Reservoir-wave analysis for measuring vascular aging

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The arterial system functions as a conduit and a reservoir. The Windkessel and wave transmission theories have been used to model the complex interactions between the heart and the arterial system and both distinctively provide explanations on the changes in the arterial pressure waveform with aging and diseases. Carotid-femoral pulse wave velocity (PWV), a measure of arterial stiffness which closely relates to the Windkessel function, and parameters of pressure wave reflections (such as the backward wave amplitude, Pb) modelled by the wave transmission theory, have been demonstrated to carry incremental prognostic value on top of traditional cardiovascular risk factors in various study populations. Furthermore, from cumulative exposure to cardiovascular risk factors, the resulting early vascular aging identified by an increased PWV could be an intermediate step and a harbinger of future cardiovascular events. Therefore, an increased PWV has been suggested as a relevant intervention target. These efforts highlight the importance of identifying the discernible morphological changes of pressure waves rather than considering only the systolic and diastolic blood pressures.

The reservoir function of vascular systems has also been successfully modelled by Wang et al as the volume related pressure change in arterial and venous vascular systems. The aorta stiffens with vascular aging process, which leads to a faster wave speed, more pronounced wave reflections and, probably more importantly, a reduced reservoir function. Parameters calculated based on the reservoir-wave concept, combining elements of wave transmission and Windkessel models of arterial pressure generation, were shown to predict clinical outcomes in hypertensive patients of two randomized control trials, ANBP2 and ASCOT-CAFÉ studies. Deterioration of the arterial reservoir function is expected to produce a larger reservoir pressure wave with accelerated reservoir filling rate (increased systolic rate constant) and faster reservoir emptying rate (increased diastolic rate constant). The buffering function of elastic arteries could be characterized by the reservoir-pressure wave theory, and excess pressure integral (XSPI), a parameter derived from the reservoir pressure-wave analysis, may represent the unrequired surplus work done by LV.

Although there have been vehement debates regarding the correctness of the reservoir-wave analysis, the famous statistician, Prof. George E.P. Box, once stated “Remember that all models are wrong; but some are useful”. Since all models are wrong the scientist cannot obtain a "correct" one by excessive elaboration. Just as the ability to devise simple but evocative models is the signature of the great scientist, so overelaboration and overparameterization is often the mark of mediocrity. We therefore, based on the perspective of pragmatism, examined the prognostic significance and clinical utility of the reservoir-wave model in many different patient populations, including general population, uremia, and stable heart failure.

In this talk, the usefulness of the parameters obtained from the reservoir-wave analysis as a tool for measuring vascular aging will be presented and discussed.