# Effect of Background Velocity Error on Measured Time of End-systole in Patients with Aortic Regurgitation by Phase Contrast MRI

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***Background***: To quantify the severity of aortic valvular regurgitation, the regurgitant volume $V_{reg}$ or regurgitant fraction RF, where RF = $V_{reg}$ / $V_{for}$, with $V_{for}$ the forward stroke volume, is often measured. Phase-contrast MRI (PC-MRI) is frequently used for this purpose. However, PC-MRI is well known to suffer from stationary offsets due to nonzero background velocity $v_{BG}$. Methods to correct for $v_{BG}$ have been developed but are not perfect. It is therefore impossible to know the true deviation of the measured velocity from the actual flow velocity. The magnitude of $v_{BG}$ is dependent on several factors, including the scan plane and spatial position; they may arise from a variety of effects, including eddy currents and concomitant gradients. The errors $v_{BG}$ are commonly at least ± 2 cm/s in magnitude (Lloyd, 2005). Even a small error $v_{BG}$ of the order of ± 1 to 2 cm/s has a large impact on the calculation of $V_{reg}$ or RF (Gatehouse, 2005). It will also affect the interpolated time the measured velocity crosses the zero line, corresponding to the end of systole $T_S$. An accurate measurement of $T_S$ is critical, as this determines the beginning time for the diastolic integration of velocities that leads to the calculation of $V_{reg}$. The impact of the velocity error offset $v_{BG}$ on $T_S$, and hence on its contribution to errors in the measurement of $V_{reg}$ or RF, has not been investigated. Therefore, we performed a theoretical error analysis of the impact of $v_{BG}$ on $T_S$.

***Methods and calculations***: Phase contrast flow data in aortic regurgitation data can be approximated as a quadratic function in time near the minimum (which occurs in early diastole, shortly after the curve crosses the zero velocity value at $t_o$, taken as the graphically determined $T_S$); this is written as

$$v(t) = a\,(t - t_{min})^2 - |v_{min}| \tag{1}$$

Introducing an offset error velocity, (1) becomes

$$v(t) = a\,(t - t_{min})^2 - |v_{min}| \pm v_{BG} \tag{2}$$

Setting equation (2) equal to zero and solving for its roots yields the error contributed by the introduction of the unknown $v_{BG}$ on the experimentally determined $T_S$. The "left" or lesser root is the meaningful value, resulting in

$$t_{\mp} = t_{min} - \left[\frac{|v_{min}| \pm v_{BG}}{a}\right]^{1/2} \tag{3}$$

And this is the total error in the measurement of $T_S$ due to the contribution of $v_{BG}$.

***Results***: As an example, the mean flow velocity as measured by phase contrast MRI in the proximal ascending aorta in a typical patient with moderate aortic regurgitation is shown in the Figure, using ECG gating triggered on the R wave. A curve fit based on equation (1) was performed to the velocity data. Fit values were $a = 2.1 \times 10^{-3}$ cm/s$^3$, $t_{min}$ = 380 ms, and $|v_{min}|$ = 7.1 cm/s in this case; the fit is shown in the dashed line in panel B. The raw data yield $T_s$ = 323 ms after onset of the R wave trigger; incorporating the effect of an arbitrarily chosen $v_{BG}$ of ± 2 cm/s (for illustration purposes), $T_S$ is found to range between 315 and 331 ms. This small range is smaller than the cine frame duration (typically 30 to 40 ms in PC-MRI scans).

***Conclusions***: Small offset errors occur in PC-MRI measurement of velocity. However, though this error may have a large effect on $V_{reg}$ and RF, it has little impact $T_S$ and need not be considered during its measurement.

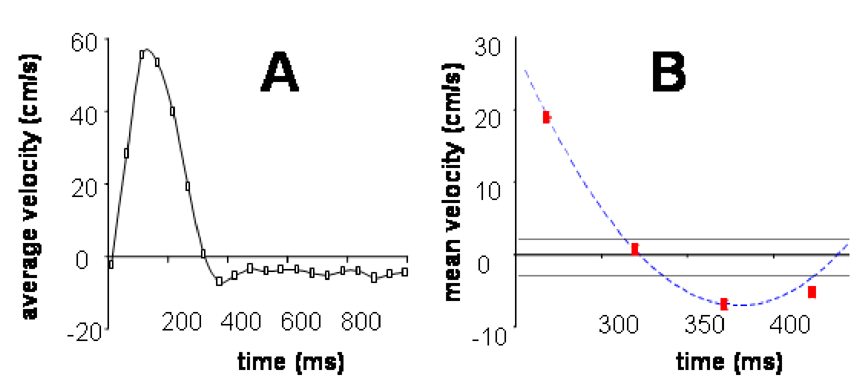


*Figure. A, raw data. B, expansion of the data near the crossing of zero velocity near 320 ms after the R wave trigger (data points in red; dashed blue line the fitted curve as described in text; horizontal lines at $v_{BG}$ = ± 2 cm/s shown to illustrate the change in the time-axis intercept introduced by the error $v_{BG}$).*

References:

(1) Lloyd SG, et al. (2005) Proc Intl Soc Mag Reson Med. 3:1729.

(2) Gatehouse PD, et al. (2005). Eur Radiol. 15 :2172-2184.