Understanding the role of blood pressure, wall shear stress and arterial wall stiffness in flow mediated dilation: A computational and *in-vivo* study

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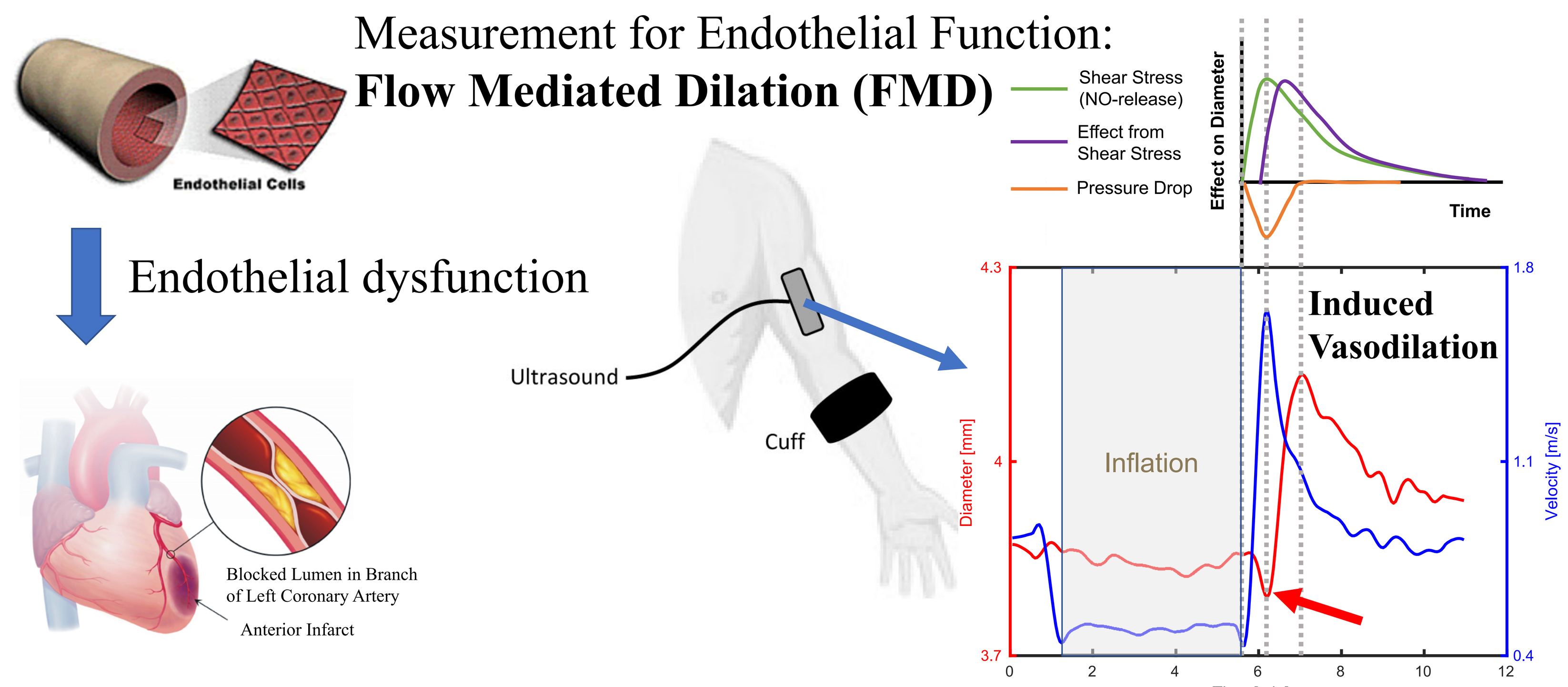
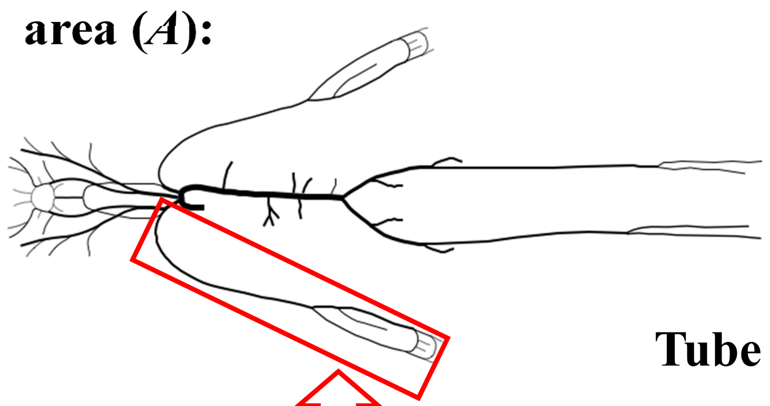
1. Motivation & Objective



- **Current FMD**: assumes vasodilation entirely induced by the increase in wall shear stress (WSS).
- **Issue**: there is evidence of vasodilation being affected by other confounding factors, such as arterial wall stiffness and blood pressure[1].
- **Aim** to investigate the effects of arterial wall stiffness on the results of FMD using computational blood flow modelling.

2. Study Design

Hemodynamic Solver for blood flow (*Q*), blood pressure (*P*), and cross-section area (*A*):



$$\begin{cases} \dfrac{\partial A}{\partial t} + \dfrac{\partial Q}{\partial x} = 0 & \textbf{Conservation of mass} \\ \dfrac{\partial Q}{\partial t} + \dfrac{\partial}{\partial x}\left(\alpha \dfrac{Q^2}{A}\right) + \dfrac{A}{\rho}\dfrac{\partial P}{\partial x} = \dfrac{f}{\rho} & \textbf{Conservation of momentum} \end{cases}$$

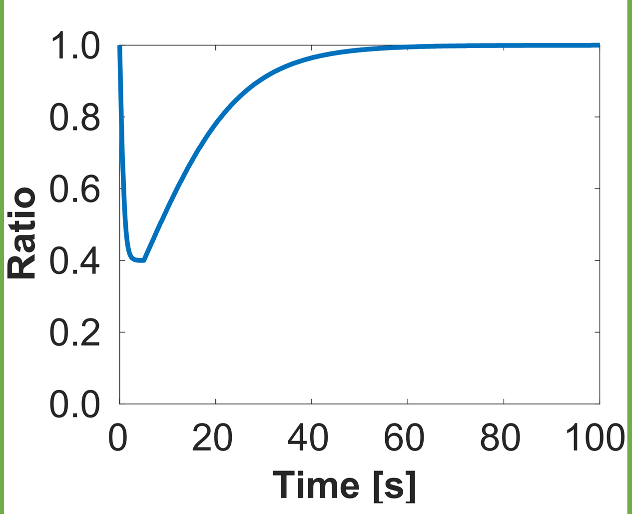
Tube Law:

$$P = P_0 + \frac{\beta(x)}{A_0(x)}\left(\sqrt{A} - \sqrt{A_0(x)}\right) + \frac{\Gamma(x)}{A_0(x)\sqrt{A}}\frac{\partial A}{\partial t}$$

$$\beta(x) = \frac{3}{4}\sqrt{\pi}E(x)h(x)$$

i) Prescribe the change of peripheral resistance and ii) change Young's modulus (*E*) induced by the increase in WSS (τ).

<u>**i) Prescribed** change of peripheral resistance (Trigger of FMD):</u>



<u>ii) The relationship between WSS (τ) & Young's modulus (E)[2] (Endothelial function) :</u>

$$E(t) = E_{base}(1 + \delta E)$$

$$\frac{d\delta E(t)}{dt} = \frac{1}{C_d}\left(\alpha_\tau \tau_{cum}(t) - \delta E(t)\right)$$

$$\frac{d\tau_{cum}(t)}{dt} = \delta\tau - \frac{\ln(2)\,\tau_{cum}}{HL}$$

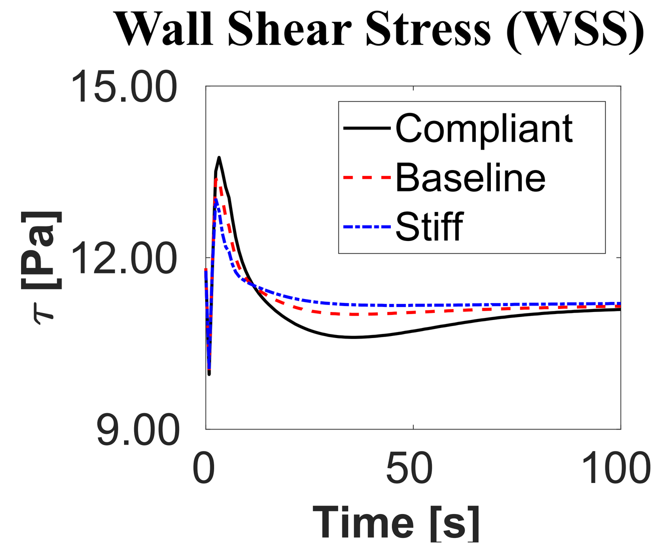
$$\delta\tau(t) = \tau_{base} - \tau(t)$$

$$\tau(t) = \mu\frac{U}{R}(\xi + 2) \qquad \xi = \frac{2-\alpha}{\alpha - 1}$$

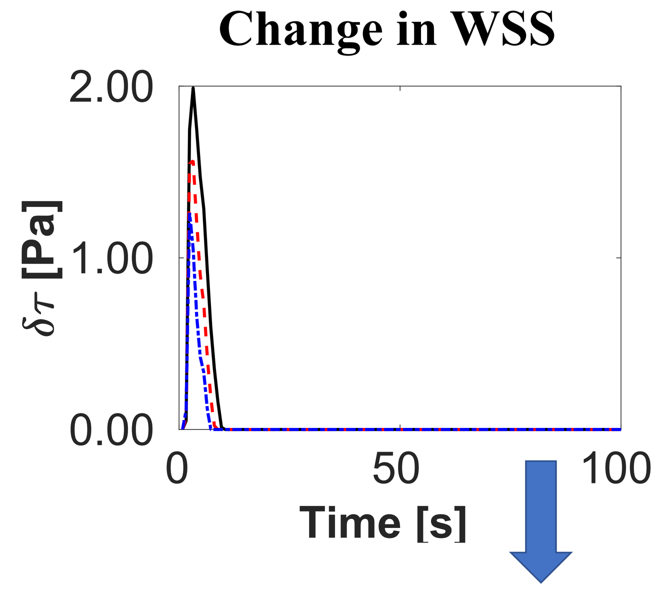
3. Results

Simulated evolution of key physical variables in FMD (displayed as mean over each cardiac cycle in the brachial artery). Results shown at **baseline** and with **stiffer** or more **compliant arteries**:

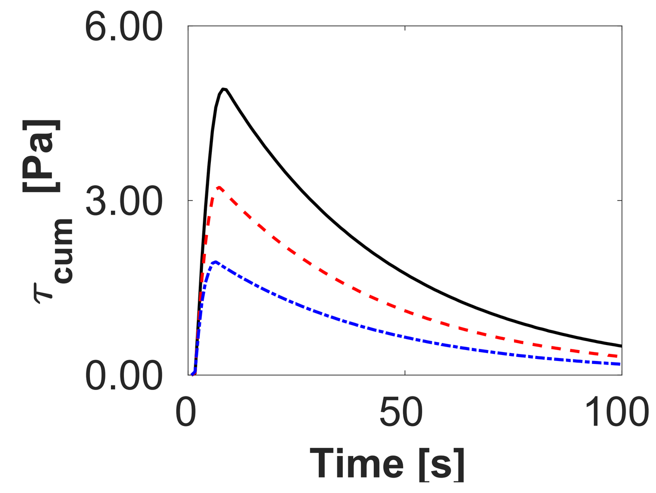
Wall Shear Stress (WSS)



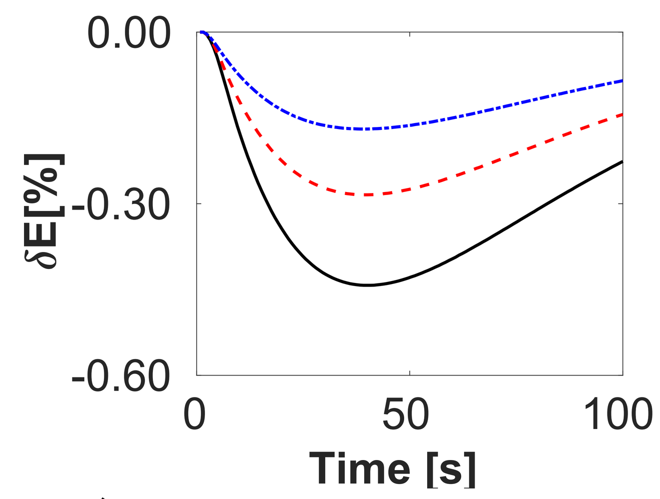
Change in WSS

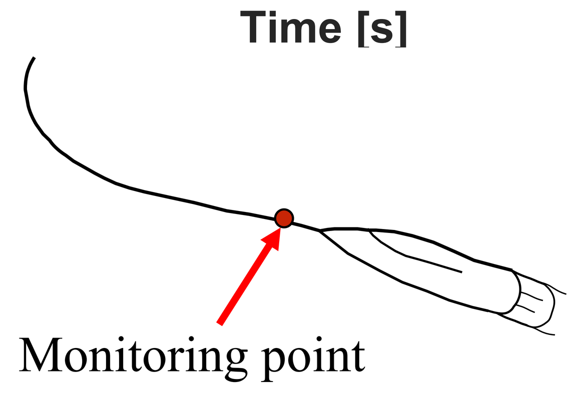


Accumulated WSS



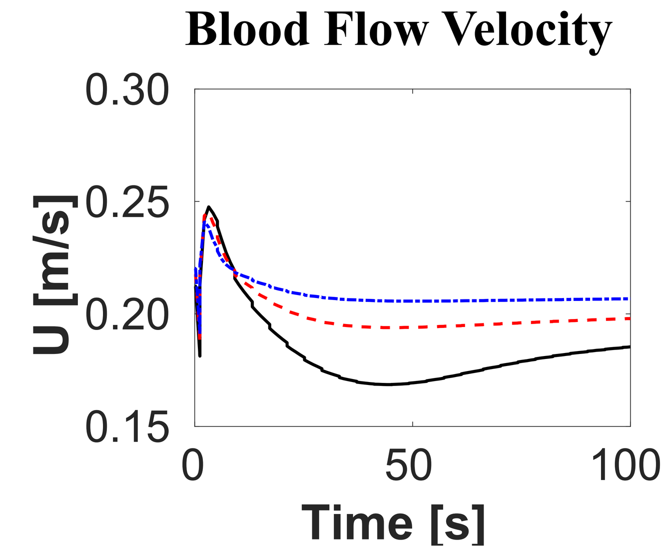
Change in Young's Modulus



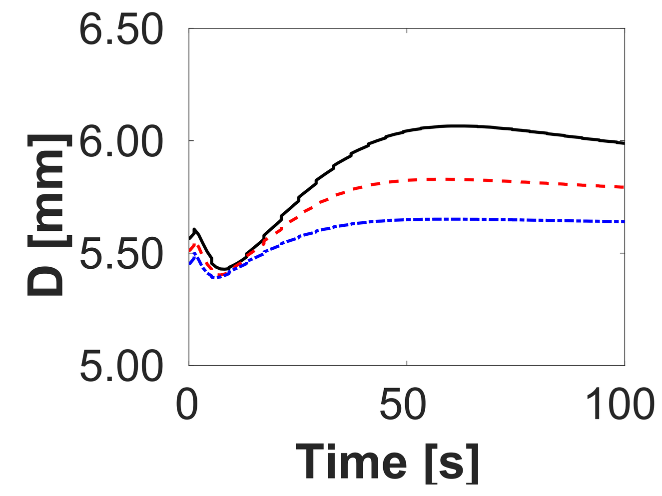


	Compliant	Baseline	Stiff
FMD [%]	8.56	5.31	3.17

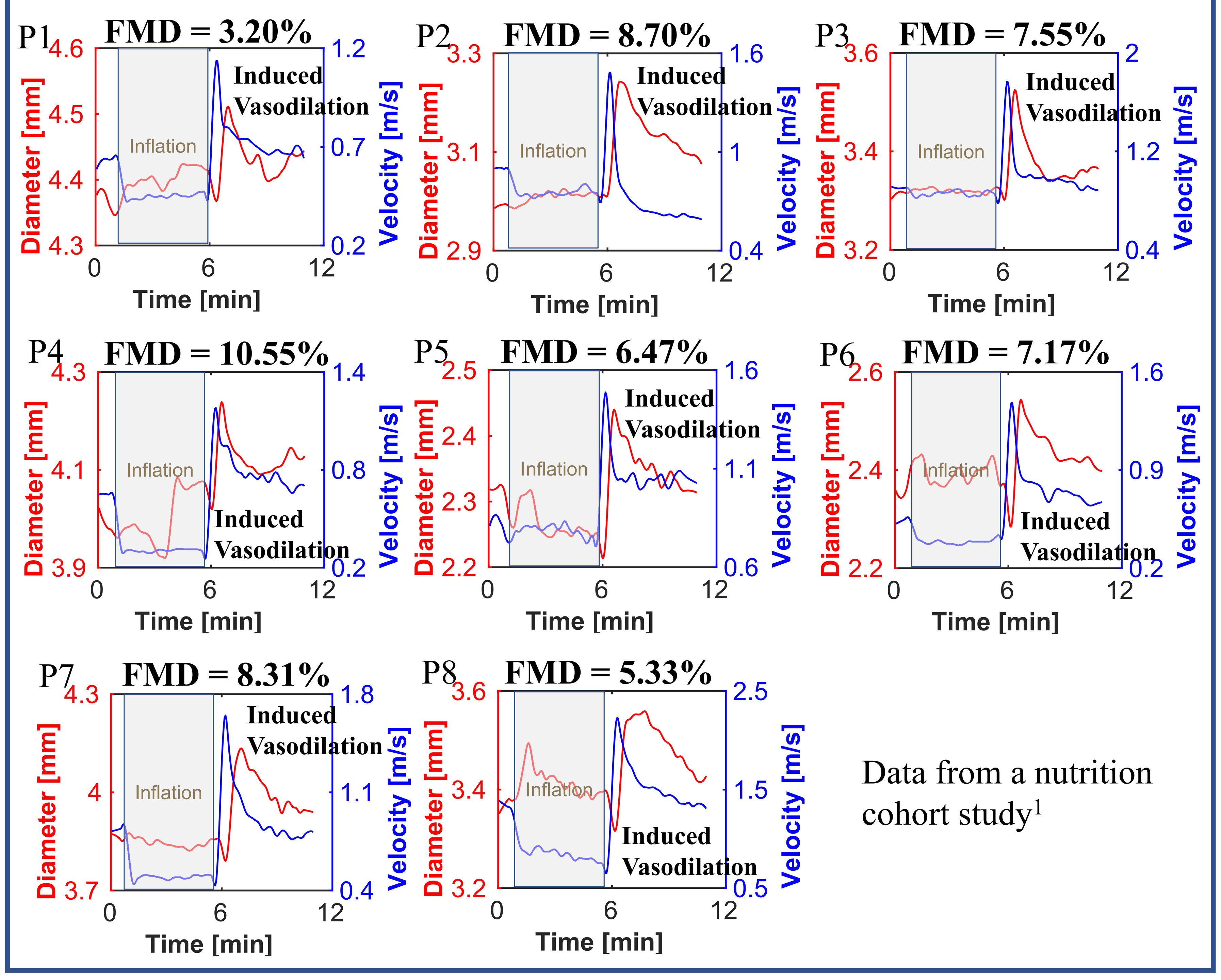
Blood Flow Velocity



Arterial Wall Diameter



<u>**In-vivo data to test the simulated velocity (*U*) and diameter (*D*):**</u>



Data from a nutrition cohort study[1]

4. Discussion & Conclusion

- We have developed a novel numerical model to simulate the process of FMD.
- In-silico FMD results agree well with in-vivo data: the simulation can capture the surge increase in velocity right after cuff deflation, the diameter drop right after cuff deflation is followed by a diameter increase.
- For the same prescribed endothelial function (relating WSS to Young's modulus variation) and decreased peripheral resistance, FMD increases with decreasing arterial stiffness.

5. Future Plan

- Investigate other confounding factors that may affect the results of FMD using our novel numerical model developed in this study.
- Apply the numerical model to investigate endothelial-dysfunction related diseases (*e.g.* coronary artery disease).
- Obtain a new FMD index that is not affected by confounding factors.

References

1. Jiang, Benyu, *et al*., *Hypertension* 57 (6) (2011): 1145-1150.
2. Van Brackle , *et al*., *Journal of Applied Physiology* 122 (5) (2016): 1292-1303.

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