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Introduction
The left ventricular ejection fraction remains the most relevant parameter when describing the heart function in a clinical setting. The left ventricular ejection fraction (LVEF) is accurately measured from various methods including radionuclide angiography. MRI is a widespread technique that has the advantage of not using ionizing radiations. It appears that the success of MRI as a routine tool for measuring the LVEF will greatly depend on the development of fast and automatic tools designed to process the considerable mass of data acquired during an MR examination of the heart. The limiting step in the calculation of the LVEF is the amount of work needed to draw manually the contours of the heart on many slices. The aim of this work is to describe an automatic method for calculating the LVEF and to compare the results to those derived from radionuclide angiography (RNA).

Materials and methods
Image acquisition technique
Magnetic resonance imaging was performed with a 1.5 T magnetic resonance whole body imager (Siemens Vision) using a phased array receive coil. The breath-hold cine magnetic resonance data were acquired using an ECG gated gradient-echo sequence (segmented FLASH-2D with view sharing, repetition time=9 ms, echo time=4.4 ms, 9 lines per segment). The matrix size varied from 108 x 256 to 144 x 256. The use of the view sharing sequence improved the temporal resolution to 50 ms per frame. Multi-slice thin (5mm) short axis contiguous images were selected perpendicularly to the long axis from the base to the apex. The whole data set comprised 10 to 15 contiguous slices.

Automatic detection of the left ventricle endocardium
The presented automatic contouring method allows the processing of a patient data set and the calculation of the left ventricular volume and of the LVEF. Initially, all the diastolic slices are processed. For each slice, three parameters are defined: the first depends on the pixel grey level, the second on the presence of an edge detected using a Kirsch gradient operator, and the third on the information retrieved on the contiguous slice previously processed. From each parameter, a fuzzy set is created. The fuzzy set of the cardiac contour points is the intersection of the three aforementioned fuzzy sets. The extent to which a pixel belongs to this fuzzy set is given by the membership degree. The cardiac contours are detected on this fuzzy matrix with the aid of a dynamic programming technique, graph searching. On each slice the surface delineated by the endocardial contour is calculated. Once the processing of the diastolic images is finished, the systolic slices are processed in the same way. Finally, from the calculation of the endocardial surface area on each slice, the end diastolic and end systolic volumes (EDV and ESV) are calculated. LVEF (%) is calculated as 100 * (EDV - ESV)/EDV.

Manual processing of MRI data
The same slices were also processed manually and the contouring was performed by an experienced observer. The LVEF was calculated by the same formula as above.

LVEF determination by radionuclide angiography
In addition to MRI, LVEF was calculated using standard RNA at equilibrium by collecting 32 frames in left anterior oblique with 200 kcounts per frame. End diastolic and end systolic regions were manually defined. The background region was drawn outside the end-systolic boundary extending around the apex and along the lateral wall of the left ventricle. RNA-LVEF was calculated from the background corrected diastolic (D) and systolic (S) counts of the left ventricle as RNA-LVEF (%) = 100 * (D - S) / D

Studied patients
Data were acquired in 24 patients with a previous myocardial infarction. LVEF calculated using the automatic processing method was compared with the LVEF determined using radionuclide angiography and also with LVEF calculated from the manually drawn contours on MRI images.

Statistical analysis
Results were compared by calculating the linear regression equation and the standard error of the estimate (SEE).

Results
A good correlation was found between the LVEF obtained with the automatic method and that obtained from RNA (y = 1.07 x + 3.27; r = 0.87; SEE = 8.1). Moreover, an excellent correlation was also obtained between the automatic and manual methods (y = 1.01 x + 5.57; r = 0.94; SEE = 5.6).

Discussion and conclusions
LVEF has been measured successfully using MRI. Favorable comparisons have been observed between MRI-LVEF and RNA-LVEF in patients with idiopathic dilated cardiomyopathy after manually drawing the contours of the left ventricle. The present study suggests that MRI-LVEF might be used in patients with abnormal wall motion as seen after myocardial infarction. Automatic delineation of the endocardial borders is also highly feasible and should allow, in the next few years, the routine use of MRI for the determination of LVEF in coronary artery disease even when the left ventricular function is severely reduced.

References