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Pre-Operative 3D CT Imaging for Virtual Planning of Minimally Invasive Aortic Valve Surgery

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MANY DIFFERENT APPROACHES ARE AVAILABLE FOR PERFORMING MINIMALLY INVASIVE AORTIC VALVE REPLACEMENT (AVR). The most commonly used incision is the upper hemi-sternotomy, which extends from the sternal notch to the right fourth intercostal space (ICS). Variations in the location of the valve within the thoracic cavity can increase the complexity of the procedure resulting in greater ischemic times or conversions to full sternotomy. Alternatives include extending the hemi-sternotomy into the right fifth ICS or the lower hemi-sternotomy extending from the xiphoid to the right third ICS. More recently, right second intercostal mini-thoracotomy incisions have been described. Potential advantages for a minimally invasive approach over conventional median sternotomy include decreased length of hospital stay, hospital costs and pain, as well as faster recovery and less red blood cell (RBC) use (1,2).

Four different cases are presented to illustrate the use of 3-dimensional (3D) reconstructed contrast-enhanced multidetector computed tomography (MDCT) images in preparation for a mini–aortic valve replacement. All cases employed MDCT technology (iCT256-slice scanner, Phillips, Andover, Massachusetts) to acquire prospectively triggered axial images following the administration of a low-osmolar iodinated contrast agent. For optimization of anatomic evaluation, multi-planar reconstruction, maximum intensity projections, volume rendered reconstructions and advanced 3D off-line post-processing were performed on a dedicated stand-alone workstation (AcquariusNET, TeraRecon, Inc., San Mateo, California).

Limiting the incision to something less than a full sternotomy offers the advantage of maintaining the integrity of the chest wall and the potential for improved respiratory mechanics. Yet mini-sternotomy incisions are not always feasible and there is a 2% to 4% conversion rate and longer ischemic times when compared with the standard median sternotomy (1,2). The operation is made much more challenging when the valve lies below the fourth ICS, which is more common with older patients and those with elongated aortas.

The current series describes 4 cases where the 3D computed tomography reconstructions were used to guide our surgical approach. The first case highlights the standard upper hemi-sternotomy through the fourth ICS. The computed tomography images in this case confirmed that the exposure would be adequate. The second through fourth cases illustrate the variability in location of the aortic valve within

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Please see page 272 for the accompanying Editorial Comment by Stelzer.

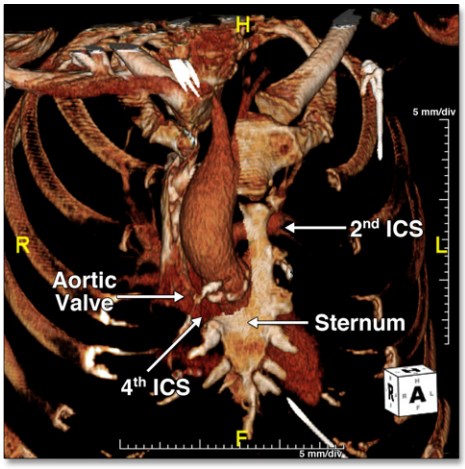

Figure 1. Standard Fourth ICS Upper Hemi-Sternotomy

This 62-year-old male presented with worsening dyspnea due to severe aortic stenosis (AS). Three-dimensional reconstructed computed tomography of his chest wall and thoracic cavity demonstrate the view expected from this approach. Note the relationship of the aortic valve well above the fourth intercostal space (ICS). It was clear with pre-operative virtual planning that a standard upper hemi-sternotomy would provide safe and comfortable exposure to the aortic valve in this patient.

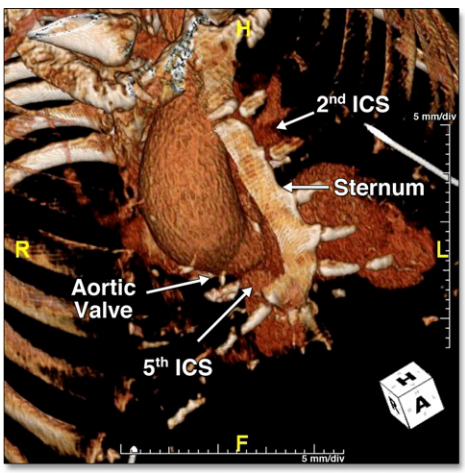

Figure 2. Extended Upper Hemi-Sternotomy

A 58-year-old man with a bicuspid aortic valve (BAV) presented with an ascending aortic aneurysm (5.2 cm) and asymptomatic moderate AS. He was referred for a mini–aortic valve replacement and ascending aortic replacement. Pre-operative virtual planning showed the location of the aortic valve to be below the fourth ICS. Although a full sternotomy was a valid option, it was evident that an upper-sternotomy extending into the right fifth ICS would also work and spare a substantial part of the inferior sternum. As anticipated pre-operatively, the exposure to the aortic valve and ascending aorta through the extended hemi-sternotomy was excellent. The aortic valve was replaced with a tissue valve and the ascending and hemiarch were replaced with a deep hypothermic circulatory arrest time of 16 min and an 8.5-cm incision. Abbreviations as in Figure 1.

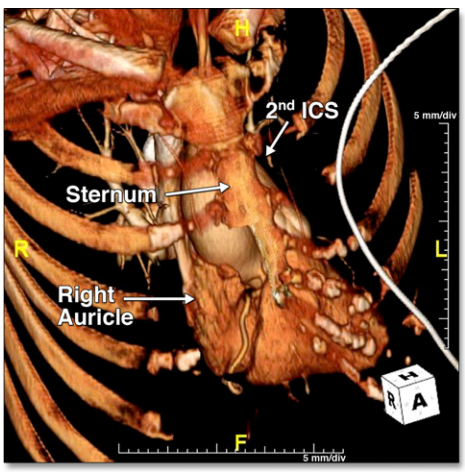

Figure 3. Lower Hemi-Sternotomy

A 68-year-old woman presented with BAV and symptomatic AS. The 3D reconstructed computed tomography images revealed a long aorta, small heart, and the aortic valve positioned between the fourth and fifth interspaces. Pre-operative virtual planning suggested that the exposure through an upper hemi-sternotomy would be adequate but challenging given the lower position of the aortic valve. Instead, it was apparent that performing a lower hemi-sternotomy extending from the xiphoid to the right third ICS would position the aortic valve within the operative field while providing a comfortable exposure for aortic cannulation. As anticipated, a 7-cm incision and a lower hemi-sternotomy provided excellent exposure to the aortic valve as well as the ascending aorta and right atrium for cannulation. Abbreviations as in Figures 1 and 2.

Figure 4. Right Second ICS Mini-Thoracotomy

A 56-year-old man presented with critical aortic stenosis. Virtual planning suggested that a right mini-thoracotomy through the second ICS would provide good exposure to the aortic valve since the patient's proximal aorta was positioned slightly to the right of the midline. A 6-cm right thoracotomy incision was performed. The working distance to the aortic valve was comfortable and the aortic valve replacement was performed with minimal difficulty. The second (2) and third (3) ribs are marked for illustration. Abbreviation as in Figure 1.

the thoracic cavity. Persisting with the standard upper hemi-sternotomy in these scenarios would have made the operations technically more demanding and potentially led to prolonged ischemic times and conversion to full sternotomy (Figs. 1–4).

Minimally invasive valve surgery is a complex undertaking. Three-dimensional reconstructed MDCT images allow virtual planning of the exposure which may decrease ischemic times and conversion rates. In the current era of advanced imaging technology this valuable and practical tool should be utilized in all patients being considered for minimally invasive aortic valve surgery.

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