Relationship Between Mitral Velocity and Mitral Flow Time-Profiles During Ventricular Filling

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Introduction: Ultrasound is the current standard for assessment of diastolic function. Particularly, blood velocity at a point in space, $v(A_0, t)$, is used as a surrogate for mitral flow, Q_{mitral}, and changes in left ventricular (LV) volume. Mitral flow is defined as $Q_{mitral} = \frac{dV(t)}{dt} = \int_{MV} v(A, t)dA$, where $\frac{dV(t)}{dt}$ is the rate of LV volume change, MV is the mitral valve area, and $v(A, t)$ is velocity over time (t) and 2D space (A). However, Q_{mitral} and the velocity measured at a point in space, $v(A_0, t)$, are linearly related only if both the velocity profile over space and the mitral valve area are constant over time. It has previously been shown that this not the case[1,2]. The relationship between $v(A_0, t)$ and Q_{mitral} for commonly derived clinical diastolic functional parameters such as the E/A ratio or deceleration time (DT) is unknown. The goal of this study is to characterize the relationship between volumetric flow and single-point velocity profiles at several points along the inflow path.

Methods: 10 volunteers were examined on a Siemens Sonata 1.5 T MRI scanner. Through-plane velocity using phase contrast (PC) was acquired for a basal short axis slice; velocities were integrated over the mitral valve area to yield flow. To estimate error due to mitral annular motion during filling[3], integrated flow curves were compared to volume time curves obtained using method of disks (MOD). In-plane velocities were acquired for a 4 chamber view. Velocity was measured at 1 cm intervals to ±2 cm from the leaflet tips (Fig. 1). Typical PC sequence parameters were: 8 mm slice thickness, 3.2/4.9 ms TE/TR, 75×128 matrix, 15/30° in/through plane flip angle, 1.2 m/s velocity encoding strength, 230×400 mm² FOV, rate 2 parallel imaging, 3 views per segment (29.5 ms temporal resolution), and reconstructed to 10 ms/cardiac phase. Images were acquired during breath holds.

Results: Time curves for velocity at the leaflet tips and flow are shown in Figure 2. Table 1 and Figure 3 compare quantitative descriptors for velocity profiles to flow profiles. Error in PC flow measurements, obtained by comparing MOD-derived volumes to integrated PC flow values, over the E-wave is 1 ± 11 mL, corresponding to a flow of 5 ± 46 mL/s.
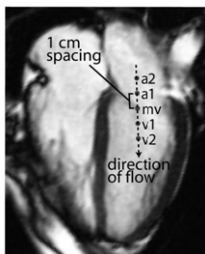

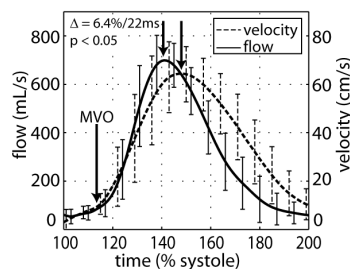Figure 1. The location of blood velocity measurements are shown.

Table 1. Quantitative descriptors

	Atrium (a1)	Leaflet (mv)	Ventricle (v1)	Flow
E (cm/s, mL/s)	62 ± 9 †	68 ± 9 *‡	64 ± 8 †	714 ± 118
A (cm/s, mL/s)	28 ± 6 ‡	27 ± 8 ‡	18 ± 10 *†	302 ± 67
E/A	2.3 ± 0.5 †‡	2.7 ± 0.8 *‡	4.3 ± 1.8 *†	2.4 ± 0.5 ‡
E peak time (% sys)	147 ± 7	147 ± 8	149 ± 9	141 ± 3 *†‡
E peak time (ms from AVC)	159 ± 23	161 ± 26	165 ± 31	139 ± 11 *†‡
DT (ms)	156 ± 25 ‡	170 ± 31 ‡	206 ± 36 *†	138 ± 26 †‡
Full width half max (FWHM, ms)	152 ± 12 †‡	165 ± 19 *‡	177 ± 28 *†	121 ± 12 *†‡

* indicates value is significantly different (p<0.05) from a1, † from m1, and ‡ from v1

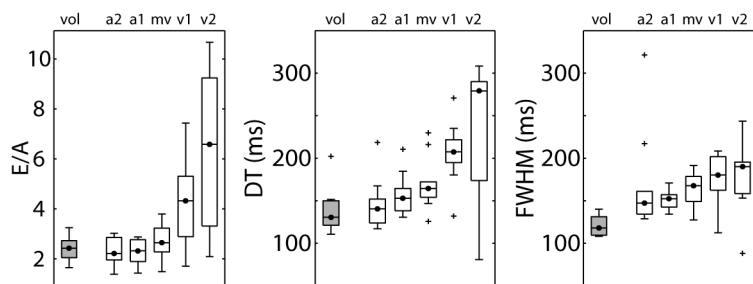Figure 2. Mitral blood velocity and flow profiles are shown for early filling (N=10).

Figure 3. The variation over space of parameters describing velocity profiles are shown and compared to values obtained from flow curves.

Conclusions: Diastolic blood velocity profiles and derived parameters are significantly different from volumetric flow profiles and vary significantly as a function of measurement location; velocity profiles peak later in time and decay to zero more slowly than flow profiles. Velocity time curves in the left atrium, slightly above the conventional leaflet tip measurement location, are less susceptible to measurement error and are most similar to flow curves.

References: 1. Bowman AW et al. Am J Physiol Heart Circ Physiol 2004;287(4):H1650-7. **2.** Flewitt JA et al. Am J Physiol Heart Circ Physiol 2007;292(6):H2817-23. **3.** Kozerke S et al. J Magn Reson Imaging. 2001;14(2):106-12.