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A reference free approach for the comparative evaluation of eight segmentation methods for the estimation of the left ventricular ejection fraction in cardiac MRI.

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Authors: A. Lalande¹, J. Leberberg^{2,3}, I. Buvat⁴, P. Clarysse⁵, C. Casta⁵, A. Cochet¹, C. Constantinidès^{2,3}, J. Cousty⁶, A. de Cesare², S. Jehan-Besson⁷, M. Lefort², L. Najman⁶, E. Rouillot³, L. Sarry⁸, C. Tilmant⁹, M. Garreau¹⁰, F. Frouin²; ¹Dijon,FR,University of Burgundy,LE2I (UMR CNRS 6306), ²Paris,FR,Inserm/UPMC,Laboratoire d'Imagerie Fonctionnelle, ³Ivry Sur Seine,FR,ESME-Sudria,PRIAM, ⁴Orsay,FR,Université de Paris Sud,IMNC (CNRS UMR 8165), ⁵Lyon,FR,Université de Lyon,CREATIS (CNRS UMR 5220), ⁶Marne La Vallée,FR,Université de Paris Est,LIGM-A3SI (UMR 8049), ⁷Aubière,FR,LIMOS,LIMOS (CNRS UMR 6158), ⁸Clermont-Ferrand,FR,Université d'Auvergne,ISIT (CNRS UMR 6284), ⁹Clermont-Ferrand,FR,Université Blaise Pascal,Institut Pasteur (CNRS UMR 6602), ¹⁰Rennes,FR,Université Rennes 1,LTISI (INSERM UMR 1099)

Purpose / Introduction

Objective evaluation and comparison of segmentation algorithms for medical imaging is still a challenging issue. The most frequently used evaluation method consists in comparing the segmentation with a manual delineation. Since obtaining such manual segmentation can be tedious, we proposed a method based on the "extended Regression Without Truth" approach (eRWT)(1). This approach is applied to the comparative evaluation of 8 segmentation algorithms with different degrees of automation from the estimated left ventricular ejection fraction (LVEF).

Subjects and Methods

Series of short-axis cine MR images covering the left ventricle were obtained in 36 patients and 9 healthy volunteers (20 frames per cycle). For each series, five automated segmentation methods(2-6) with different degrees of automation were used, and manual contouring was also performed by three operators, providing 8 independent estimates of the LVEF (eLVEF). The principle of our non-supervised method consists in estimating the parameters of a linear model linking the measurements (eLVEF) and the true value (tLVEF). The distribution of the tLVEF is assumed to follow a Beta distribution ($\mu=4$ and $\nu=5$) :

$$Pr(tLVEF) = \frac{tLVEF^{\mu-1} \times (1-tLVEF)^{\nu-1}}{B(\mu, \nu)} \text{ with } B(\mu, \nu) = \int_0^1 x^{\mu-1} (1-x)^{\nu-1} dx$$

The relationship between the tLVEF and the eLVEF is given by :

$$eLVEF = a \times tLVEF + b + error$$

The determination of a, b and the standard deviation of the error makes it possible to compare the accuracy of the methods. Methods are ranked as a function of their accuracy, based on a figure of merit (Fm) :

$$Fm = (a-1)^2 \times \frac{\mu(\mu+1)}{(\mu+\nu)(\mu+\nu+1)} + 2(a-1) \times b \frac{\mu}{\mu+\nu} + b^2 + \sigma_{error}^2$$

Results

The obtained ranking suggests that the LVEF estimations provided by manual methods were the most accurate and the least variable.

Methods	Fm
Manual	0.002
Manual	0.004
Manual	0.004
Semi-automatic(2)	0.006
Semi-automatic(3)	0.009
Automatic(4)	0.010
Semi-automatic(5)	0.011
Semi-automatic(6)	0.012

Discussion/Conclusion

All automated methods considered in our study were less accurate than manual delineations. The main limitations are due to segmentation failures in some particular slices. Their combination to provide one optimized mutual contour is currently under study.

The eRWT approach proved to be relevant to compare different segmentation methods without the use of gold standard and without any prior concerning the automation degree of the method. Moreover, it can be used to evaluate the improvement of a method in progress.

References

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