AEROSPACE ENGINEERING

DIMEAS - Cerebral fluid dynamics: an integrated clinical-computational approach to investigate the link between atrial fibrillation and dementia

Funded By	Dipartimento DIMEAS
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Context of the research activity	The PhD project is an interdisciplinary collaboration between Politecnico di Torino (PI: Prof. S. Scarsoglio) and the University of Turin (PI: Prof. M. Anselmino), combining fluid dynamics and cardiology expertise, and is funded within the PRIN 2022EAN2BB CODEAFIB Project. The research proposal aims to computationally quantify mechanistic atrial fibrillation (AF) effects on the cerebral microcirculation underlying the association between AF and cognitive decline.
	Atrial fibrillation (AF), characterized by an irregular heart rhythm, is the most common cardiac arrhythmia, counting nearly 60 million prevalent cases worldwide in 2019 and with epidemiological projections foreseeing a further rise during the next decades [1]. Dementia is a progressive neurological degeneration leading to decline in memory, reasoning, communication, and capacity to carry out daily activities, which currently affects more than 50 million people worldwide and with 150 million cases estimated in 2050 [2]. Both diseases share several common risk factors, many of which are modifiable, except for age and genetic factors. Through a constellation of potential underlying hemodynamic mechanisms - such as silent microembolic cerebral infarctions, altered cerebral blood flow, hypoperfusion and microbleeds - there is growing evidence that AF is independently associated with an increased risk of dementia and cognitive impairment [3-5], even in the absence of clinical strokes [6]. However, causality mechanisms have not been established yet, and the impact of AF treatments on dementia development is far from being clear. Among the possible contributors, the hypothesis of an altered cerebral blood flow due to the AF irregular beating is the most intriguing and the least investigated. The complex interplay between pressure-flow wave propagation in a network of tapered viscoelastic vessels with different size and the irregular pulsatile flow makes AF effects on the brain microcirculation presently unknown. In fact, currently adopted clinical techniques to assess cerebral hemodynamics in vivo, such as transcranial Doppler and magnetic resonance imaging (MRI), lack the resolving power to provide insights on the deep cerebral regions. We here propose to develop a patient-specific computational approach,

Objectives	based on our validated multiscale cardiovascular model [7], able to accurately reproduce the cerebral hemodynamic response to cardiac arrhythmias exposure. The research proposal aims to contribute at filling the gaps in the pathophysiological knowledge of the cerebral hemodynamics during AF and providing scientific evidence to reduce AF impact on cerebral circulation. In this respect, a delay of the onset of dementia by just few years would have huge socio-economic implications, in terms of the patient's quality of life and burden of health care costs. The present topic has a broad medical and technological relevance due to the following reasons: (i) Increasing AF prevalence AF prevalence is increasing in the general population but also in specific subgroups, such as active astronauts. In fact, although AF prevalence is similar to the general population, its onset occurs at a younger age in the astronaut population. Long-term human spaceflight leads to cardiovascular deconditioning, from blood volume reduction to cardiac atrophy, which may cause transient changes in atrial structure and electrophysiology [8]. AF is especially reported during the most demanding spaceflight conditions, such as launch/reentry, extravehicular activity, and exercise sessions; (ii) Still poorly understood cerebral microcirculation An accurate cerebral fluid dynamics description is still nowadays extremely challenging due to the lack of resolving power of currently adopted clinical techniques (transcranial Doppler and MRI) in the microcirculation. A computational approach describing the deep cerebral hemodynamics can increase the understanding of cerebrovascular diseases related to aging on Earth, as well as spaceflight-induced alterations. In fact, there is growing evidence that altered cerebral microcirculation is the underlying cause of cognitive fatigue and Spaceflight Associated Neuro-ocular Syndrome (SANS), both classified among the major risks of the human space exploration [9]. Results will therefore shed light on the underlying mechanisms altering cerebral hemodynamics in pathological scenarios (such as AF) as well as extreme environments (such as human spaceflight). The PhD research project is funded by the Italian Ministry of University and Research within the PRIN 2022EAN2BB CODEAFIB Project "Cerebral fluid dynamics: investigating the association between atrial fibrillation and dementia through an integrated in silico-in vivo framework". [1] G. A. Roth et al, J. Am. Coll. Cardiol (2020) [2] E. Nichols et al, Lancet (2022) [3] L. Rivard et al, Circulation (2022) [4] V. Jacobs et al, Trends Cardiovasc. Med. (2015) [5] M. Anselmino et al, Sci. Rep. (2016) [6] L. Chen et al, J. Am. Heart Assoc. (2018) [7] M. Fois et al, Front. Physiol. (2022) [8] H. W. Khine et al, Circulation (2018) [9] P. Jirak et al, Eur. J. Prev. Cardiol. (2022)

Skills and competencies for the development of the activity	- Good knowledge of cardiovascular fluid dynamics and modeling-computational aspects related to biomedical processes - Good knowledge of programming languages (Python, Matlab, etc) and advanced numerical methods for computational modeling - Interest for multidisciplinary research activities related to biofluid dynamics