Comparison of bSSFP-Cine Imaging and PV Loop Measurements in a Swine Model of Chronic Ischemic Cardiomyopathy

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Target Audience Scientists interested in functional cardiovascular assessment.

Purpose Pressure-Volume Loop (PV-Loop) assessment has an established place in the measurement of ventricular function; a major limitation is that the use of conductance catheters is invasive. By changing the amount of blood available to the heart (e.g. balloon occlusion of the inferior vena cava (IVC)), pressure vs. volume relationships can be generated which reflect the response of the heart to varying load conditions, and parameters such as the end-systolic pressure-volume relation (ESPVR) are used to assess ventricular contractility (Fig. 2) [1]. Alternatively, cardiac MRI is a minimally invasive method for heart functional assessment. Ventricular volumes and ejection fraction (EF) measured by MRI are considered reliable for assessing heart structure and function [2]. Cardiac output measured with a PV-loop catheter has been compared with MRI using bSSFP cine MRI and cine PC flow imaging under rest/stress conditions with good agreement in normal swine [3]. However, accurate PV loop measurement may be compromised in the presence of myocardial infarction. In this study, we compare stroke volumes measured with MRI and with PV-Loop methods in a swine model of myocardial infarction under rest conditions.

Methods This study was approved by the institutional Animal Care and Use Committee. Balloon occlusion of the LAD coronary artery was used to induce myocardial infarction in 12 Yorkshire mini-swine (Day 0: mean 35 kg, range 30-40 kg; Day 55: mean 61kg, range 40-70kg), with a goal of approximately 15% infarction by volume of the LV. Cine MRI with segmented bSSFP imaging (20x5mm slices; 1.5T Signa HDxt, GE Healthcare, Milwaukee, WI) was performed at 55 days to assess myocardial function; late-Gd enhanced imaging (0.15 mmol/kg; Omniscan, GE Healthcare, Milwaukee, WI) demonstrated infarct location. Following MRI, each animal was catheterized and a PV-Loop catheter (Scisense, London, Ontario) was used to acquire PV Loops at rest using IVC balloon occlusion to vary pre-load.

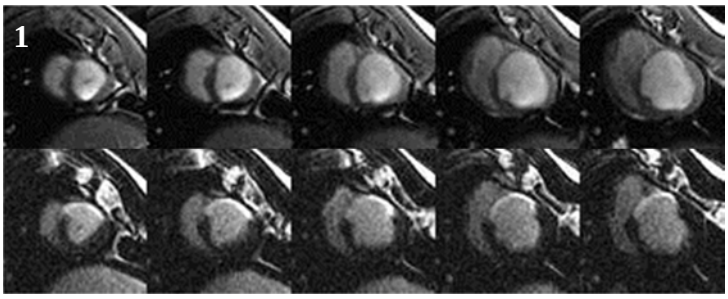

Fig 1 Five slices of diastolic-phase cine bSSFP (top) and LGE viability (bottom)

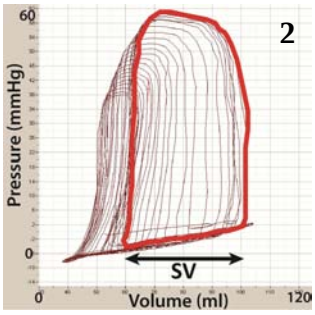

Fig 2 PV loop for one pig; one baseline loop is highlighted in red.

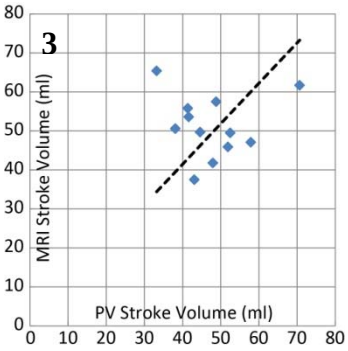

Fig 3 Correlation between bSSFP MRI and PV-Loop stroke volume (SV).

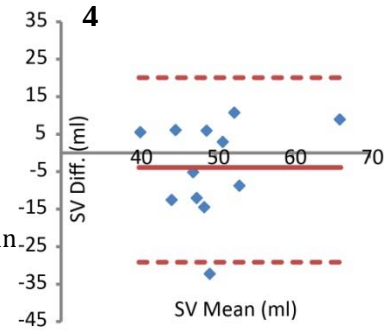

Fig 4 Bland-Altman analysis of data from Fig. 3.

Results Five bSSFP slices from end-diastole, with matching LGE images, are shown in Fig. 1. Manual segmentation was used to determine end-systolic volume (ESV) and end-diastolic volume (EDV). An example PV-Loop curve under rest conditions is shown in Fig. 2; a baseline cycle with no IVC occlusion is highlighted in red. (Decreasing pre-load shifts the curve to the left.) Stroke volume (SV) was measured for both methods; a linear fit (dashed line in Fig. 3) gave SV(MRI) = 1.03*SV(PV), $r^2 = 0.94$. A Bland-Altman plot for the same data is shown in Fig. 4.

Discussion and Conclusions PV-Loop measurements using a conductance catheter or cardiac MRI can be used to provide information about cardiac function. In this study, the relationship between stroke volume (SV) measured with MRI and PV-Loop catheterization was determined in a swine model of chronic ischemic cardiomyopathy, and the two methods compared favorably. Other measurements such as ESV and EDV were not as well correlated; this could be due to the limitations in calibrating absolute PV-Loop volumes, and the effects of time and catheterization on physiological state.

References [1] Kass DA, et al, *Cathet Cardiovasc Diagn* **15:**192–202 (1988). [2] Walsh TF, Hundley WG, *Cardiol Clin* **25:**15-33 (2007). [3] Lin HY, *et al, J Magn Reson Imaging* **34:**203-210 (2011).