Restructuring of myocardium using shape memory alloy fibres

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Background and objectives

Recently, the ventricular assist devices are widely applied for a surgical treatment of the final stage of severe heart failure as the bridge to heart transplantation or the destination therapy. However, it was anticipated that the artificial components in the ventricular assist devices might cause the problems concerning thrombosis and infection. As heart failure involves the decrease in myocardial contractile function, the mechanical assistance by using an artificial myocardium might be effective. The authors have been developing a mechano-electric artificial myocardial assist system (artificial myocardium), which is capable of supporting natural contractile function from the outside of the ventricle. The system was originally designed by using sophisticated covalent shape memory alloy fibres (Toki Corp., Biometal®), and no special surface modification of the device was not applied for enhancing blood compatibility. The purpose of the project on the development of an 'intelligent artificial myocardium' was to design a sophisticated myocardial assist device, which could represent direct mechanical myocardial assistance in response to physiological demand.

Structural design for functional improvement

Some methodologies using novel devices other than the artificial hearts are proposed so far with severe heart disease. However, it was also anticipated that the decrease in cardiac functions owing to the diastolic disability might be caused by using those 'static' devices. Then, this study was focused on an artificial myocardium using shape memory alloy fibres with a diameter of 100 um, and moreover the structural design was examined for its functional improvement. The authors investigated the myocardial structure in native hearts, and fabricated several types of myocardial assist device based on these results; the circumferential type, and the oblique types which were three-dimensionally constructed. Their hydrodynamic or hemodynamic functions were also examined in a mock circulatory system as well as in animal experiments using goats.

Results

The structure of myocardial fibers of a goat's heart could be represented by a single muscular band [1]. The oblique design of the myocardial assist device was made to form the contractile streamlines from the apex to ascending aorta. Basic characteristics and hemodynamic effects of the circumferential or oblique types were examined in goat experiments (n=4) as well as in the mock circulatory system. The results were as follows:

a) In the hydrodynamic test using the mock circulatory system, the volume assisted which was elevated by 39% by morphological design.

b) Hemodynamic data obtained in goats indicated the more effective volumetric assistance by the oblique design, and on the other hand there was no significant difference in systolic assisted pressure.

Therefore, it was suggested that the morphological design of artificial myocardial support system could be more effective for the functional improvement of artificial myocardium as well as its control system design.

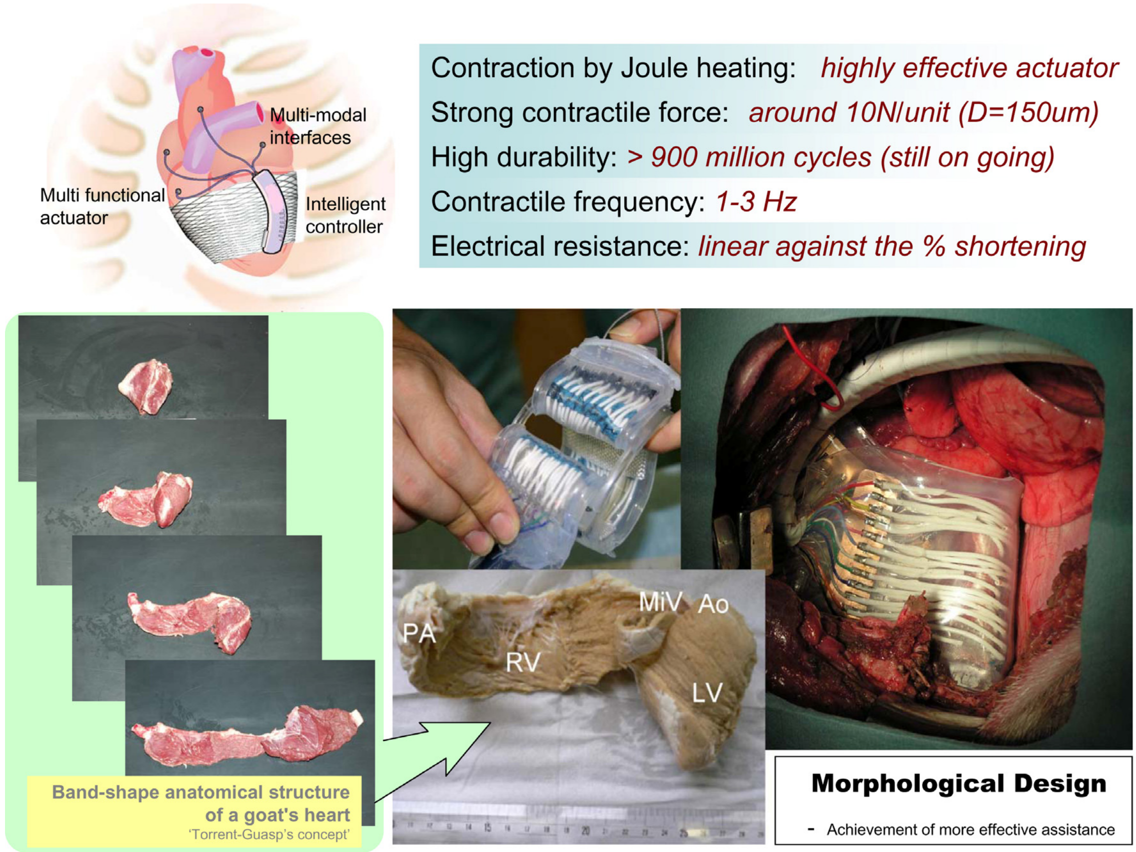

Figure: Oblique type of artificial myocardium (bottom right), which was girdling the goat's ventricle designed from the native myocardial structure (bottom left), might be more effective.

Reference:
[1] Torrent-Guasp F, et al, J Thorac Cardiovasc Surg. 2001 Aug;122(2):389-92