Letter to the Editor

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Response to Aortic Pulse Wave Velocity, Reflection Site Distance, and Augmentation Index

We thank Nichols and O'Rourke[1] for their remarks about our recent article showing that the effective reflection site is elusive.[2] The main point of our article is that wave speed calculations from ascending aortic pressure and flow are inaccurate, because it is implicitly assumed the arterial tree can be modeled with a single uniform tube with real reflection (a resistor) at its distal end.

McDonald and Taylor[3] indeed studied reflections, but they never discussed the implications regarding aortic wave speed calculations from the ascending aorta pressure and flow. Taylor[4] discussed reflections by describing the arterial system in the frequency domain, whereas we purposely avoided going into this type of analysis. Taylor showed that the use of a single, uniform tube with reflection at its end is a very poor model of the systemic arterial tree. We agree, but perhaps did not emphasize this sufficiently. One of Taylor's arguments is that, for high frequencies, the input impedance and apparent wave velocity reach a constant, frequency-independent, value, characteristic impedance, and phase velocity, respectively, suggesting a reflectionless system. In other words, this implies that reflection depends on frequency.

We agree with Nichols and O'Rourke[1] that reflections occur at junctions, most of them located in the arterioles, and these reflections may possibly lead to an effective reflection site. However, at this site each harmonic of pressure (and flow) encounters a reflection coefficient with a different magnitude and phase shift. We do not agree with Nichols and O'Rourke[1] that the phase shift of reflections at branch points can be considered insignificant, because Womersley[5] showed otherwise (phase shift considerable and dependent on Womersley's α). Another way to see that an arterial tree cannot be modeled with a uniform tube loaded with a resistor is that the load on the distal abdominal aorta, ie, the impedance of the iliac arteries, is not a simple resistance.

It is not clear to us what Nichols and O'Rourke[1] mean with disputing the theory applied. We see no basic difference between Taylor's frequency domain and our time domain theory.

We did on purpose not discuss errors in the Δt by estimating the foot of the forward and backward waves in the determination of pulse wave velocity. We also do not want to discuss errors in estimating Δt from the shoulder of the pressure wave,[6] because we consider them technical rather than basic aspects. Nichols and O'Rourke[1] remark that changes in Δt and pulse wave velocity cause effective length to increase, in agreement with our data and those of others. We did not suggest a relation between an increase in effective length with a decrease in augmentation index.

There is no second tennis player in our model, and we do not take into account frictional (balloon air) losses. We just stated that when you do not know how the ball is reflected you cannot calculate the distance of the reflection site.

We are happy to read that Nichols and O'Rourke[1] agree that the location of the reflection site is elusive, but we do not see that our reasoning could be incorrect, because it is not different from that of Taylor.

We want to emphasize that the calculation of forward and backward pressure is correct, and that the magnitude and time difference, Δt, are valuable parameters. Augmentation index is less accurate but also valuable.[7] These quantities do not depend on a model choice. Our point is that investigators calculate pulse wave velocity from Δt by assuming the uniform tube loaded with a resistor, and this model is incorrect.

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