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Fusion of Myocardial Perfusion Data with CT Coronary Angiography

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Abstract

Our current approach to fusion of CTCA and PET perfusion data uses the epicardial surface from the perfusion data onto which the CT coronary arteries are aligned and warped. This work was undertaken to improve the alignment and the display realism by using CT epicardial boundary information. PET and CTCA images from a combined scanner were used. Based on the location of the LV detected from PET during standard perfusion processing, the LV chamber of the CT was located. Hounsfield units were used to define an estimated endocardial surface in the CT. Based on the endocardial surface, the epicardial boundary was detected, again using Hounsfield units, or when that failed, by estimating its position based on the detected endocardium. Coronary arteries were detected using a commercial program; the epicardial surface was forced to be congruent with all detected artery points. A confidence factor in each epicardial boundary point was maintained based on how each was detected, whether through threshold, through estimation, or by using the coronary artery points. The epicardial boundary surface points were nonlinearly filtered; erroneous surface points, as defined by local properties and confidence factors, were replaced with values interpolated from the nearest points deemed more accurate. The resulting epicardial surface was linearly aligned to the epicardial boundary detected from the PET, and the CT boundaries were then color-coded based on the PET perfusion. Resulting surfaces were much more realistic than those created using PET epicardial boundaries (Fig 1.) Forcing the CT epicardial surface to lie on the detected coronary arteries eliminated problems with alignment and warping of the coronary arteries onto the PET surface.

I. Introduction

Combined PET/CT scanners are capable of high-resolution imaging of cardiac anatomy, including the coronary arteries, in addition to myocardial perfusion and metabolism. While separate 3D displays of both types of data are available, there may be incremental value in combining the information in a single, fused display. We have developed a method to segment the left ventricle (LV) from the computed tomographic coronary angiogram (CTCA) and align to it the myocardial perfusion data obtained from the positron emission tomogram (PET). Quantitative information computed from the nuclear image regarding both

infarction and viability can then be displayed concurrently with the anatomical information from the CT, and the two can be visually and quantitatively compared.

II. Methods

A. CT Boundary Detection

Standard processing programs were applied to the perfusion (or metabolism) images in order to reorient transaxial slices into short axis sections, isolate the LV, and resample the myocardial count distribution into a 3D map of perfusion. In addition, a commercially available program was used to segment and extract 3D coronary artery trees from the CTCA..

We used the parameters obtained from automatic processing of the PET image to reorient the CT and then identify the LV chamber. Since the CT image was created using intravenous contrast, the LV chamber has very high contrast, and the Hounsfield units can be used to define the basal and apical extents. The endocardial boundaries of the LV chamber were detected by radial sampling from the LV long axis by determining where the Hounsfield units drop off from the high-intensity contrast to the lower intensity of myocardium. The radial sampling was continued for 2cm outside of this point to find the location where the Hounsfield units either drop to the level of air in the lungs, or rise once more to the level of contrast in the right ventricle (RV). If such a point was found, the boundary was accepted. If an endocardial chamber point was found but no corresponding epicardial boundary point was located, then the endocardial radius + 1cm was used to estimate the epicardium. If the endocardial boundary detection failed, then the average radius of the correctly detected endocardium in the rest of the short axis slice was used as the endocardial point, and the epicardium was again set at the endocardial point + 1cm.

Then, the 3D coronary artery boundary points were transformed to the same short axis coordinate system used to resample the CT LV. The detected LV epicardial points were replaced by the coronary artery tree points at the proper angular locations, so that the epicardium was essentially forced to lie congruent with the coronary arteries. Throughout the operation, confidence factors were maintained that related to the likelihood that a detected point was really on the epicardial surface. For example, if the point was obtained by using the detected coronary arteries, then the confidence factor was 1. If the point was obtained using an average endocardial location + 1cm, the confidence value was 0. Finally, a non-linear smoothing operation was performed by fitting surface patches to small segments of the epicardial boundary using the confidence factors as weights in the fitting operation. Points which were far from the patch were replaced with their corresponding points obtained from the fit. Finally, a linear smoothing operation was performed to create a visually pleasing surface. After all processing was completed, the goodness of the epicardial boundary was estimated by measuring the distance between it and the user-segmented coronary arteries, which are presumed to lie on the surface.

B. Fusion of the Nuclear Perfusion Data to the CT

Both the PET perfusion image and the CT image were sampled using the same coordinate system, but at different resolutions. Thus, we presumed that the PET was in the same orientation but not at the same scale or at the exact location of the CTCA. Therefore, the PET data was translated so that its center matched the center of the sampled CT data, and then scaled along the LV long axis so that its length matched that of the CT LV. Finally, the PET perfusion data was interpolated to match the resolution of the CT surface. The 3D display of the CT LV epicardium was color-coded according to the quantitated perfusion information

III. Results

Figure 1 shows an example of the surface detection approach, first using the basic thresholding technique and then after non-linear smoothing. After processing, the mean distance that of the CT epicardial surface from the coronary arteries was 1.4mm, measured from 5 subjects. Figure 2 shows examples of the final display generated with the described methods. 3D displays were shaped realistically and the relationship between quantified perfusion and coronary anatomy could be appreciated.

IV. Conclusions

Use of epicardial surfaces from CTCA improves the fusion and visualization of CTCA and perfusion data.

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Fig. 1.

Example of epicardial surface detection on a single transaxial slice through the CTCA. A. Boundary points using Hounsfield unit-based thresholding and estimation from endocardial surface points. The boundary finding fails in regions near the RV, and near papillary muscles. B. Boundary points after non-linear smoothing.

Fig. 2.

Examples of the 3D displays obtained by segmenting the CT epicardial surface and the aligning the perfusion information to it. Colors are proportional to blood now in the myocardium; black areas are those which have quantitatively been determined to be abnormal.