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Turbulence downstream of subcoronary stentless and stented aortic valves

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ABSTRACT

Regions of turbulence downstream of bioprosthetic heart valves may cause damage to blood components, vessel wall as well as to aortic valve leaflets. Stentless aortic heart valves are known to posses several hemodynamic benefits such as larger effective orifice areas, lower aortic transvalvular pressure difference and faster left ventricular mass regression compared with their stented counterpart. Whether this is reflected by diminished turbulence formation, remains to be shown. We implanted either stented pericardial valve prostheses (Mitroflow), stentless valve prostheses (Solo or Toronto SPV) in pigs or they preserved their native valves. Following surgery, blood velocity was measured in the cross sectional area downstream of the valves using 10 MHz ultrasonic probes connected to a dedicated pulsed Doppler equipment. As a measure of turbulence, Reynolds normal stress (RNS) was calculated at two different blood pressures (baseline and 50% increase). We found no difference in maximum RNS measurements between any of the investigated valve groups. The native valve had significantly lower mean RNS values than the Mitroflow ($p=0.004$), Toronto SPV ($p=0.008$) and Solo valve ($p=0.02$). There were no statistically significant differences between the artificial valve groups ($p=0.3$). The mean RNS was significantly larger when increasing blood pressure ($p=0.0006$). We, thus, found no advantages for the stentless aortic valves compared with stented prosthesis in terms of lower maximum or mean RNS values. Native valves have a significantly lower mean RNS value than all investigated bioprostheses.

1. Introduction

Stentless bioprostheses are claimed to exhibit excellent hemodynamic characteristics. They have larger effective orifice areas, lower aortic transvalvular pressure difference and faster left ventricular mass regression compared with their stented counterparts (Funder et al., 2010b; Lehmann et al., 2009; Dunning et al., 2007). Although considerable effort has been committed to research in clinical parameters, limited thorough research has been devoted to blood flow characteristics. Matsue et al. found superior blood velocity profiles of especially full root stentless heart valves compared with porcine stented valves (Matsue et al., 2001, 2005). However, our earlier studies showed velocity profiles of subcoronary stentless valves to be inferior to stented pericardial valves (Funder et al., 2010a). In vivo turbulence measurements in stentless valves have not yet been reported. Turbulence occurs after implantation of an artificial heart valve which to some extent obstructs the lumen compared with native valves resulting in disturbed blood flow and turbulence. This may cause regions of altered shear stress, increasing the risk of atherosclerotic plaque deposition and aortic wall calcification (Tenenbaum et al., 2004; Kilner et al., 1993). An association between calcification of the aortic wall and aortic valve calcification has been shown (Tenenbaum et al., 2004; Adler et al., 2002). Turbulence has, furthermore, been shown to initiate pathological processes such as activation of platelets and damage to red blood cells (Nyboe et al., 2006).

Stentless valves may intuitively exert less obstruction of the lumen resulting in less disturbed blood flow and, thereby, less turbulence. The aim of this study was, therefore, to evaluate turbulence downstream of two different subcoronary stentless valve types implanted in pigs compared with stented and native porcine valves.

2. Methods

2.1. Experimental animals

The study comprised 31 Danish Landrace/Yorkshire pigs, weighing 90 kg each. Immediately after the experiments, the pigs were euthanized during continued anesthesia. The experiments were conducted according to the guidelines and approval from the Danish Inspectorate of Animal Experimentation under the Danish Ministry of Justice (Funder et al., 2010b).

2.2. Study valves

The stentless Pericarbon Freedom Solo (Sorin, Italy) is a pericardial valve which is implanted by use of a single suture line (10). The second stentless valve

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