

Letter to the Editor

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Response to Uncertainties in Estimating the Site of Arterial Wave Reflection

We thank Schillaci et al¹ for their interest in our work.² We appreciate the opportunity to answer the questions that they put forward. The first question concerns the change in return time of the reflected pressure wave at the proximal end of a uniform tube when the load at its distal end changes. First, we occluded the tube (loaded it with an infinite impedance), giving a real reflection coefficient of 1: no phase shift occurred, and the time of return was determined by twice the travel time. Next, we loaded the tube with the 3-element Windkessel and set its characteristic impedance equal to that of the tube. The Windkessel is a lumped model, wave travel does not exist, and the reflection site remains at the same position. However, in this case, there was a phase shift of reflected waves (complex reflection coefficient), and this gave the delay in the backward wave seen in our Figure 2B.² In the anatomically correct model, the reflected wave increases with distal aortic occlusion but arrives back in the ascending aorta at approximately the same time, whether the distal aorta is occluded or not. In the anatomically correct model, the aorta is not a single uniform tube, and many reflection sites exist (as in the real systemic tree). The low harmonics of pressure, ie, those that are reflected, happen to exhibit the same phase shift after occlusion, suggesting a reflection site at the bifurcation but not proof of it. Latham et al³ experienced great difficulty in attempting to determine the reflection site and suggested 2 major sites of reflection. From the perspective of the heart, the exact site of pressure reflection is not important; it is the timing and magnitude of the reflected wave arriving in the ascending aorta that determine the widening of the pulse pressure. Indeed, a doubling of aortic pulse wave velocity does not result in a decrease of the return time by a factor of 2, showing that the distance of the reflection site is not constant. In effect, each harmonic of pressure is reflected with a different phase.

Segers et al⁴ determined several measures of time of return of the reflected wave, such as inflection point and shoulder of the carotid pressure. Although the decrease of inflection-based return time was inversely related to an increase of pulse wave velocity, these authors also report that this return time did not correspond with the timing obtained from wave separation analysis, which they consider the reference method. In a group with a wider age range studied by McEniery et al,⁵ the change in pulse wave velocity was much larger than the change in inflection time. From these data we calculated an increase in effective length with age, as did Mitchell et al,⁶ whereas Segers et al⁴ observed a decrease in effective length. Thus, in any case, all of these studies show that effective length is not constant.

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