Vena Cava Tissue as an Alternative to Pericardium in Percutaneous Heart Valves

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Statement of Purpose: In the United States, the most common form of heart valve disease is aortic stenosis [1]. Currently, the best cure for valve disease is to replace the defective valve with an engineered substitute. Each year, over 300,000 heart valve replacement surgeries are performed worldwide [2], and this number is expected to continue growing as life expectancies increase. However, valve replacement surgery is very invasive, and high risk patient populations are often denied this procedure. Over 50% of elderly populations with aortic stenosis are not offered surgery because the mortality risk is too great [3]. Due to the limitations of traditional heart valve replacement surgery, a new, less invasive option, percutaneous valve replacement (PVR), has been developed [4]. PVR involves transcatheter delivery of a crimped, stented valve to the aortic annulus. While not yet commercially available, two percutaneous heart valves (PHVs) are currently in clinical trials [4]. These models are composed of glutaraldehyde-fixed bovine or porcine pericardial tissue.

A major limitation of PHVs is the minimum diameter to which the stent can be crimped. The device profile precludes use in small or tortuous vascular systems, limiting the candidate patient pool for PVR. An alternative material for PHVs may be porcine vena cava, as this tissue may provide enhanced flexibility and resilience, allowing the device to be crimped to a smaller diameter.

Methods: The vena cava's structural, mechanical, and in vivo properties were compared to those of bovine pericardium. Porcine vena cava and bovine pericardium were obtained fresh and then fixed with standard glutaraldehyde crosslinking (GLUT). Structural stability was assessed with collagenase and elastase digestion and histology. Uniaxial tensile testing was performed to assess tissue stiffness, and compression was performed to infer how the tissue will respond to stent crimping. Extent of calcification levels were evaluated after subdermal implantation of the tissues into juvenile Sprague Dawley rats.

Results and Discussion: Vena cava contains significantly more elastin than pericardium (35.656% ± 5.470 dry weight and 10.513% ± 0.710 respectively). In contrast, the pericardium extracellular matrix contains a greater proportion of collagen than the vena cava. Whereas the extracellular matrix fibers of pericardium are randomly oriented, the vena cava contains highly aligned collagen and elastin fibers that impart strength to the vessel in the circumferential direction and elasticity in the longitudinal. The mechanical properties of the vena cava are highly anisotropic, with the tissue exhibiting a much lower elastic modulus in the longitudinal direction than the circumferential. Furthermore, even after GLUT crosslinking, the vena cava remains rather compliant and is significantly less stiff than the pericardium. Compression tests revealed that the vena cava retains this compliance, while the pericardium becomes stiffer after crimping. Finally, following three weeks of in vivo implantation, the GLUT vena cava contained approximately half as much calcium and phosphorus as pericardium (Figure 1).

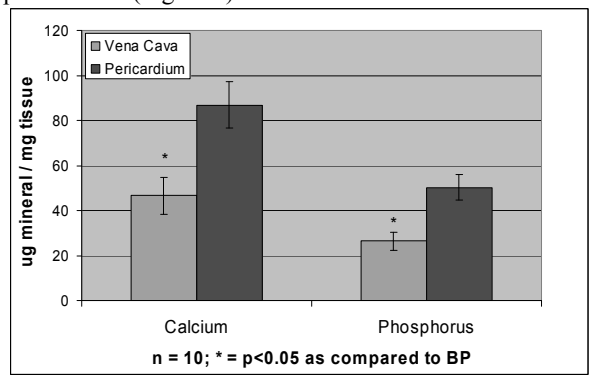

Figure 1. Mineral Content of Bioprosthetic Tissues

The results of our studies clearly show that vena cava has several advantages over pericardium. The vena cava has significantly higher elastin content, a factor which imparts enhanced flexibility to the tissue. Moreover, the elastin and collagen fibers in the vena cava are highly aligned, resulting in mechanical directionality and consistency. In contrast, the pericardium contains more collagen and less elastin, and the extracellular matrix fibers are more randomly oriented, leading to a stiffer tissue with less predictable mechanical properties. While the pericardium stiffens drastically after GLUT fixation, the vena cava retains much of its flexibility. After crimping, the vena cava experienced a less significant change in elastic modulus, suggesting that the tissue may be more resilient to the compressive forces imparted by a stent. Additionally, the vena cava was intrinsically less prone to calcification, a factor which plays a large role in tissue durability. While these results suggest the vena cava may be a good candidate for use in PHVs, more work is needed to fully characterize the mechanical properties of the tissue. Most importantly, a PHV should be constructed from vena cava and fatigue studies performed to evaluate how the vena cava will respond to the cyclic stresses experienced by the aortic valve.

Conclusions: Porcine vena cava tissue can be an excellent alternative to currently used pericardium tissue for construction of percutaneous valves.

References:

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