Can additive manufacturing improve cardiac surgery through production of patient-specific implants?

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Surgical Background

In the years 2014-15, mitral valve repairs alone constituted 1,614 cases in the NHS, with mitral valve replacements producing a further 1,268 (HSCIC, 2015). Mitral regurgitation can arise from a number of causes, but the identifying factor is a lack of coaptation of the two leaflets of the mitral valve (Enriquez-Sarano et al. 2009). Replacement of the mitral valve is becoming less common, with repair of the existing valve now being favoured as less invasive and with better outcome (Gammie et al., 2009; Sawazaki, Tomari, Zaikokuji, & Imaeda, 2014). Different techniques of repair are available to surgeons, however common to all these is the implantation of an annuloplasty ring, used to ensure the long-term endurance of the repair.

Existing Annuloplasty Rings

Currently available rings consist of titanium or plastic core, surrounded by sponge and fabric for suturing. Rings have been designed with a range of minor modifications to the structure, including the incorporation of a three-dimensional saddle shape, as shown in figure 1b (Jensen et al., 2008). They are produced in a range of sizes from which surgeons choose the best fit during surgery. Current choice of annuloplasty ring is led primarily by surgeons’ preferences, influenced by the brands available at hospitals and training programmes (Arora & Anyanwu, 2015; Wan et al., 2015). Choices leading to imperfect fitting can produce complications following surgery and often require reoperation.

Current Design and Future Work

Figure 1a: Use of an annuloplasty ring in mitral valve repair surgery, taken from (Madesis et al. 2014)
Figure 1b: A selection of existing annuloplasty ring implants, image from Wikimedia Commons

So far, it has been shown that the most effective way of designing bespoke ring shapes according to patient scans involved placing points on the edge of the valve from different angles of echocardiographic scans, then joining the points and producing a 3D shape. This appears to be more successful and replicable than previous techniques which involved isolating the full shape of the valve then drawing the ring shape on by hand.

Future work aims to involve:
- Use of actual patient data taken from the Trent Cardiac Centre
- Production of a supportive implant, rather than a replica shape of the existing annulus
- Investigation into material choice for production of the ring, and later fabrication of the designs by additive manufacturing

References