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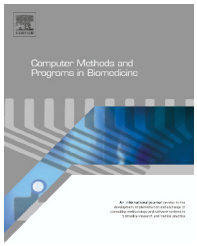

A novel approach for the automated segmentation and volume quantification of cardiac fats on computed tomography

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ABSTRACT

The deposits of fat on the surroundings of the heart are correlated to several health risk factors such as atherosclerosis, carotid stiffness, coronary artery calcification, atrial fibrillation and many others. These deposits vary unrelated to obesity, which reinforces its direct segmentation for further quantification. However, manual segmentation of these fats has not been widely deployed in clinical practice due to the required human workload and consequential high cost of physicians and technicians. In this work, we propose a unified method for an autonomous segmentation and quantification of two types of cardiac fats. The segmented fats are termed epicardial and mediastinal, and stand apart from each other by the pericardium. Much effort was devoted to achieve minimal user intervention. The proposed methodology mainly comprises registration and classification algorithms to perform the desired segmentation. We compare the performance of several classification algorithms on this task, including neural networks, probabilistic models and decision tree algorithms. Experimental results of the proposed methodology have shown that the mean accuracy regarding both epicardial and mediastinal fats is 98.5% (99.5% if the features are normalized), with a mean true positive rate of 98.0%. In average, the Dice similarity index was equal to 97.6%.

1. Introduction

The cardiac epicardial and mediastinal (also termed pericardial) fats are correlated to several cardiovascular risk factors [1]. At the present, three techniques appear suitable for the quantification of these adipose tissues, namely: magnetic resonance imaging (MRI), echocardiography and computed tomography (CT). Although these modalities have been widely used in several studies in the literature [2–4], computed

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tomography provides a more accurate evaluation of fat tissues due to its higher spatial resolution when compared to ultrasound and MRI [5]. In addition, CT is also widely used for evaluating coronary calcium score [4].

The automated quantitative analysis of epicardial and mediastinal fats may add a prognostic value to cardiac CT trials, ensuring an improvement on its cost-effectiveness. Besides, that automation diminishes the variability introduced by different observers. In fact, quantifying these data by direct user intervention is highly prone to inter and intra-observer variability. Thus, quantified samples may not be associated to a unified common sense of segmentation. Moreover, Iacobellis et al. [6] addressed the fact that the thickness of the epicardial fat and coronary artery disease, for instance, correlate independently of obesity. This evidence supports the individual segmentation and quantification of the adipose tissues rather than merely and simply estimating their volumes based on the overall fat of the patient.

1.1. *Contributions of this work*

In this work, we propose a novel methodology for automatically segmenting and consequently discriminating both the epicardial and mediastinal fats on cardiac CT images. To the extent of our knowledge, there is currently no unified method in the literature capable of both types of autonomous segmentations. On the entire extent of the proposed methods for cardiac fat segmentation [5,7–10], the addressed issue is specifically the segmentation of the epicardial fat, whereas no work has ever attempted to segment the mediastinal. Moreover, we resolve the segmentation issue diverging greatly with respect to the basis of the approach in relation to other works by employing an intersubject registration along with classification algorithms to produce the segmentation.

Summarily, this work contributes mainly to the field of visual computing by, namely: (1) proposing an accurate intersubject registration for cardiac CT images, (2) developing and analysing a robust hybrid similarity measure, applied within the registration procedure, (3) designing a new feature based on the Gaussian Kernel, (4) corroborating on the appliance of classification algorithms for image segmentation, (5) analysing the performance and accuracy of various classifiers for the problem, (6) creating a ground truth of cardiac fats available online and, mainly, by developing and evaluating (7) a unified and fully automatic segmentation methodology for both epicardial and mediastinal fats on cardiac images.

2. Literature review

The human heart is enclosed in the pericardium, a fibroserous sac comprising three concentric layers. The outermost layer is a densely fibrous, tough and inelastic structure, the fibrous pericardium. Inside the fibrous pericardium is the serous pericardium, which consists of two layers; the outer of these (which is firmly applied to the inner surface of the fibrous pericardium) is termed parietal layer. This layer is reflected around the roots of the great vessels to become continuous with the visceral layer (epicardium), which covers the internal surface of the heart and is firmly applied to it [11]. Each one of these layers is depicted in Fig. 1.

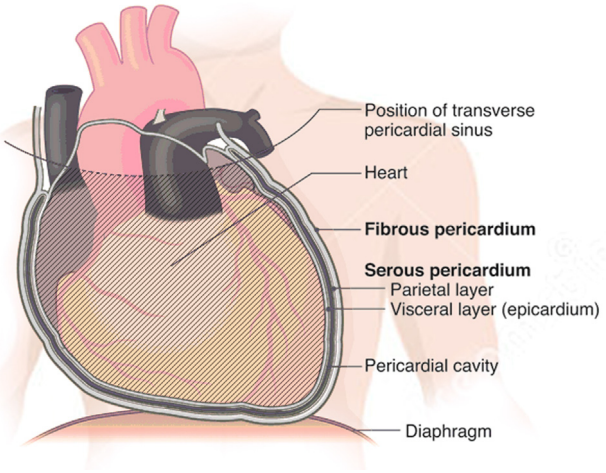

Fig. 1 – Outermost layers of the heart.

Sacks et al. [12] define the epicardium or visceral layer of the pericardium as a population of mesothelial cells that migrate onto the surface of the heart from the area of the septum transversum (the embryological source of the diaphragm). Furthermore, they define that, in the normal adult, the epicardial fat is concentrated in the atrioventricular and interventricular grooves and along the major branches of the coronary arteries as well as, to a lesser extent, around the atria, over the free wall of the right ventricle and over the apex of the left ventricle. The authors also define pericardial fat as all the epicardial plus the paracardial fat and, consequently, define that paracardial is the fat located on the external surface of the parietal pericardium (also within the mediastinum). They also highlight that paracardial fats have been alternatively termed mediastinal fats in the literature. The mediastinal area is shown in Fig. 2.

Sicari et al. [2] define that cardiac fats can be distinguished between two types of deposits: (1) the epicardial, which they describe exactly with the same words as defined by Sacks et al. [12] and, (2) the pericardial, which they define as being the fat situated on the external surface of the parietal pericardium within the mediastinum (alternatively termed mediastinal or

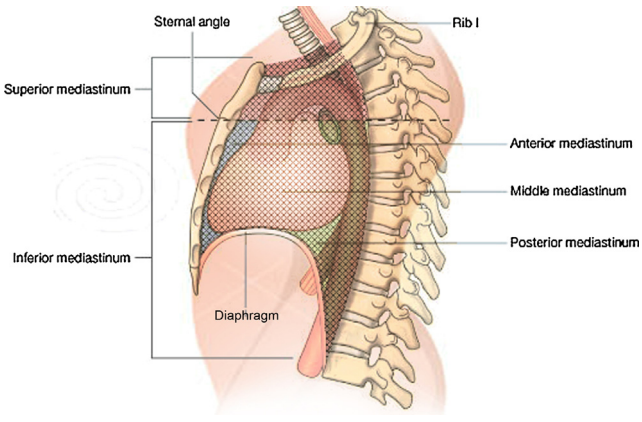

Fig. 2 – Mediastinal space.