capture detailed aspects of these anatomical structures (e.g., neurovasculature within and around the heart). Our project seeks to create a protocol for accurately capturing soft-tissue data from embalmed organs using Diffusible Iodine-based Contrast-Enhanced Computed Tomography (diceCT) to artificially enhance the contrast of these tissues and better capture these details in a CT scan. Alcohol-fixed pig hearts were used as a test model. Hearts were diceCT prepared using a 1% and 3% iodine solution and allowed to set for 1 month. Specimens were then scanned at St. Bernard's Radiology Service Department. Our preliminary results found the higher concentration solution (3%) to be the most effective at perfusing the hearts within the window of time provided, albeit with excessive iodine uptake along the outer edges of the heart (rinding). The next stage of our study will be to send our prepared hearts to the NYITCOM μCT scanner in Long Island for more detailed imaging. Once we have obtained the appropriate concentration gradient and setting time for our suidae hearts, we intend to transfer our protocol to human heart. This will allow medical students to visualize aspects of human anatomy that are difficult to capture using standard 3D programs.

INTRODUCTION

The anatomy lab is often the first time medical students are exposed to complex, 3-dimensional relationships of anatomy, as well as the specialty of radiology. Unfortunately, in cadaver-based labs, the anatomy as well as the intimate association between deep internal organs is lost during dissection. This study seeks to create a protocol for accurately capturing soft-tissue data from embalmed organs using Diffusible Iodine-based Contrast-Enhanced Computed Tomography (diceCT). This study compares and contrasts how 1% and 3% iodine concentrations penetrate pig hearts and affect soft tissue resolution under standard hospital CT scans.[1]

MATERIALS & METHODS

Fig. 1

SPECIMENS

Two hearts from *Sus domesticus* (Suidae) were used as pigs have proven to be useful analogs for human clinical anatomy.[2] Specimen 1 weighed 373 grams (Fig. 1) and Specimen 2 weighed 388 grams (Fig. 2).

Fig. 2

PROTOCOL

Following the methods of Gignac et al.[1], both specimens were soaked in a 20% sucrose solution for 48 hours to prophylactically reduce dehydration from the iodine agent. Specimen 1 was then placed in a 1% iodine solution and Specimen 2 into a 3% iodine solution. Both specimens were stored in a dark room for four weeks. Following the iodine soak, the specimens were taken to St. Bernard's Imaging facility for CT scanning using a GE LightSpeed VCT 64 slice CT scanner at a slice thickness of 0.625 mm. CT data were exported in DICOM format for reconstruction using the imaging and 3D analysis software, Avizo (*ThermoFisher Scientific)*.

RESULTS

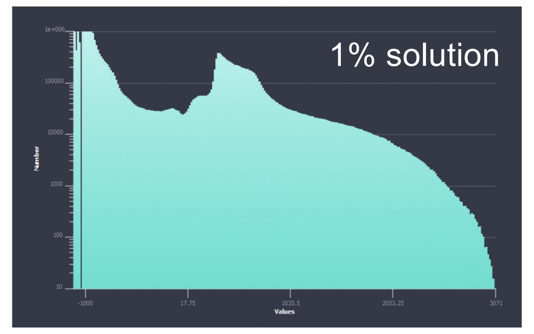

Fig. 3

In Fig. 3 and Fig. 4, there were equal Hounsfield ranges for both hearts. In Fig. 4, the second peak drop off for the 3% solution is more gradual than the 1% solution (Fig. 3), indicating better contrast for the 3% specimen.

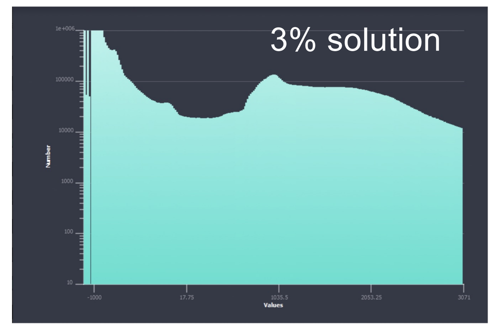

Fig. 4

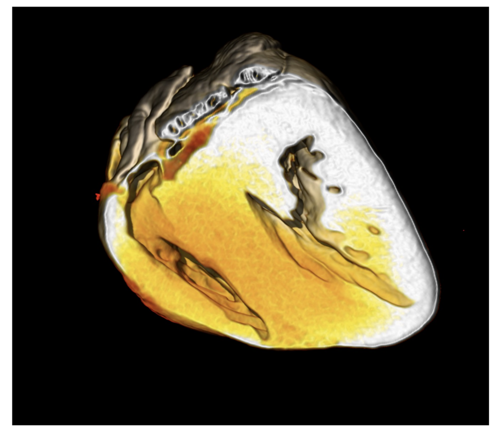

Fig. 5

Fig. 5 (1%) and Fig. 6 (3%) compare volume rendered specimens. We found that a 3% solution was more effective at penetrating the muscular wall of the heart and better at capturing the soft-tissue anatomy. However, this higher concentration also led to extensive "rinding" along the outer surface, suggesting that a 4-week soaking period may be too long for this higher concentration.

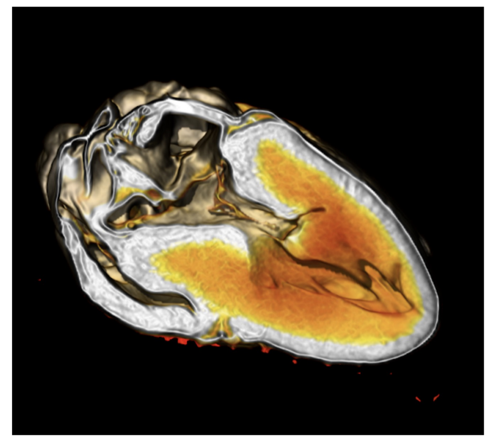

Fig. 6

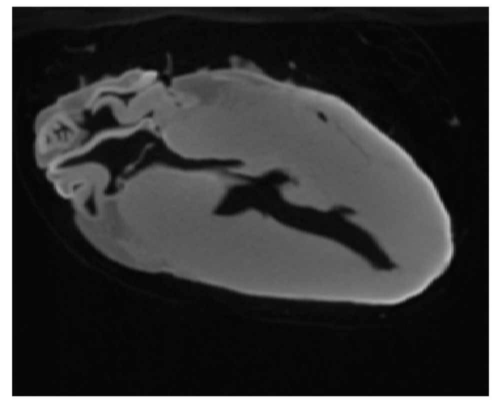

Fig. 7

Fig. 7 (1%) and Fig. 8 (3%) are hearts shown in lateral view. Note the fainter contrast at the same Hounsfield range for the 1% heart. Overexposure along the outer surface of the 3% heart specimen indicated rinding from the high iodine uptake along the surface.

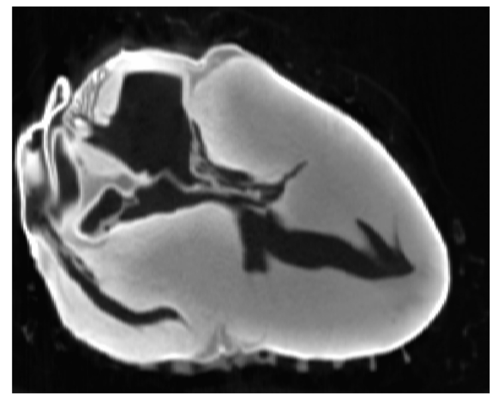

Fig. 8

DISCUSSION

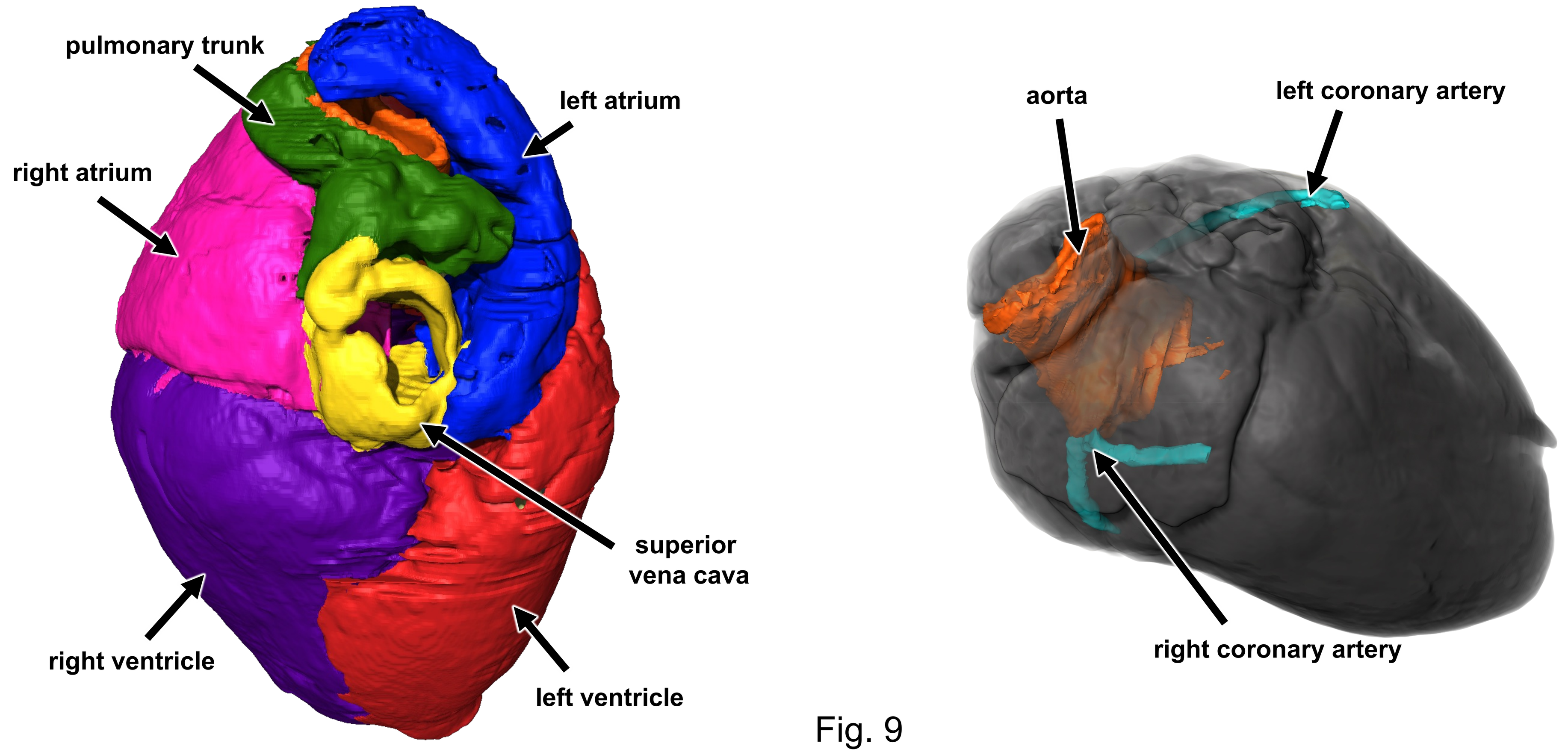

Fig. 9

Fig. 9. Segmentation example of the 3% pig heart using full segmentation of individual structure (left) and targeted segmentation of specific structures (right).

The next phase of this study is to have these specimens μCT scanned using the μCT scanner on the Long Island campus of NYITCOM. This will allow us to determine how effective this current concentration was at capturing the different tissues in the heart. Our future work aims to target the best mix of iodine concentration and soaking time for the most effective contrast. For instance, our 1% solution could provide equivalent or more contrast at the cost of a substantially longer soak time. In contrast, our 3% solution had a high amount of rinding on the perimeter at only 4 weeks. It is possible that an iodine solution of 1.5%–2% is the most appropriate mix. The appeal of this protocol is that it can be injected into the blood vessels of cadaveric specimens, allowing the vessels to distribute the iodine more naturally and with faster uptake; a process called SPICE-CT. This would allow images to be generated with the heart still inside the cadaver. In this manner, complex 3D relationships can be maintained and studied.

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