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Introduction

Impedance plethysmography (IPG) is a non-invasive sensing technique to assess variations in fluid volumes based on changes in bioelectrical impedance. While physical impedance phantoms are quite common for other methods such as electrical impedance tomography, they are rare for IPG. In fact, IPG investigations require a dynamic system with conductive blood and tissue simulants. Such a dynamic fluid phantom might provide well-defined test scenarios toward more sophisticated analysis methods.

Methods

In this proof of concept study, we implemented two separate impedance phantoms made of gelatin and silicone to assess their suitability for dynamic fluid phantoms in IPG. Our concept for the aquagel phantom involved a full-body structure in which the fluid flows through the body via a narrow channel. For the silicone phantom, we manufactured a conductive tube, which acted as a elastic fluid channel inside of a body filled with tissue simulant solution. We integrated both phantoms into a fluid circulation system with a pulse wave generator, a multi-frequency impedance analyzer, and sensors to assess pressure and volume flow.

Results

For both phantoms, we were able to obtain time-varying impedance signals, which qualitatively correspond to the recorded fluid dynamics in terms of an impedance decrease when more of the conductive blood simulant (pulse wave) passes through the phantom made of less conductive tissue simulant. The recorded base impedances ($42 - 55 \Omega$) and impedance variations ($0.15 - 0.4 \Omega$) were in a value range in accordance with typical IPG signals.

Conclusion

While the aquagel phantom showed mechanical limitations, the silicone phantom appears promising for further research. We understand this study as first step toward a more comprehensive dynamic fluid phantom, which might consider different and more sophisticated operating conditions and the integration with complementary sensor types (e.g., optical sensors) into a multi-modal phantom.