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Real-time recording of annuloplasty suture dehiscence reveals potential mechanism for dehiscence cascade

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We present a case of annuloplasty suture dehiscence in a live ovine model, with novel, real-time suture force recordings throughout the event.

Clinical Summary

Following repair of mitral regurgitation, annuloplasty ring suture dehiscence is a major cause of post-operative failure, accounting for approximately 19% of reoperations.[1] Dehiscence may occur at one or multiple suture positions. We recently demonstrated novel transducers capable of quantifying tension in individual sutures in the beating heart, post-mitral annuloplasty.[2] We have expanded these methods to evaluate the effects of ring size, shape, and ventricular function on suture forces, to identify physiologic and device-specific factors that may affect suture dehiscence risk. As part of this study, a Profile3D ring (size: 26; Medtronic, Dublin, Ireland), instrumented with transducers, was implanted in a healthy 45kg subject (annulus size:30). Implantation (Figure 1) was analogous to clinical annuloplasty, using ten 2-0 Ti·Cron™ sutures (Covidien, Dublin, Ireland) with approximately 10mm suture width and 1.5mm depth; transducers did not affect ring or suture function.[2] Animal care complied with protocols approved by the Institutional Animal Care and Use Committee at University of Pennsylvania, according to guidelines for humane care (National Institutes of Health Publication 85–23, revised 1996).

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The animal was weaned from cardiopulmonary bypass; resting hemodynamics were reestablished. To investigate the impact of hypercontractility on annuloplasty suture tension, a 0.2mcg intravenous bolus of epinephrine was administered, causing LVP to rise over 30–40sec to 195mmHg. Suture force within a cycle trended positively with LVP at every position (Figure 2). One suture, located between the trigones along the anterior aspect, experienced peak loading 2-fold greater than any other, at all LVPs. At LVP=188mmHg a dramatic force decrease was observed at this position, from 16.7N to 0.6N. Simultaneously, peak forces at the two adjacent sutures were observed to increase by 3.1N and 2.6N. Two other sutures experienced small increases (1.3N and 0.3N); all other suture forces decreased. After euthanizing the animal, visual examination revealed the suture in question had torn through the annulus tissue, likely due to technical misplacement above the annular hinge (**1D**). The suture itself remained intact. The ruptured tissue was not examined histologically.

Discussion

This case provides the first demonstration of a tensile force responsible for annuloplasty ring suture dehiscence in the beating heart. After a 16.7N load induced dehiscence, a combined 5.7N shifted to the two adjacent sutures. This observation provides a likely mechanism whereby a single problematic suture could induce a cascade of dehiscence at multiple anchor points, as observed clinically.[3] A less eccentric redistribution of force across the remaining sutures may be preferable.

Greater suture loads may be expected along the anterior annulus in general. Cyclic changes in the anterior annulus' saddle shape[4] due to aortic filling and fibrous trigone motion, as well as its denser collagen,[5] may augment overall suture tension in this region. Still, it is noteworthy that the observed force distribution was so highly concentrated on the one failed suture, even at lower LVPs. This case was likely a consequence of misplacement of the suture in question; we believe placement too high above the annular hinge heightened suture tension by adding an out-of-plane force component at that position. Beyond suture placement, valve-specific anatomy and/or ring selection may also contribute to dehiscence risk. Degenerative or ischemic disease may further complicate loading dynamics and suture pullout thresholds. Ultimately, any steps during device selection, suture placement, and tie-down that minimize sharp force concentrations on single sutures will likely help to ensure prosthesis security. To concretely identify such steps, an improved understanding of the factors that most directly relate to suture dehiscence risk is first necessary. These are the subjects of ongoing work.

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Central Message

Dehiscence of one mitral annuloplasty ring suture redistributes tension to two adjacent sutures, creating risk for further dehiscence.

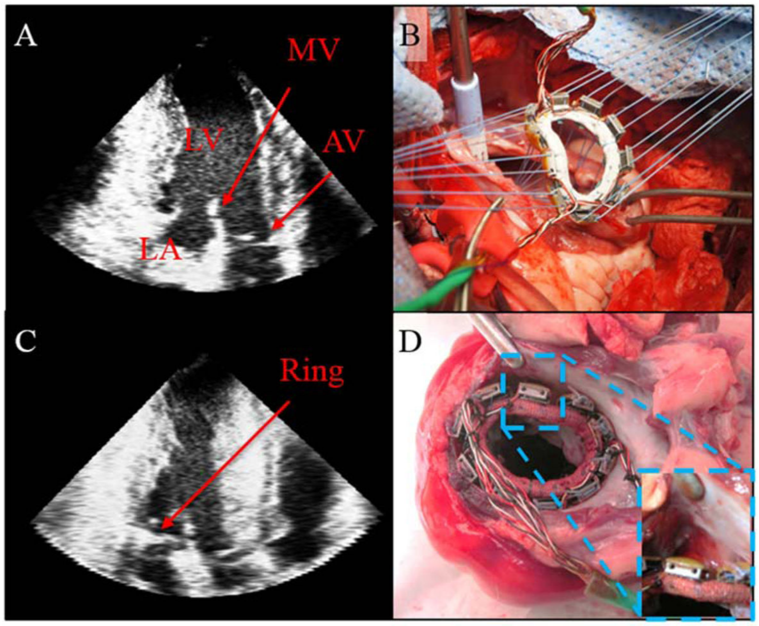

Figure 1.

An annuloplasty ring, instrumented to record tensile forces on individual sutures, was implanted in the mitral valve of a healthy ovine subject (A) using standard technique (B). Implantation was unremarkable (C). Following LVP elevation above 188mmHg, one suture dehisced (D).

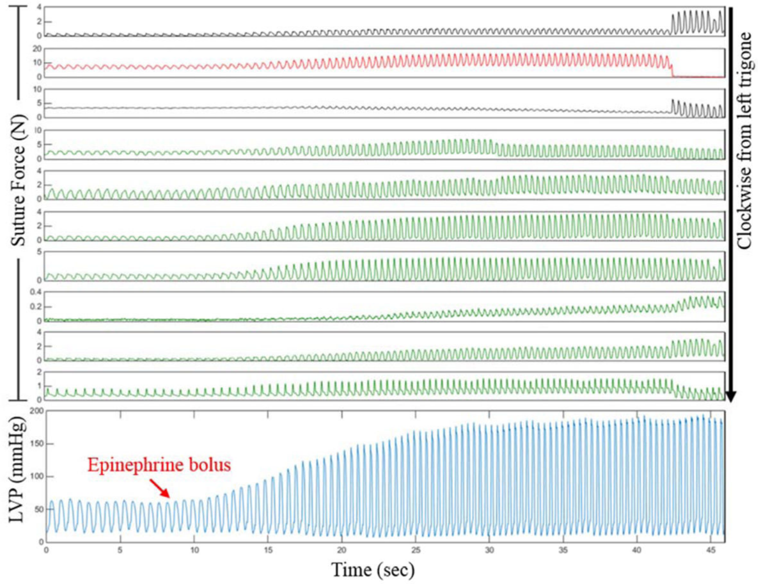

Figure 2.
The failed suture dehisced following peak force of 16.7N (red). 5.7N of this force shifted to the two adjacent sutures (black). Loading on all other sutures either increased slightly (<1.3N) or decreased (green).