



DESIGN AND CONSTRUCTION OF A VASCULAR FLOW CIRCUIT FOR MAGNETIC RESONANCE IMAGING STUDIES

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Cardiovascular disease (CVD) is the leading cause of death in the United States - approximately 840,000 deaths per year. Recent advancements in phase-contrast magnetic resonance (PCMR) imaging, which is a non-invasive, non-ionizing radiation-based imaging modality, now provide the ability to visualize and quantify the hemodynamics (i.e. blood flow patterns) in the human body. Given the known association between CVD and disturbed blood flow patterns, PCMR holds tremendous clinical value as a diagnostic and prognostic tool for functionally and structurally assessing the heart and great vessels. However, the continued use of PCMR imaging to evaluate hemodynamic-induced CVD requires rigorous, well-controlled experimental testing, and validation prior to clinical implementation. These improvements to PCMR are best performed in an experimental setting, without the need for human subjects, in order to refine the validity of PCMR-acquired hemodynamics for human use. The aim of our study was to design and construct an MRI-compatible flow circuit that subjects patient-specific arterial models to physiological fluid dynamic conditions in order to advance PCMR imaging. The flow circuit consisted of a positive-displacement pump, controlled via a servomotor, to produce (output) a user-defined flow waveform. The pump was connected to the arterial models with PVC fiber-reinforced tubing filled with water. Real-time fluid dynamic measurements were acquired with an in-line ultrasonic flow meter and pressure transducer. All components were controlled via a data acquisition card connected to a laptop computer to simultaneously control the pump head rotation velocity, and acquired flow rate and pressure readings. Our research efforts have successfully manufactured a custom computer-controlled flow circuit, capable of accurately simulating a range of physiologically relevant waveforms with minimum cycle-to-cycle variation (Fig. 1). Our data showed that under steady flow conditions, the difference between the desired and measured flow waveform was 0.002 ± 0.013 L/min ($p = 0.16$), with maximum differences of 0.03 L/min. Furthermore, the difference in sinusoidal waveforms was 0.064 ± 0.082 L/min ($p = 0.21$), and the maximum difference was 0.25 L/min. A latency of 20 ms was observed between desired and measured sinusoidal flow waveforms. Finally, the difference in aortic flow waveforms was 0.018 ± 0.13 L/min ($p < 0.05$), with a maximum difference 0.61 L/min, and latency of 30 ms. The developed testing apparatus will allow for the robust analysis, validation, and subsequent improvement of current PCMRI imaging techniques and processing for patient-level CVD risk-assessment in the clinical setting.

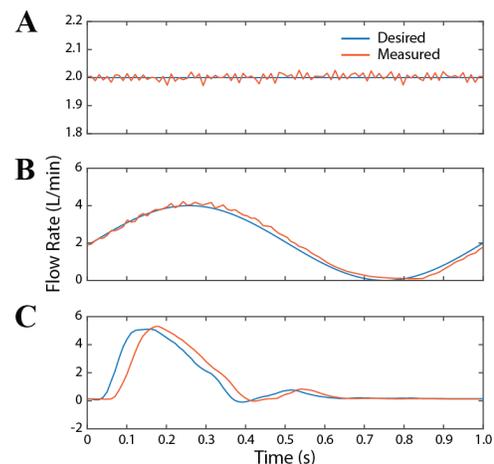


Figure 1. Representative desired and measured A) steady, B) sinusoidal, and C) aortic flow waveforms in an ideal flow circuit configuration.