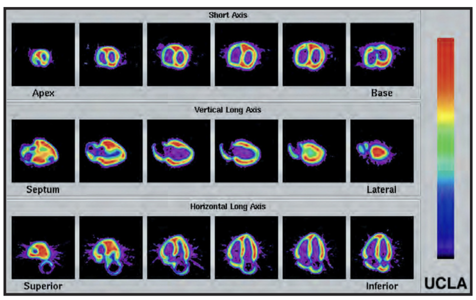
RSD
Radiology Support Devices, Inc.

Heart & Thorax Phantom



EVALUATION OF DETECTABILITY, EXTENT, AND SEVERITY OF MYOCARDIAL INFARCTS IN PATIENTS

- **Receptor Quantification as a Function of Uptake Ratio(s)**
- **Partial Volume Effects**
- **Scatter and Attenuation – Correction Schemes**
- **Threshold for Changes in Uptake(s)**
- **Comparison of Different Acquisition Modes, e.g. 2D vs. 3D Pet(s)**

RSD's Heart & Thorax Phantom is designed to provide different reconstruction strategies, imaging protocol for patients, and testing and validation of image registration techniques. It also delivers a valid assessment of mammoscintigraphy techniques.

Heart: An accurately anatomic heart model is based on vacuum-formed shells. It was designed using high resolution, contrast-enhanced, ultrafast CT data from a normal patient, slightly modified to facilitate its use. The left and right chambers are connected at the atrium region to make a single compartment which can be filled and flushed independently using two ports labeled HC (heart chambers). The right ventricle is slightly modified to allow air to escape during filling. The myocardial wall (MW) has two ports, flushing and independent filling. The volume of the heart chambers is 284 ml, while the volume of the myocardial wall is 238 ml, without inserted defects. The standard model includes three defects with volumes of 8.9, 13.5, and 41.7 ml, respectively. Each of the defects can be filled separately. Defects of different dimensions can be ordered at no added cost. A disassembled heart is sent on request, so that dimensions of a special set can be established. Note that different defects cannot be retrofitted in the assembled heart.

Basic Thorax: The thorax is molded of polyurethane, modified for tissue equivalence, with a mass density of 1.10 g/cc. The narrow beam linear attenuation coefficient measured at 140 keV (Tc-99m) is 0.160 cm -1. The volume of the thoracic cavity, when all organs (heart, lungs, and liver) are inserted, is about 8,200 ml. It is filled from the top, with either an inert or a radioactive solution, to simulate the thoracic background. A valve is installed at the base for conveniently draining the phantom. The residue on the walls of the cavity can be easily flushed with the fittings provided at the top of the phantom. A second, smaller fitting is also provided as an air-bleed during filling.

Lungs: Perfusable lungs are molded in hollow, vacuum-formed shells, filled with Styrofoam beads. The final mass density of 0.40 g/cc is attained by adding an inert or radioactive solution through a filling port at the top of each lung shell. Extra sets of lungs can also be furnished for work continuity. The volumes of the left and right lung shells are 907 ml and 1,134 ml, respectively.

Liver: A liver with a volume of 980 ml is included to evaluate the effect of its uptake on quantitative myocardial imaging. It is a vacuum formed shell, mounted on acrylic tubes to minimize artifacts. The liver can be filled with an inert or radioactive solution.

Fillable External Markers: A set of fillable capsules is provided to serve as external markers. Capsules can be filled with a radioactive solution and attached to the external surface of the phantom. The phantom can then be imaged, using SPECT or PET modalities to compare image registration techniques.

Thorax Overlay, Removable Breasts, and Breast Tumors: The thoracic phantom without the overlay simulates an average male patient. The overlay, with or without breasts, simulates a large female or a still larger male patient, respectively. It is then possible to evaluate the effect of additional attenuation and scatter on quantitative myocardial imaging. The volume of each vacuum-formed breast is 972 ml. A tumor, filled with a radioactive solution can be inserted to evaluate the planar and tomographic imaging techniques used for mammoscintigraphy. A set of breast tumors (3, 6, 9, 12 and 15mm diameters) is included. They are supported by thin, threaded nylon rods which pass through ports and are sealed by O-rings. They can be bent by hand to reach any part of a breast.

RSD Materials

<u>Soft Tissues:</u> There are unlimited, small variations in density and absorption throughout the human body. Phantom soft tissue is closely controlled to have the average density of these tissues.

<u>Skeletons:</u> RSD skeletons are highly detailed polymer moldings which reproduce the shape, mass density and attenuation coefficients of cortical bone and spongiosa. RSD's proprietary moldings allow for continuous production, eliminate the restrictions of human skeleton bones (including limited availability, unethical collection of human bone specimen, variable size, and uncertain chemical composition), and avoid the loss of marrows in dried natural skeletons thereby making RSD skeletons superior to "real bone."

<u>Molds:</u> Molds for the RSD cortical bone and spongiosa were made from human skeletons consistent with the sizes of the soft tissue molds.

<u>ICRU 44:</u> RSD skeletons conform closely to the standards established by the International Commission on Radiation Units and Measurements (ICRU Report No. 44); mass density is reduced slightly to take into account a small decrease in calcium content for older patients.

LINEAR ATTENUATION DATA

1. Monte Carlo simulation was used to calculate linear attenuation coefficients as a function of beam.
2. Monte Carlo results were validated with linear attenuation coefficients derived from Hounsfield Unit measurements at discreet energy levels.
3. RSD Phantom material linear attenuation data was compared to NIST data using ICRU Report 44 compositions of human tissues.
4. NIST data was interpolated when necessary.

MATERIALS	DENSITY (g/cc)
RSD Soft Tissue (Opaque)	1.08
RSD Soft Tissue (Transparent)	1.10
RSD Cortical Bone	**1.83**
RSD Trabecular Bone	**1.17**

RSD SOFT TISSUE					
Energy (MeV)	Mean (HU)	Calculated (M)	µ (ICRU 44)	% Difference	Ratio
00.08	60.30	0.1948	0.1932	0.0080	0.9921
00.10	52.88	0.1797	0.1795	0.0015	0.9985
00.12	57.10	0.1717	0.1709	0.0044	0.9956
00.14	52.95	0.1623	0.1624	0.0007	1.0007
00.20	--	0.1477	0.1439	0.0261	0.9746
00.30	--	0.1245	0.1246	0.0004	1.0004
00.60	--	0.0950	0.0941	0.0101	0.9900
00.80	--	0.0825	0.0826	0.0013	1.0013
01.00	--	0.0744	0.0743	0.0018	0.9982
02.00	--	0.0520	0.0519	0.0018	0.9982
03.00	--	0.0351	0.0357	0.0171	1.0174
06.00	--	0.0288	0.0291	0.0088	1.0088
08.00	--	0.0252	0.0255	0.0098	1.0099
10.00	--	0.0229	0.0232	0.0149	1.0151
15.00	--	0.0203	0.0203	0.0015	0.9985
20.00	--	0.0189	0.0189	0.0017	1.0017

RSD CORTICAL BONE					
Energy (MeV)	Mean (HU)	Calculated (M)	µ (ICRU 44)	% Difference	Ratio
00.08	1365	0.4345	0.4280	0.0151	0.9851
00.10	1048	0.3496	0.3562	0.0184	1.0188
00.12	0977	0.3211	0.3274	0.0191	1.0195
00.14	0902	0.2932	0.2986	0.0180	1.0184
00.20	--	0.2511	0.2513	0.0009	1.0009
00.30	--	0.2155	0.2137	0.0084	0.9916
00.60	--	0.1596	0.1598	0.0011	1.0011
00.80	--	0.1403	0.1402	0.0010	0.9990
01.00	--	0.1274	0.1261	0.0106	0.9895
02.00	--	0.0883	0.0885	0.0017	1.0017
03.00	--	0.0611	0.0625	0.0229	1.0235
06.00	--	0.0512	0.0525	0.0246	1.0253
08.00	--	0.0468	0.0474	0.0120	1.0121
10.00	--	0.0446	0.0444	0.0039	0.9962
15.00	--	0.0410	0.0409	0.0016	0.9984
20.00	--	0.0393	0.0397	0.0102	1.0103

RSD TRABECULAR BONE (SPONGIOSA)					
Energy (MeV)	Mean (HU)	Calculated (M)	µ (ICRU 44)	% Difference	Ratio
00.08	551	0.2849	--	--	--
00.10	515	0.2586	--	--	--
00.12	439	0.2337	--	--	--
00.14	318	0.1541	--	--	--