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SWIRLING FLOW VISUALIZATION IN BLOOD VESSELS AND ITS HYDRODYNAMIC MODELS

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Visualization methods: ultrasound Doppler color flow mapping, hydrogen bubble timelines, computational fluid dynamics
Other keywords: blood flow phantom

ABSTRACT: At the present time referring to the great number of investigations, including modern visualization methods, we can confirm with a high probability, that in large vessels blood flow has circumferential velocity besides longitudinal one, i.e. flow is swirled [1]. This circumstance claims attention in studying of blood flow swirl formation and conservation physiological mechanisms, estimating of swirl influence on prevention and stimulation of pathological processes in cardiovascular system, constructing of implants, forming physiological swirl. Complication of such investigations is the absence of circumferential blood flow velocity recording methods in main clinical visualization techniques such as nuclear magnetic resonance imaging and Doppler ultrasound. Phase contrast magnetic resonance angiography is the most informative method for full resolution blood flow structure studying. This method is not in use for serial investigations because of its high cost. Promising and available methods for swirling blood flow studying are ultrasound Doppler techniques, e.g. color flow mapping [2].

Hemodynamic problems listed above can be solved by the methods of physical and mathematical modeling. At the present time quantitative visualization methods and first of all optic, ultrasound and X-ray modifications of particle image velocimetry replaced laser Doppler and hot-film anemometers commonly used early. There are less informative, but cheaper methods of quantitative visualization – photochromic, hydrogen bubble and oil-film.

In present work blood flow phantom has been constructed for physical modeling of swirling flows with physiological swirl angles φ = 0-20°. Constant or pulse flow circulate in blood vessel models with frequency f=1-2 Hz, mean longitudinal velocity V_z = 0-30 cm/s and mean circumferential velocity V_φ = 0-5 cm/s. Flow rate calibration is conducted with electromagnetic flow meter and velocity profile calibration – with hydrogen bubble timelines technique. More precise definition of clinical measurement techniques is conducted with standard ultrasound scanner. Results of swirling flow numerical simulation [3] are in good agreement with experimental results of ultrasound and optical visualization [4] (fig.1).

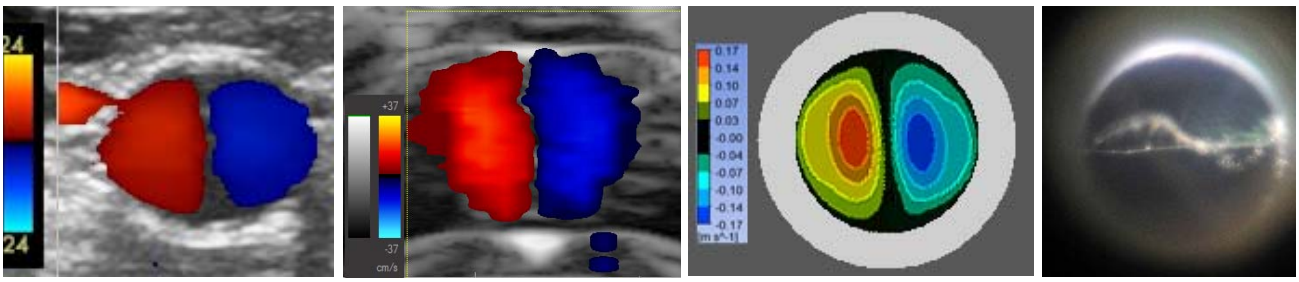

Fig. 1 Swirling flow visualization with ultrasound Doppler color flow mapping (a,b), computational fluid dynamics (c), hydrogen bubble timelines (d) in carotid artery (a) and in vessel model (b,c,d)

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