Computer Assisted Surgical Planning for Coronary Artery Bypass Grafting

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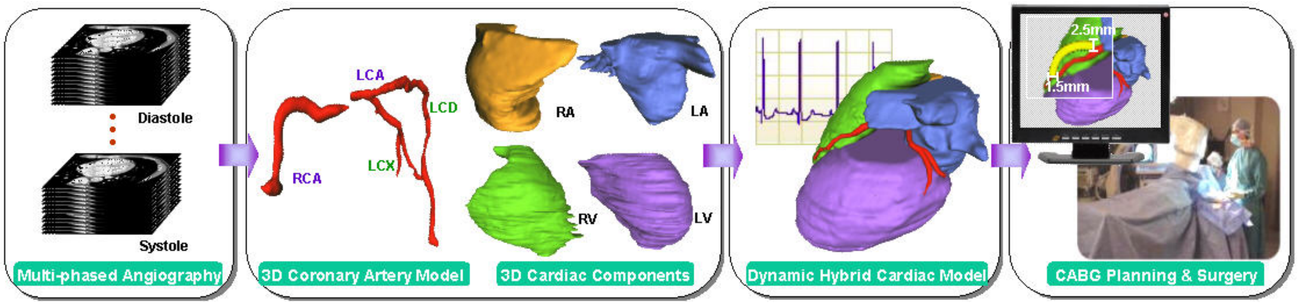

Figure 1: Construction of Hybrid Cardiac Modeling for Coronary Artery Bypass Graft Surgery Planning

1 Introduction

Surgical reconstruction of blocked arteries began in the late 1960s and has proved to be remarkably successful. The coronary artery bypass grafting (CABG) operation is the foundation of surgical management. The goal of this operation is to restore the blood supply to the heart muscle by creating a new route for the blood to flow around the blockages. CABG is the most common operation performed on the human heart. Current surgical planning is very dependent on the expertise of the surgeon and uses only a limited amount of information obtained from sectional images. Therefore, the accurate position of the occluded region and the length of the vessel to be transplanted need to be known before CABG in order to reduce the time required for surgery and the risk. Our research aims at interactive surgical planning for CABG based on a hybrid cardiac model composed of ventricles, atria, and coronary artery. Using the proposed model, the position of the occluded or narrowed portion of the coronary artery can be found easily and the site of the transplant can be planned interactively. Moreover, an accurate quantitative estimate of the length and thickness of the vessel to be transplanted can be provided.

2 Exposition

Planning a bypass graft requires the creation of a 3D model of the vessel to be transplanted and to union with the original coronary artery. However, it is difficult to distinguish the accurate position of the occluded region and to measure the length of the vessel to be transplanted only by using tree-like artery models. Therefore, a unified model composed of the coronary artery and total cardiac shape are necessary to design the transplantation route more accurately. And this should be a time-varying model that tracks the coronary artery and the total shape of the heart to simulate dynamic cardiac motion.

In our work, a hybrid cardiac model is developed, which is composed of coronary artery having a tree-like structure and a total heart volume divided into the right atrium (RA), left atrium (LA), right ventricle (RV) and left ventricle (LV) to analyze the relationship between the vessel occlusion and the function and motion of the atria and ventricles. Computer-assisted surgical planning can be performed more efficiently using the dynamic hybrid model and the transplant vessel model together.

Figure 1 shows the construction of a dynamic hybrid cardiac model for CABG surgery planning. Initially, we extract the coronary artery, the RA, LA, RV and the LV from CTA images for all phases of the heart. The coronary artery is extracted using 3D region growing based on an eigen value of Hessian matrix. The RA, LA, RV and the LV are segmented using Intelligent Scissors. Then, we reconstruct dynamic models of the heart and coronary artery based on 3D models of each phase. Correlation of the coronary artery models is based on feature points such as tree branches. And the atria and ventricles over a cardiac cycle are registered by using a physics-based dynamic model[S.M.Choi 2001][M.H.Kim 2002]. Finally, we search the region of the occluded area in the hybrid cardiac model to plan a transplant route.

Surgeons design several types of routes using the visualization provided by our model in the desktop personal computer. The vessel to be transplanted can be automatically created in the form of a tube-shaped parameterized implicit surface with the length and end cross-sections required for every planned route. The surgical plan is represented as a union of the transplant whole coronary artery within the dynamic hybrid cardiac model.

3 Conclusion

The proposed hybrid cardiac model is very useful for understanding the position of an occluded coronary artery relative to other cardiac components. It will also make possible more objective and accurate estimate of the position and size of the transplanted vessel, based on the visualization of myocardium viability, by analyzing the shape of the coronary artery and the motion of the atrium and ventricle. This will lead to less trial-and-error during surgical time. This model can also be useful for clinical experiments such as the correlation of coronary artery disease and the functions of cardiac components, as well as the support of pre-surgical planning for CABG surgery. Also, we can compare the shape and motion of the coronary artery before and after surgery by constructing a dynamic hybrid model using images acquired after surgery. In the future we expect to be able to analyze the effectiveness of surgery by measuring blood flow and plaque within blood vessels before and after an operation.

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References

S.M.CHOI, Y.K.LEE, M.H.KIM, 2001. Quantitative Analysis and Visualization of the Endocardial and Epicardial Walls Using Gated SPECT Images. In proceedings of SPIE's International Symposium on Medical Imaging.

M.H.KIM, ET AL., 2002. Visualization and Quantitative Analysis of the Left Ventricle Function Using MRI. Proceedings of International Society for Magnetic Resonance in Medicine Tenth Scientific Meeting and Exhibition.

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