



Low pulse pressure with high pulsatile external left ventricular power: Influence of aortic waves

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ARTICLE INFO

Article history:

Accepted 11 May 2011

Keywords:

Pulse pressure
Aorta
Wave dynamics
Pulsatile load
Wave intensity

ABSTRACT

Elevated pulse pressure (pp) is considered to be a risk factor for adverse cardiovascular events since it is directly related to an elevated myocardial workload. Information about both pressure and flow wave must be provided to assess hemodynamic complexity and true level of external left ventricular power (ELVP). pp value as a single feature of aortic waves cannot identify true level of ELVP. However, it is generally presumed that ELVP (and consequently LV workload) is positively correlated with pp . This study examined this positive correlation. The aim of this study was to test the hypothesis that aortic wave dynamics can create destructive hemodynamic conditions that increase the ELVP even though pp appears to be normal. To test this hypothesis, a computational model of the aorta with physiological properties was used. A Finite Element Method with fluid–structure interaction was employed to solve the equations of the solid and fluid. The aortic wall was assumed to be elastic and isotropic. The blood was assumed to be an incompressible Newtonian fluid. Simulations were performed for various heart rates (HR) and different aortic compliances while keeping the shape of the inlet flow and peripheral resistance constant. As expected, in most of the cases studied here, higher pp was associated with higher LV power demand. However, for a given cardiac output, mean pressure, and location of total reflection site, we have found cases where the above-mentioned trend does not hold. Our results suggest that using pp as a single index can result in an underestimation of the LV power demand under certain conditions related to the altered wave dynamics. Hence, in hypertensive patients, a full analysis of aortic wave dynamics is essential for the prevention and management of left ventricular hypertrophy (LVH) and congestive heart failure.

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1. Introduction

The workload on the left ventricle (LV) is composed of steady and pulsatile components. The pulsatile load is the result of the complex dynamics of arterial waves. The dynamics depends on both the heart's pumping characteristics (stroke volume, heart rate, and ejection fraction) and the arterial system's wave characteristics (wavelength, wave speed, and reflection sites) (Milnor, 1989; Nichols and O'Rourke, 1998; Zamir, 2000).

Pulse pressure (pp) is the difference between the peak and the foot of the pressure wave, and it has been known to be an indirect measure of pulsatile load on the LV. Clinical investigations have confirmed that an abnormal pulsatile load plays an important role in the pathogenesis of left ventricular hypertrophy (LVH) and the progression of LVH to congestive heart failure (CHF) (Curtis et al.,

2007; Hashimoto et al., 2008; Mitchell et al., 2010; Mitchell et al., 2001; Ooi et al., 2008). Although the LV pulsatile load accounts only for approximately 6–12% of the total load in young healthy adults (O'Rourke, 1967); this percentage can increase significantly in subjects with vascular disease, hypertension, or vascular aging (Safar and O'Rourke, 2006).

Wave dynamics in a compliant tube depends on three parameters: (1) fundamental frequency of the propagating waves, (2) wave speed (which depends on material properties of the tube), and (3) reflection sites (Aвраhami and Gharib, 2008; Hickerson et al., 2005). Therefore, for a given inlet flow wave generated by the heart, wave dynamics in the aorta (compliant tube) is controlled by the heart rate (fundamental frequency), aortic rigidity (which influences the wave speed), and location of the reflection sites.

The aim of this study was to test the hypothesis that aortic wave dynamics can create destructive hemodynamic conditions that increase the external LV power (ELVP) even though the pp appears to be normal. We chose a computational approach to

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