**Digital Twin-Based Prognostic Modeling in Aortic Coarctation and Hypoplastic Aortic Arch**

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1. Introduction

Congenital heart defects are identified in around 1% of newborns [1]. In particular, defects such as aortic coarctation and hypoplastic aortic arch can cause symptoms in neonates such as poor feeding tolerance, respiratory distress, cold extremities, diminished or absent femoral pulses, pallor, and tachycardia.

1. Description of the problem

Current procedures for identifying congenital cardiovascular defects rely primarily on fetal echocardiography (ECHO) during pregnancy [2]. However, the limited resolution of this imaging technique, combined with the growing prevalence of maternal obesity, makes it particularly challenging to diagnose conditions such as aortic coarctation and hypoplastic aortic arch. As an alternative, other imaging methods such as magnetic resonance imaging (MRI) may be considered, although MRI is not yet a standard procedure during pregnancy or in newborns [3], [4]. Moreover, in the case of small vessels, MRI may not provide sufficient image quality. Therefore, it is necessary to use artificial intelligence techniques to upscale and enhance the quality of medical images.

1. Related work

The use of magnetic resonance imaging combined with artificial intelligence for the development of new diagnostic methods is an active area of research at the intersection of medicine and engineering [3], [4], [5]. This topic strongly resonates within the scientific literature, reflecting growing interest in interdisciplinary approaches to improving diagnostic accuracy and patient outcomes.

1. Solution to the problem

As part of the study, 4D Flow MRI examinations were conducted on newborns after obtaining approvals from the bioethics committee and informed consent from the children's legal guardians. The acquired 4D Flow MRI data were subsequently upscaled using a neural network to improve spatial resolution and enhance the signal-to-noise ratio [5], [6]. These data were used to develop both a generalized numerical model of aortic coarctation and personalized models, which served to identify key parameters enabling the diagnosis of these congenital cardiovascular defects. The results of the CFD analyses were compared with data obtained from the 4D Flow MRI using the 4D Flow MRI Toolbox for MATLAB [7] and the Cass software.



**Fig.1.** Wall shear stress [Pa] distribution contours for an newborn with aortic coarctation.

1. Conclusions and future work

Our research enabled the identification of key parameters essential for the accurate diagnosis of aortic coarctation and hypoplastic aortic arch in infants, based on 4D Flow MRI data enhanced by artificial neural networks and supported by CFD simulations.

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