Title : Iliac arterial endofibrosis : parametric study and analysis of wall shear stress in a curved pipe, and feasibility of focused ultrasound treatment

Keywords : Iliac artery endofibrosis ; Wall Shear Stress ; Dean flow ; Laser Doppler Velocimetry ; HIFU

Abstract : External iliac arterial endofibrosis (AE) is a non-atheromatous vascular disease specific to athletes. 90% of patients are young cyclists with no traditional cardiovascular risk factors. EA is a paucicellular stenotic lesion characterized by a thickening of the arterial wall and a subsequent reduction in its lumen, leading to defective blood flow to the lower limbs of athletes. The only current treatment, if the patient wishes to continue high-level sportive activity, is surgical and involves performing an endofibrosectomy.

Although various etiological hypotheses have been proposed, no specific study has yet tested these hypotheses through *in vitro*, *in vivo*, or *in silico* experiments. This work is dedicated to the hypothesis that excessive wall shear stress (WSS), caused by the overcurvature of the artery, may trigger the development of EA.

To investigate this hypothesis, a highly simplified model of external iliac artery flow without stenosis is adopted : Newtonian flow in a rigid cylindrical conduit with radius R and a single curvature, characterized by a radius of curvature (R_c), a curvature ratio ($\delta = R/R_c$), and an opening angle (θ_o). For a first approach, we focus on steady-state flow to prepare for future studies on pulsatile flow.

Two approaches, experimental and numerical, were developed to analyze the effect of curvature radius and opening angle on the magnitude and location of WSS. A numerical model is implemented using the CFD software OpenFOAM®, and an experimental model is designed based on Laser Doppler Velocimetry. A comparison of axial velocity profiles and axial WSS estimations, between numerical and experimental results for the following configurations : $\delta = 1/6$, $\theta_o = 55°$ and $90°$, $Re = 550$ and 2200, provides cross-validation.

A numerical parametric study was then conducted, based on the parameters $\delta = [1/10, 1/2]$, $\theta_o = [25°, 180°]$, and $Re = [275, 2720]$. The study reveals that the axial component (WSS1) is dominant, and there are two zones of extreme WSS1 if the flow in the bend is fully developed. The maximum WSS1 value is always reached at the bend's exit, regardless of δ, θ_o, or Re. However, the location of the second maximum depends on the square root of the curvature ratio ($\sqrt{\delta}$). The values of these two maxima depend on the square root of the Dean number ($\sqrt{Re\sqrt{\delta}}$). On the other hand, for undeveloped flow in a short curved conduit, typically representative of the iliac artery, only one extreme WSS1 zone exists, always at the bend's exit, with a higher magnitude than that of fully developed Dean flow. Thus, we identified unfavorable configurations for the artery, i.e., undeveloped Dean flows, where excessive WSS is most significant.

In parallel, to explore the possibility of treatment via ultrasound, a secondary objective of this work focuses on the feasibility of destroying an AE plaque fragment using focused ultrasonic cavitation. An experimental study on tissue samples collected perioperatively from patients provides encouraging qualitative results.