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Deformation controlled load application in heart valve tissue-engineering

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Introduction
Mechanical behavior of tissue-engineered heart valves still needs improvement when native aortic valves are considered as a benchmark [1]. Although it is known that cyclic straining enhances tissue formation, optimal loading protocols have not been defined yet.

To study the effect of mechanical conditioning on tissue development, it is desired to monitor and control induced deformations during load application.

Objective
To develop a bioreactor system for heart valve culture in which leaflet deformation is assessed and controlled in real time and non-invasively.

Materials & Methods
A combined experimental-numerical approach [2] was developed to assess volumetric and local leaflet deformation of the cultured heart valve in diastolic configuration (Fig. 1).

Figure 1: (a) Picture of 4 bioreactor systems. (b) Schematic drawing of a single bioreactor system, consisting of a pneumatic-air valve (A), a pulsatile pump (B), a bioreactor (C), including two pressure sensors (P) and a flow sensor (F), and a medium container (D).

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Results & Discussion
Good correspondence between the measured and the prescribed deformation values was found in both experiments (Fig. 4a,b). Mean relative error values of all valves did not exceed 5%. However, controlled load application was not possible for heart valves having leak flows larger than ~10 ml/min (Fig. 4c,d).

Figure 4: Measured volumetric deformation values (a, b) and leak flows (c, d) of tissue-engineered heart valves, given as a function of the culture time for (a, c) experiment I and (b, d) experiment II.

Conclusion
This bioreactor system has promising possibilities to systematically elucidate the effects of temporal loading patterns on tissue properties, and to develop an optimal conditioning protocol for tissue-engineering of aortic heart valves.

References
1. Mol A et al., Circulation 2006; 114(19):152-158.
2. Kortsmit et al., Submitted for publication.