Comparing Cardiac Volume Measurement Modalities

How to determine the ideal volume measurement technique for heart hemodynamic studies.

There are a variety of techniques which can be used to determine common hemodynamic parameters in the research setting. Choosing the best method requires careful consideration of both the technology and the experimental protocol. Four well-established cardiac volume measurement techniques (echocardiography, pressure-volume catheterization, computer tomography (CT) and cardiac magnetic resonance (CMR)) are compared below. Advantages of the Pressure-Volume Catheter method include the relatively low start-up and maintenance costs, and the ability to measure both load dependent and load independent parameters including contractility.

	ECHOCARDIOGRAPHY (TRANSTHORACIC)	PV CATHETER (ADMITTANCE)	CARDIAC COMPUTER TOMOGRAPHY (CT)	CARDIAC MAGNETIC RESONANCE (CMR)
Required hardware	Echo unit & probes	PV unit & catheters	Sectional X-ray for computer reconstruction	Common CMR magnets (6.3-7 Tesla)
Specialized technician	Often, but not always	No	Yes in most US states	Yes in most US states
Portability	Unit on wheels	Light & portable	Heavy & stationary	Not portable
Measurement technology	Sound waves	Admittance via tetra-polar catheter	Radiation transmission through tissue	Magnetic properties of tissue
Use of radiation	No	No	Ionizing radiation	No
Specifically designed cradles for animals	No	No	Yes	Yes
Examination time	5 - 10 min	30 min	20 - 30 min	1 - 3 hrs
Use in publications	Very common	Increasingly common	Common	Moderately common
Spatial resolution (axial, lateral)	50 μm^2 (2D echo)	Not applicable	100 μm^3 (3D) microCT	200-300 μm^2 (in plane); 1 mm thick
Temporal resolution	Low	Very high, captures live transient events	Low	High
Contrast resolution	Limited	Not applicable	High	Very high
Signal to noise ratio	Acceptable	Acceptable	High	Acceptable
Common artifacts (streaks & blur)	Caused by breathing (need synchronization) can be limited by cardiac gating	Caused by breathing, can be contolled by a ventilator	Caused by breathing (need synchronization), can be limited by cardiac gating	Caused by breathing (need synchronization), can be limited by cardiac gating
Model-based estimation (geometric)	Volumetry relies on geometric assumptions	PV system corrects geometric assumptions live	Volumetry relies on geometric assumptions	Volumetry relies on geometric assumptions

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THE MEASURE OF BETTER RESULTS.

Comparing Cardiac Volume Measurement Modalities Cont.

	ECHOCARDIOGRAPHY (TRANSTHORACIC)	PV CATHETER (ADMITTANCE)	CARDIAC COMPUTER TOMOGRAPHY (CT)	CARDIAC MAGNETIC RESONANCE (CMR)
Reproducibility of volume data	Good	Good	Poor	Poor
Real time/ post processing	Volume calculations are based on geometric formulas. Need post-processing	Volume calculations are done in Real-Time. DO NOT need post processing	Volume calculations are based on geometric formulas. Need post processing	Volume calculations are based on geometric formulas. Need post processing
ECG Gating	Reconstruction of images based on gating	Not necessary to use cardiac gating	Reconstruction of images based on gating	Limited by cardiac ECG triggering, respiratory gating
Respiratory Gating	Compulsory	Optional	Compulsory	Compulsory
Inter-user variability	High	Very Low	High	High
Versatility/ Other information from scan	Real-time, increases with use of Doppler or 3D echo	Collects multiple parameters (ESPVR, EDPVR, PVA, PRSW, Et, Ea, dp/dt min/ max)	Quantitative measure of tissue density can be used to examine myocardial viability. Ability to produce 3D	High tissue contrast, No contrast agent necessary, ability to acquire 3D
Accuracy of volume estimate	Usually over estimates EDV based on histomorphometry	Usually good EDV estimation based on histomorphometry	Usually over estimates EDV based on histomorphometry	Usually over estimates EDV based on histomorphometry
Contractility	Basic (EF%, FS%); load dependent	Excellent with IVC occlusion; load independent	Basic (EF%, FS%); load dependent	Basic (EF%, FS%); load dependent
Preload/ Afterload detection	Difficult (probe positioning)	Excellent with IVC occlusion	Difficult	Difficult
Invasiveness	Moderate	High	Moderate	Moderate
Longitudinal studies	Yes	No	Yes	Yes
Initial price of system	High	Low	High	High
Price for experiment	Low	Moderate	High (rental & technician fees)	Very High (rental & longer tech time)
Maintenance costs	Low	Low	High	Very high
Application fields	Cardiovascular (cavity size, valve function etc.), Fluid around heart (pericardial effusion) Cancer (chest tumor biology etc.), Developmental biology (CV morphogenesis), Gene therapy (cardiac sonoporation).	Cardiovascular (left and right cavitary pressure-volume, resistance in the lungs, cardiovascular pressure-volume coupling, cardiac elastance) Isolated working heart (left ventricle pressure-volume).	Cardiovascular (cavity size, valve function, coronary artery calcification etc.), Cancer (chest tumor biology), Developmental biology (CV morphogenesis).	Cardiovascular (cavity size, valve function etc.), Fluid around heart (pericardial effusion) Cancer (chest tumor biology etc.), Developmental biology (CV morphogenesis).