Perspective

Image-Based Simulative Training for Myectomy in Hypertrophic Cardiomyopathy: An Emerging Necessity

Abstract

Surgical myectomy was initially advocated only for patients with symptoms refractory to maximal tolerated medical therapy. These were mainly symptoms of cardiac failure. In recent times, there has been a call for revision of guidelines to include patients earlier. As the disease progression cannot be reversed by most currently used drugs which become ineffective with time, this need for earlier myectomy seems mandatory. Presently, surgical expertise in myectomy is limited to specialized centers. The complexity of surgical myectomy is enhanced by the complex and variable anatomic substrate. With the need for earlier myectomy, a vast population of patients with hypertrophic cardiomyopathy will need surgery, predicating a requirement for more skilled cardiac surgeons. Mentoring programs in specialized centers may not be the solution, as is training surgeons using image-guided simulation techniques. Here, we discuss the existing simulative techniques and novel image-based preoperative planning techniques which may help guide myectomy.

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Three-dimensional (3D) printing has shown promise in both LV outflow tract obstructive HCM and midventricular obstructive HCM. This technology however does not lend itself to widespread use in large populations because of its cumbersome nature and several logistic constraints. Besides, thinner structures such as the mitral valve leaflets and papillary muscles do not lend themselves to 3D printing technology, making myectomy difficult because most patients with HCM have associated mitral valve abnormalities.

Simulative surgical training has shown promise in several prototypes, requiring sophisticated refinements in imaging technology. Three broad categories of surgical simulators include the simple bench model (SBM), virtual reality simulator (VRS), and human performance simulator (HPS). SBMs are “partial-task” tools that simulate a small component of a larger operation. They may be synthetic (e.g., rubber vessels to simulate coronary anastomosis) or consist of biological tissue (e.g., porcine or bovine organs to practice valve suturing). The VRS is computer-based and often lacks a physical component. Thoracoscopic or laparoscopic tools are used to manipulate virtual organs, making virtual reality simulation readily reusable with little maintenance, an advantage that can offset high initial costs. With sophisticated programming, these models can be adapted to clinical variations, interactively respond to the user, and provide performance assessment and feedback. The biggest disadvantage of this technology is the use of a two-dimensional (2D) computer screen that compromises depth perception and tactile sensation of the real 3D environment.

The HPS is a high-technology system that fuses an elaborate physical component with a computer interface. Similar to VRS, HPS can include patient variation and capabilities for assessment and feedback. However, use of biological tissue and numerous intricate parts increase resource use and maintenance time. All these tools have been confined to small sample sizes, and long-term outcome data are lacking.

The 2D interface of the VRS can be modified using a 3D image processing interface on cardiac magnetic resonance images. The epicardial and endocardial borders can be traced to render a 3D image of the LV, and the location and extent of regional hypertrophy can be indicated within the LV cavity as a color map depicted on the endocardial surface, in the interest of guiding surgical myectomy. The tool can be additionally enabled to algorithmically and interactively deform the endocardial surface in user-specified locations—simulative of myectomy—in the interest of facilitating optimal surgical resection of the hypertrophic myocardium.

Virtual myectomy can be accomplished in three dimensions within an interactive presurgical planning software program, using a free-form surface deformation tool applied to the endocardial surface at hypertrophic regions. This tool offers parametric control for the regional influence and magnitude of myectomy to provide the surgeon with dexterous control for virtual correction of the LV shape. Regional color maps help visualize the precise location and extent (in mm units) of the virtual myectomy on the LV endocardium, in three dimension. Although this 3D computer-based technology does not simulate surgical tools, it offers a guide for the operator regarding the magnitude and location of hypertrophy with a map of surrounding structures and the respective distances of vital structures such as papillary muscles and mitral annulus from the regions of hypertrophy (Figures 1 and 2).

The predicted postoperative LV shape can be compared against 3D LV endocardial surface reconstructions from postoperative cardiac magnetic resonance (CMR) images to validate surgical efficacy (Fig. 3).

Although overall performance in cardiac surgical procedures may improve with simulation-based training, mentoring cannot be replaced by any technological advance. There may not be a universally workable solution to this, but it remains important to derive competence in HCM surgery. It is also important that the surgical expertise gained should be passed down and perpetuate over time. While surgical expertise is well documented in centers in the US, Canada, and some centers in Europe, a dire need is felt for such centers in India, making imaging options for preoperative planning and simulation imperative. Given this revision in practice guidelines for earlier myectomy, many thousands of such patients need to be identified for surgery, making the need for expertise in

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Fig. 1. End-diastolic 3D renderings of the preoperative LV endocardial surfaces (green), illustrating sites of midventricular or apical hypertrophy as dents or depressions in the surface. Midventricular hypertrophy is indicated by indentations seen on the endocardial surfaces which correspond to regionally thicker myocardial walls (i.e., space between gray epicardial and the green endocardial surface). (C) Apical hypertrophy. 3D, three-dimensional.
myectomy emergent. A team approach is mandatory to achieve this goal, as are image-based tools, to aid optimal results of myectomy.

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**Conflict of interest**

All authors have none to declare.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ihj.2019.03.006.

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