Effect of Ageing on Oscillometric Blood Pressure Measurements using Finite Element Analysis

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Summary

This study investigates the effect of ageing on oscillometric Blood Pressure (BP) measurements using a Finite Element Analysis (FEA). The FEA model employs hyperelastic properties and BP levels for two different age groups to simulate oscillometric waveforms. The ageing effect simulated by different BP and artery stiffness causes a change in oscillation patterns affecting BP estimations.

Introduction

Oscillometric blood pressure measurements rely on detecting arterial oscillations with changing cuff pressure. Pattern of oscillations varies depending on different biomechanical factors including stiffness of brachial artery [1]. Age related changes affect the hyperleastic response of brachial artery (stiffness) that results in varied pattern of oscillations. With change in stiffness of artery its ability to accommodate blood volume in systole also changes, that results in change of BP. Previous studies [2] reported the effect of change in artery stiffness with muscle relaxation on pressure oscillations keeping BP same but collective response of patient's physiological conditions with age on oscillometric signals is still an open question. Therefore, this study investigates oscillometric signals simulated by employing hyperelastic properties and BP of two different age groups [3,4] with a goal to improve accuracy of oscillometric devices.

Methods

A 3D upper arm was modelled in Abaqus® using geometry from Ref. [2]. Two different hyperelastic material properties of artery were used from the Refs. [3,4] corresponding to two different age groups. Mean age and BP readings for Group 1 (G1) were 37.5 ± 4.4 and 118 ± 3/67 ±3 mmHg while for Group 2 (G2) were 42 ± 5 and 136 ± 6/78 ± 2 mmHg, respectively. Artery properties for both groups are presented in Figure 1 (a), G2 on average with older subjects attained stiff artery and vice versa. The hyperelastic material formulations were selected using a MATLAB code, good fit was achieved for Ogden N = 2 and N = 3. To simulate oscillometric waveform, external pressure was quickly increased to 150 mmHg and then linearly decreased at a rate of 5 mmHg/s in 30 s. The pressure oscillations were obtained by tracking artery lumen area changes.

Results and Discussion

The pressure oscillations simulated using the model are presented in Figure 1 (b). A larger amplitude of oscillations is observed for G1, while oscillations are more damped for G2, owing to stiff artery properties. Broad envelopes are observed for Ogden N = 3 formulation compared to N = 2, that has a narrow distribution as shown in Figure 1 (c). Ogden N = 2 formulation had sudden compliance changes in fit compared to N = 3 with steeper curve, which caused the waveform difference. Ogden N = 2 was used for further analysis as its oscillometric waveforms were closer to the analytical waveforms reported by Ursino and Cristalli [1]. For respective artery stiffness and mean BP levels of G1 and G2, the envelopes shown in Figure 1 (d) were both shifted and varied in trend. DBP estimation for different artery stiffness of G1 and G2 but same BP levels showed a difference of about 3 mmHg with a minimal difference in SBP estimations, Mean Arterial Pressure (MAP) was overestimated by 1 mmHg for older age group (G2) due to shift in maximum amplitude.

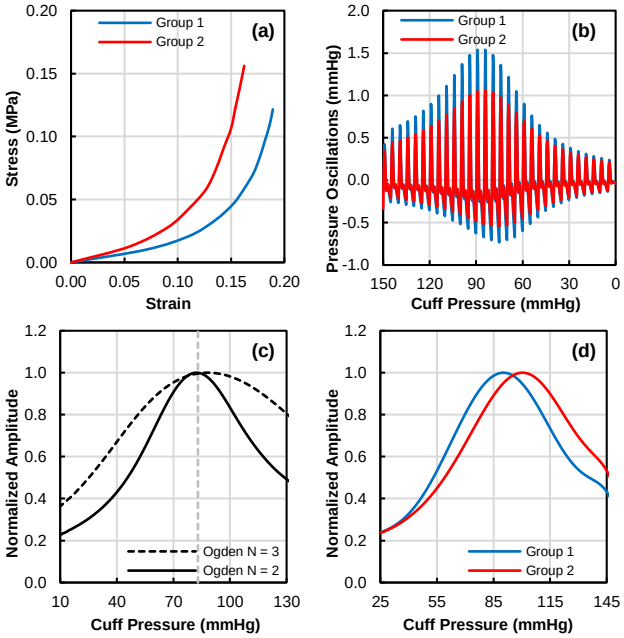

Figure 1: (a) Brachial artery properties for G1 and G2 (b) simulated oscillometric waveforms (c) difference of envelopes for Ogden N=2 and N=3 formulations (d) difference in envelopes for G1 and G2.

Conclusions

Study concludes that Ogden N = 2 formulation achieves realistic oscillometric waveforms. Collective effect of ageing simulated using respective artery stiffness and BP causes a shift in waveforms and change in trend of envelopes. Different stiffness but same BP achieves different oscillation patterns for older age group with MAP being slightly overestimated.

References

[1] Ursino, Mauro, and Cristina Cristalli. *IEEE transactions on Biomedical Engineering* 43.8 (1996): 761-778.

[2] Lan,H.,et al. *Medical engineering & physics* 33.10 (2011): 1287-1292.

[3] Bank, Alan J., et al. *Circulation* 94.12 (1996): 3263-3270.

[4] Bank, Alan J., et al. *Circulation research* 77.5 (1995): 1008-1016.