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BIOMEDICAL ENGINEERING RESEARCH

Quantifying Indwelling Catheter Performance using Computational Modelling

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www.ics-eus.org/2025/abstract/424

Introduction

Optimised catheter designs can be used to improve patient safety and comfort. We developed a computational platform that provides quantifiable results on catheter performance, supporting informed catheter selection for patients and guiding future catheter design. It assesses bladder damage, infection risk, voiding speed, and urethral trauma associated with urinary catheters. Here with emphasis on the Foley catheter, the most commonly used catheter in clinical practice.

Methods

The platform uses geometrical analysis, computational fluid dynamics (CFD) and finite element analysis (FEA) to assess:

- **Bladder damage:** assessed with catheter height and maximum von Mises stress (a reliable predictor of biomaterial damage by representing the overall stress state of the material).
- **Infection risk:** computed from residual volume and minimum wall shear stress.
- **Voiding speed:** calculated from flow rate.
- **Urethral trauma:** evaluated with immersed surface area.

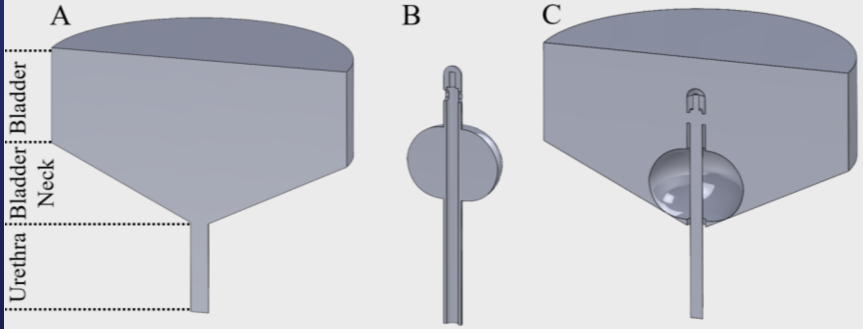

Figure 1: Schematic of A) lower urinary tract model including bladder, bladder neck and urethra, B) foley catheter, and C) combined model of catheter in lower urinary tract, used for the computational platform.

Results

The Foley catheter has a high residual volume, due to the side holes being located above the inflation balloon, low wall shear stress, caused by stagnant fluid which allows biofilm to adhere, and high potential bladder damage caused by the pointed tip which localises the stress.

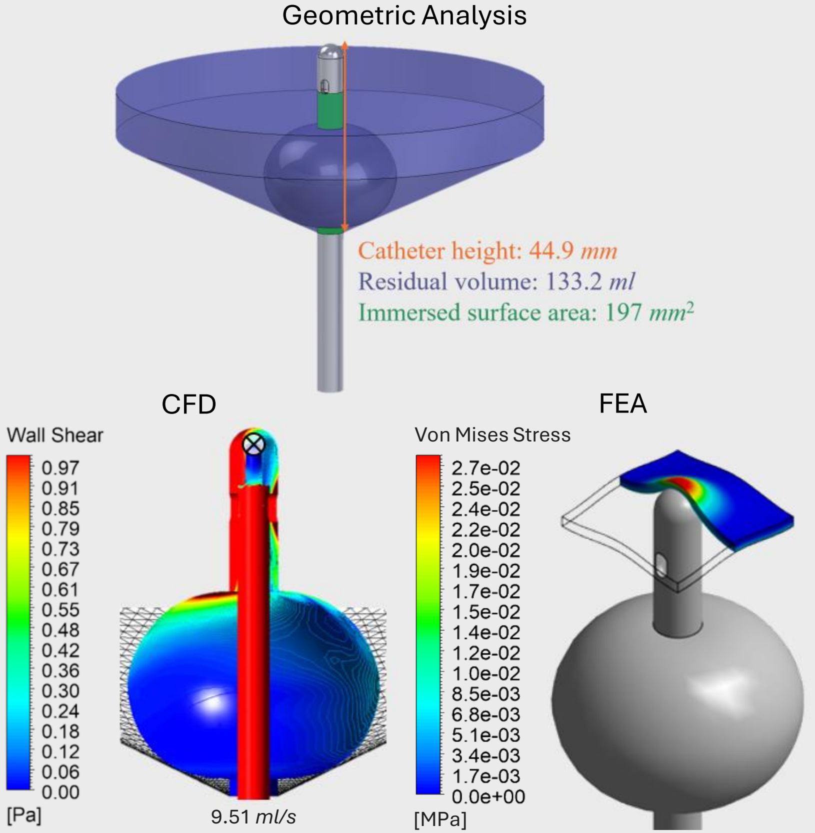

Figure 2: Geometric Analysis: Catheter height (orange), residual volume (blue) and immersed surface area (green) displayed. CFD: Wall shear stress on catheter surface (minimum location marked with X) and associated flow rate. FEA: Bladder tissue strip compressed on catheter tip with von Mises stress contour presented.

Discussion

This computational platform will be applied to other catheter designs, and the results will be used to make decisions to optimise patient outcome.