# FRICTION MODULATION OF CATHETERS USING ULTRASONIC WAVES

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## KEYWORDS
Biotribology, Friction, Fluid Lubrication, Ultrasonic Lubrication

## ABSTRACT
Friction plays a pervasive role in the interaction between medical devices and human tissues, significantly impacting their efficacy and overall outcomes. In endovascular catheterization procedures, where catheters traverse blood vessels, frictional forces between the catheter and vessel walls, depicted in Fig.1(a), can induce damage to the vessel inner wall, which may lead to infectious diseases or thrombus formation [1][2]. While reducing friction is crucial to prevent such damage, it complicates catheter stabilization, particularly during high-force tasks like cutting or puncturing tissues. This highlights the necessity for advanced catheters with adjustable frictional properties tailored to different phases of the procedure. For instance, having low friction while navigating and switching to high friction while performing the surgical task. Addressing this need, we propose the concept of a friction-modulating catheter.

Our catheter design utilizes ultrasonic lubrication, a technology that actively regulates friction between an oscillating surface and its counterpart, offering versatile applications in surface haptics and squeeze-film bearings [3]. Friction modulation is achieved by integrating friction control modules along the catheter. These modules generate transverse ultrasonic vibrations along their surface in contact with tissue. These vibrations induce the formation of a pressurized squeeze film of fluid from the surrounding medium. This fluid film effectively separates the two surfaces, resulting in a nearly frictionless interface, as depicted in Fig.1(b). The capability of ultrasonic lubrication to transition between high and low friction states facilitates the development of variable friction catheters.

To assess the viability of employing ultrasonic lubrication technology in catheters application, we developed and tested prototypes of the friction control modules. These prototypes generate transverse ultrasonic vibrations at a frequency of $22.3\ kHz$ and a maximum vibration amplitude of $4.2\ \mu m$ . We conducted proof-of-concept sliding friction experiments on ex-vivo porcine aorta tissue at a sliding speed of $(1\ mm/s)$, for a stroke of $(15\ mm)$, and under a $(1\ N)$ load. Each experiment was repeated for six sliding cycles. Upon activating vibrations, the experiment demonstrated that the friction control module promptly reduced friction by up to 42%with an average of 35% across six different tissue samples, highlighting the potential of this technology for enhancing catheter applications.

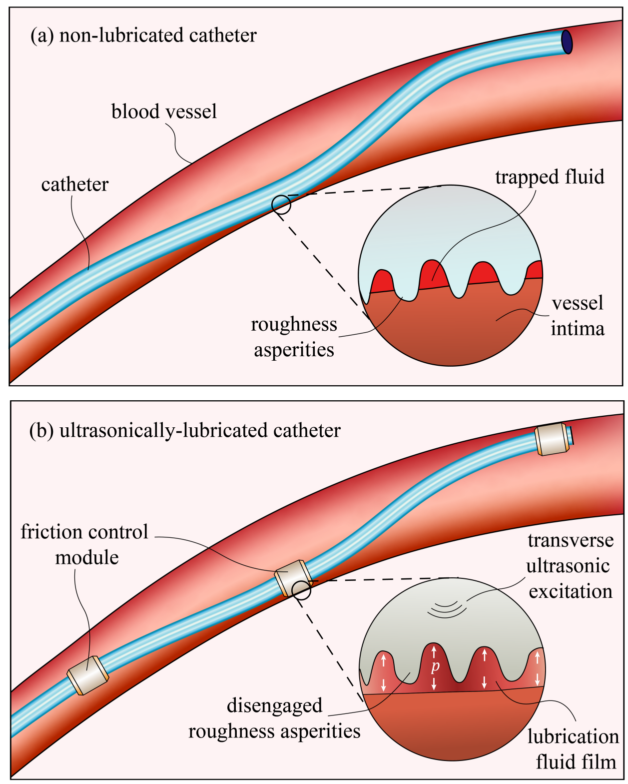


Fig.1 Concept of ultrasonic friction-modulating catheters

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