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COMPUTATIONALLY SIZING A LEFT VENTRICULAR ASSIST DEVICE GRAFT: A PRE-PROCEDURAL TOOL TO IMPROVE SURGICAL OUTCOMES

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ABSTRACT

Implanting Left ventricular assist devices (LVADs) can be life saving therapies that improve life expectancy for the patients that receive it. The target patient population suffer from end-stage heart failure and are therefore susceptible to morbidities arising from a less than ideal surgical implantation. Importantly, the graft that carries the blood from the LVAD pump to the aorta needs to be sized accordingly so as to not cause any compounding complications. The current typical surgical method, is to perform a visual estimation at the time of implantation. This present study proposes a computational tool that utilizes pre-procedural imaging to better calculate the personalized, ideal, LVAD graft length.

Keywords: LVAD, heart failure, computational tool, imaging, MRI, CT.

INTRODUCTION

For some patients with end stage-heart failure, the remaining option for survival is the implantation of a left ventricular assist device (LVAD) for providing mechanical circulatory support. Such a device decreases the work load on the diseased heart and increases survivability: these can allow for a bridge to a critical medical decision, a bridge to transplant, a bridge to recovery or be used as a destination therapy. However, the overall implantation procedure can be very complex and unforgiving given the expected longevity of the device inside the body and a thorax with internal movements. While the technological advancements in the machinery involved continues to improve, the surgical procedure has been relatively unchanged throughout; yet, there have been shift towards minimally invasive approaches. Given the seriousness of complications, any potential improvements on these procedures should be addressed.[1]

An avenue for possible chronic problems lies in the blood flow from the pump to the aorta [2]. This flow is carried commonly by a corrugated graft that is sized and cut at the moment of implantation. The sizing of this graft is typically done by placing this tubing over the patient's body and estimating the relative length from the outflow of the LVAD pump to the attachment site on the ascending aorta; i.e., circumventing the heart on the outside perimeter of the right ventricle.

A mismatch of the graft length, from the actual anatomical distance within the patient will likely result in less than an ideal implantation procedure. For examples, if the graft is too long, it is susceptible to kinking and possible obstruction of blood flow. This poses risks for clotting and the device having less of an assistance than intended [3]. Whereas, if the outflow graft is too short, it could cross over the anterior surface of the heart and put undue pressure on the right ventricle yielding to future complications with the graft or/and right sided heart issues.

In order to achieve an empirical estimate of the LVAD outflow graft, a computational tool was developed. Using pre-procedural MR or CT imaging, a virtual segmentation can be employed to appropriately measure the length from the LV apex, the ideal pump location, to the ascending aorta. This should lead to fewer complications and thus a higher success rate for LVAD implantations.

METHODS

Perfusion fixed human hearts that were MR imaged by the Visible Heart® Laboratories were used to develop this unique computational measuring tool. Each DICOM image set was imported into Materialise Mimics® and a 3D mask rendering of the attitudinally anatomical heart was created. This 3D mask was then imported into MATLAB (Figure 1) where the graft length calculations were performed. A point cloud was generated from the matrix and used to find the appropriate anatomical landmarks.

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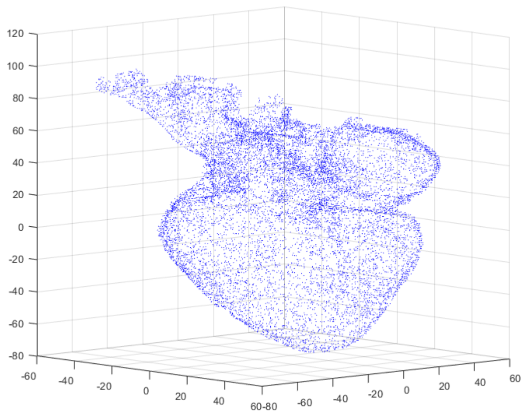

Figure 1: MATLAB point cloud rendering of 3D mask of the heart model derived from the MRI scan.

Each heart was then oriented to generate the anteroposterior view that was estimated to be the gerenal position of a patient on the oprating table, and a 2-dimensional projection was generated (Figure 2). This projection can be used to calculate the perimeter around the given heart that will serve as a hard boundary. The calculated graft path must adhere and not cross this boundary, essentially following the ideal path for the LVAD implant.

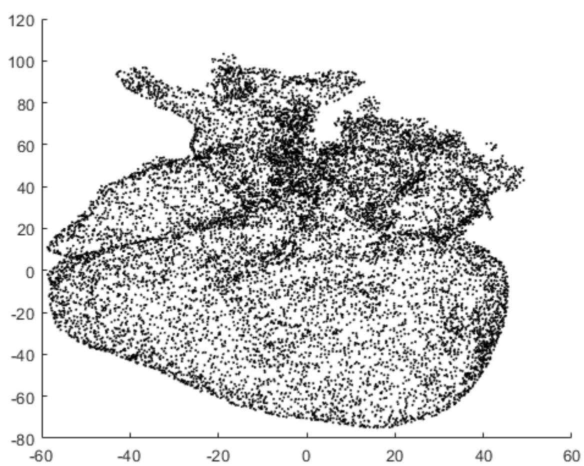

Figure 2: A 2D projection of the heart in an AP orientation.

Using the AP projection, the implanter could be provided with the option to choose the graft end-points. Using this information the ideal graft length can then be better calculated.

RESULTS

From the matrix of the 2D projection for this given heart, a path using the 10 mm diameter of a common LVAD graft was generated (Figure 3).

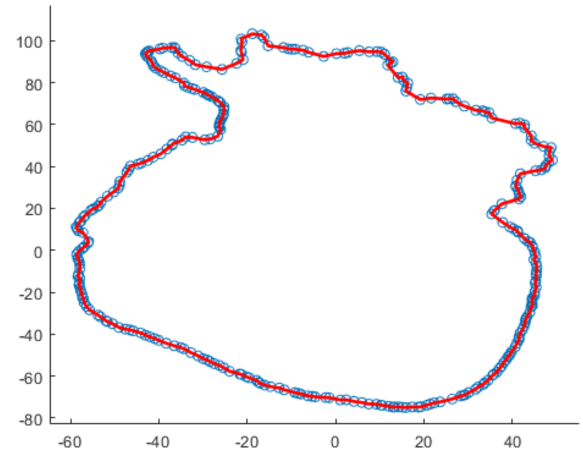

Figure 3: The generated perimeter around the AP projection of the heart.

Following the user inputs the LVAD graft length can be calculated and displayed (Figure 4). This gives flexibility for surgeon to inspect the pre-operative imaging and also decide on pump and graft implantation sites. The path has also been smoothed to account for the graft's maximum bending radius

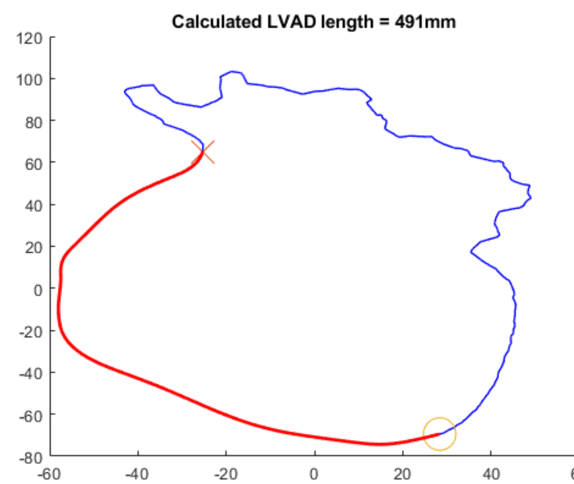

Figure 4: The final calculated LVAD graft length and its visualization. Start and end points are marked with an O and a X respectively.

DISCUSSION

Pre-operative imaging is already in use for LVAD implantation procedures, therefore it is imperative to attempt to utilize this information for planning so to ensure improved outcomes. The outflow graft sizing is an important step in LVAD implantation that may be best outsourced to computational tools in order to move towards aiding in reliability and reproducibility.

Future work by our group will concentrate on computationally locating the ideal pump implantation site

(Figure 5) as well as the optimal angle for anastomosis onto the aorta.

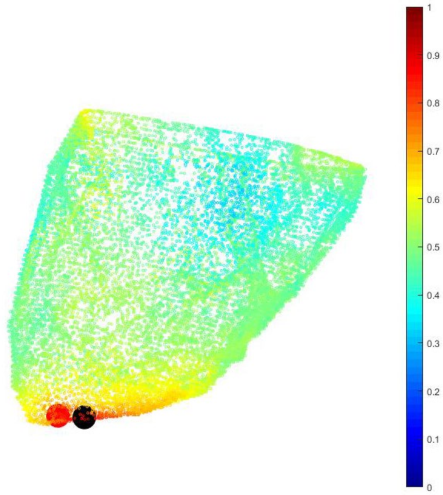

Figure 5: Computationally located sites for LVAD implantation. Site collocated to the apical dimple

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