

Reconciling the Increased Pulse Wave Velocity and Reflected Wave Transit Time Paradox

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Background: Previous studies suggest that, despite the clear increase in PWV with aging, reflected wave transit time (RWTT) does not change significantly. This has led to the proposition of a “distal shift” of reflecting sites with aging. This conclusion is critically dependent on the methods to assess RWTT. We aimed to assess how different RWTT measures vary with age and show that increased PWV with age is indeed associated with decreased RWTT when a proper RWTT method is used.

Methods: We studied 200 subjects (mean age 62 years; range=26 to 93). Carotid tonometry and phase-contrast MRI were used to assess central pressure and flow, respectively. We assessed RWTT based on: (1) wave separation analysis (RWTT_{WSA}); (2) inflection point of the pressure waveform (RWTT_{INF}); (3) partially distributed tube-load arterial system modeling (RWTT_{TUBE}). Tube-load based RWTT takes into account information contained in entire pressure and flow waveforms, rather than arbitrarily chosen regions of interest and empirical methods to impose a ‘foot’ to waves.

Results: Consistent with previous reports, RWTT_{INF} (B=-0.0488 msec/year; P=0.65) and RWTT_{WSA} (B=-0.217 msec/year; P=0.075) demonstrated relatively “flat” relationships with age. RWTT_{TUBE} demonstrated a much greater reduction in RWTT (B=-0.968 msec/year; P<0.001), corresponding to changes with aging ~20 times greater than by the timing of the inflection point (and ~4.5 times greater than those assessed via RWTT_{WSA}).

Conclusion: Tube-load modeling suggests that RWTT declines much more rapidly with age, consistent with earlier arrival of reflections to the aorta as age and PWV increases in tandem. The apparent asymptotic RWTT from standard methods misleads to the identification of a reflection-free period in early systole, at odds with the assumption of steady-state oscillation. Tube-load modeling resolves the paradox and leads to logical trends of RWTT that is consistent with increased PWV and reflections with age.

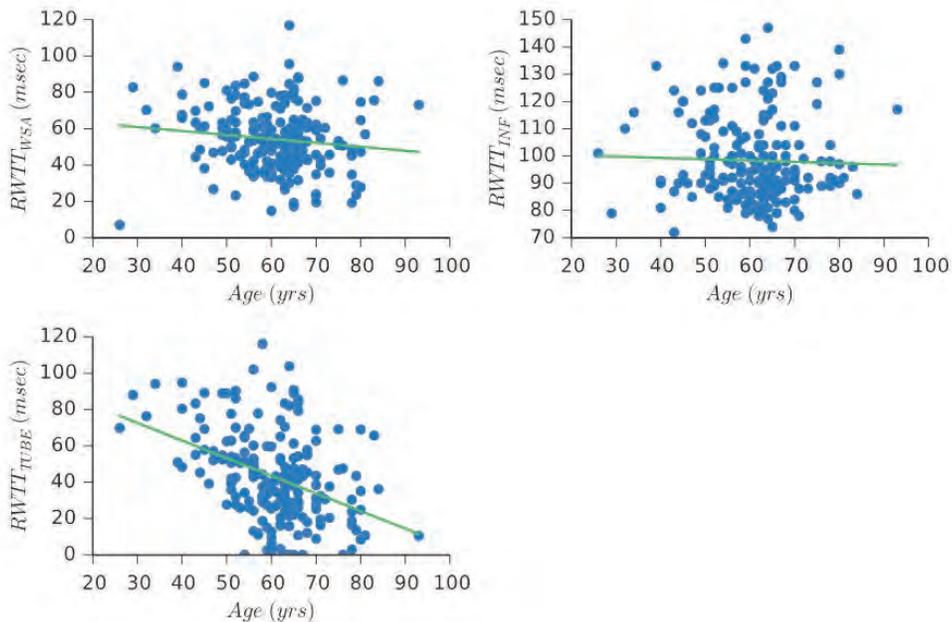


Figure. RWTT relationship with age via wave separation analysis method (top left), pressure waveform inflection point method (top right), and tube-load modeling method (bottom left).