

Silicone Casting of the Chambers of the Heart and the Great Vessels

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Abstract

Orientation of the overlapping chambers of the heart is difficult for first year veterinary medical students to conceptualize and confounding when attempting to determine ventricular volume using imaging techniques. To better visualize and understand the spatial relationship between the ventricles, silicone casts of the heart and great vessels were made from unembalmed sets of heart and lungs. The major vessels of the heart were either ligated or cannulated for silicone injection. Room temperature vulcanizing silicone was activated, colored and injected until the cardiac chambers were filled. After hardening, the specimens were first macerated in boiling water and maceration was completed in 5% hydrogen peroxide. A highly durable, anatomically precise replica of the cardiac chambers, valves and great vessels was thus obtained for student instruction and image analysis.

Introduction

Conceptualization of the orientation of the cardiac chambers and their overlap can be difficult for first year veterinary medical students. The overlapping chambers and their spatial relationship to each other are difficult concepts to master before one can interpret diagnostic images of the heart. The overlapping chambers can also result in errors in quantitating nuclear medicine images of the heart. To aid understanding of ventricular overlap and to determine the actual overlap of the ventricles, silicone casts of the cardiac chambers were made from en bloc heart and lung specimens. Silicone has been used for casting of various cavities since 1966 (Frank and Yoder).

Materials and Methods

Specimen preparation

The heart and lungs were removed as a unit from 40 pound canine cadavers. The descending aorta (proximal to its first intercostal branch), brachiocephalic trunk, left subclavian artery and cranial vena cava were ligated and transected distal to the ligatures. The caudal vena cava was

transected near the diaphragm and cannulated with appropriate sized tubing. The left caudal lobar pulmonary vein was incised and cannulated with appropriate sized tubing directed toward the left ventricle.

Two room temperature vulcanizing (RTV) silicone polymers were used for this experiment [Silastic E RTV (Dow Corning, Midland, MI, USA); and P45 (Silicone Inc., High Point, NC, USA)] The polymers with their respective hardeners were mixed at a ratio of 10:1. The silicone was divided into 2 aliquots and colored, pink or blue, by adding color paste (Biodur, Heidelberg, Germany) until the desired color was achieved. Silicone injections were accomplished using catheter tip 60 ml syringes. Approximately 100 ml of pink silicone was injected into the left side of the heart via the cannulated pulmonary vein. Approximately 120 ml of blue silicone mix was injected into the right side of the heart via the caudal vena cava. Injection volume was determined sufficient when the silicone was observed filling the proximal ends of the pulmonary vessels. To maintain proper alignment of the ventricles, 3 applicator sticks were pushed at diverging angles through the left ventricular wall and its silicone

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filled chamber, through the interventricular septum, into the silicone of the right ventricle and finally through the wall of the right ventricle.

Curing

In order to maintain the pulmonary vessels in proper anatomical position, the trachea was cannulated and laboratory air was utilized to inflate and maintain inflation of the lungs in normal inspiratory anatomical position until the lungs were dry and the silicone had cured (24 hours).

Maceration

Once the polymer was cured, the specimens were placed in boiling water for 8 hours until most of the tissue was eroded away. A high pressure hose was used to remove the majority of the remaining tissue. Final tissue removal was accomplished by submersion of the cast in 5% hydrogen peroxide until the specimen was free of tissue debris.

Results

A highly durable, anatomically precise replica of the cardiac chambers, valves and great vessels was obtained (figure 1).

Discussion

Silastic E RTV has excellent tensile strength which produces a durable specimen and molding qualities which produce an intricate, detailed cast. Of the many polymers which we have tried for casting (Henry, 1993a, b) both Silastic E RTV and P45 produce high quality casts. These casts were used for study of the heart and great vessels along with silicone-plastinated whole hearts and silicone-plastinated valve preparations by our first year veterinary medical students.

Casts were also used to aid the research effort of radiology faculty. A common nuclear medicine study of the heart is the radionuclide ventriculogram. This study is acquired following equilibration of a blood pool agent, "Technetium, labeled to red blood cells (Sisson et al., 1989; Daniel et al., 1993; Daniel, 1996; Daniel and Bright, 1997). The gamma camera records the distribution of the radiolabeled blood cells within the body. For cardiac imaging, the gamma camera creates images of the blood pool of the heart. During a cardiac cycle, the blood volume in the ventricles decreases from diastole to systole. Since the ^{99m}Tc-RBC's are in equilibrium with the blood pool, changes in blood volume correspond to changes in radioactivity recorded by the gamma camera. By recording the changes in activity in the cardiac chambers during a cardiac cycle, volume curves can be created from which indices of heart function are derived. The canine car-

diac chambers overlap each other and determining the best camera position to separate the various chambers is difficult. The cast of the heart is an anatomic 3-D representation of the cardiac chambers as seen on the nuclear medicine images (figure 2). The cast was used to determine the best camera position with which to view individual cardiac chambers. By imaging the cast from both sides and then merging the two images (figure 1), the extent of ventricular overlap was readily discernible which allowed for extrapolating calculations of radionuclide imaging results.

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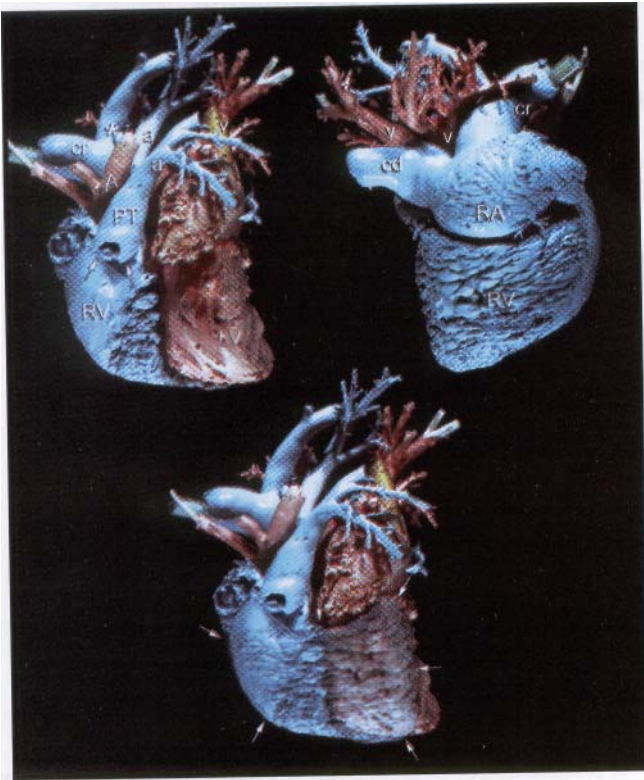


Figure 1. Silastic E RTV cast of cardiac chambers and great vessels. Upper right - As viewed from the right side; Upper left - As viewed from the left side (arrows - sinus of pulmonic valve);

Lower - Left view of cast with right ventricle (outlined by arrows) superimposed over the left ventricle, a - pulmonary artery, A - aortic arch, cd - caudal vena cava, cr - cranial vena cava, LV - left ventricle, PT - pulmonary trunk, RV - right ventricle, * - azygos vein.

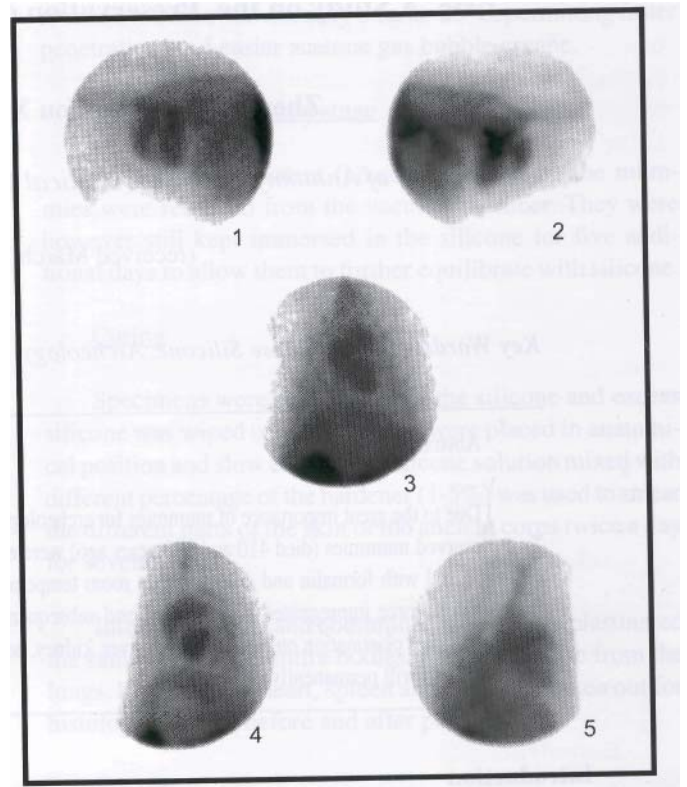


Figure 2. Radionuclide ventriculograms of the canine heart. 1 - Left lateral, 2 - Right lateral, 3 - Ventral, 4 - Ventral 30° left lateral oblique, 5 - Ventral 30° right lateral oblique.