

Atrial Septal Defect Assessed by Cardiovascular Magnetic Resonance: Comparison with Doppler Echocardiography

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SUMMARY

Atrial septal defect (ASD) is one of the most frequent congenital defects diagnosed in adult patients. Doppler echocardiography (DE) is the method of choice for its diagnosis and follow-up. Cardiovascular magnetic resonance (CMR), with its multiple applications, may be an excellent alternative for the assessment of this disorder.

To analyze the usefulness of CMR in ASD, we evaluated 30 patients with ASD and compared the results with those of DE. Twenty three patients had a ostium secundum type of ASD, 6 had a sinus venosus ASD and 1 had an ostium primum ASD. There was good correlation between CMR and DE in the aortic flows ($r=0.67$, $p<0.007$), pulmonary flows ($r=0.62$, $p<0.01$) and Qp/Qs ($r=0.56$, $p<0.003$). The frontal view of the ASD could only be assessed with CMR, which also allowed quantifying the flow through the defect. Direct planimetry of the ASD correlated adequately with quantitative pulmonary flow and the flow through the interatrial defect; additionally, the results obtained with both techniques were confirmed by CMR. We conclude that CMR correlates well with DE and is a valid alternative for the assessment of ASD. The frontal visualization of the defect and its flow quantification represent an advantage of CMR over DE.

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Key words > Magnetic Resonance Imaging, Echocardiography, Atrial Septal Defect.

Abbreviations >	ASD Atrial Septal Defect	DE Doppler Echocardiography
	TEE Transesophageal Echocardiography	CMR Cardiovascular Magnetic Resonance

INTRODUCTION

Atrial septal defect (ASD) is the congenital heart disease that is most frequently diagnosed in the adult. Doppler echocardiography (DE) is the method of choice for its diagnosis and tipification. At present, the characterization of the defect (size, morphology and relation with neighboring structures) is of crucial importance for the adequate selection of method as well as the closing device to be used. (1-3)

The need to rule out the presence of multiple septum orifices or anomalous venous returns that accompany ASD, forces to complement DE assessment with transesophageal echo (TEE). We believe that cardiovascular magnetic resonance (CMR) -with its different techniques for flow measurements, (4-6) and high-definition morphologic images- appears as a valid alternative to complete the study of ASD. (7-10). In order to analyze this hypothesis, the present study was focused on the following objectives: 1) to study

CMR ability in the evaluation of ASD. 2) To analyze the morphological and functional parameters obtained with CMR and compare them with those obtained by transthoracic Doppler echo in a similar group of patients.

MATERIAL AND METHODS

Patient selection

From September 2002 to April 2004, 30 consecutive patients, who were diagnosed with ASD by echocardiography, were enrolled in the study. All the patients were referred to perform a CMR. Echocardiographic studies, as well as CMR included the quantitative analysis of the aortic and pulmonary flows. As from these relations the respective Op/Qs were obtained. The time elapsed between both studies was 3.57 days (range 1 to 35 days). The CMR assessments were performed and analyzed by the same operator, experienced in the analysis of cardiovascular images. The Doppler echo assessments were performed by three different operators with experience in congenital diseases. Results

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were recorded in independent databases that were crossed for their final analysis.

Doppler Echo Study

ATL HDI 5000 and GE System Five echographs were used with 2-4 MHz frequency range transducers. The echographic assessment was performed according to the guidelines of the American Society of Echocardiography. (10) Assessment of the right ventricle morphology was performed subjectively. Anteroposterior measures of the defect were obtained from the apical and subcostal views. With DE it was not possible to obtain the precise ASD cephalocaudal measures. The quantitative analysis of the aortic flow was performed by measuring the diameter of the left ventricle outflow tract at the left parasternal long-axis. In the same place, and using a pulse Doppler, with a 10 mm sample size, the spectral wave flow was obtained. Pulmonary flow was measured at the outflow tract of the right ventricle, from the short axis of the big vessels, with a similar technique to that used for the aortic flow. In six patients a TEE was performed with multiplanar probes. To four patients percutaneous closure of the defect was performed and the study was carried out before or during the procedure. The scarce number of patients with TEE prevented the comparison of results with CMR and transthoracic DE.

Cardiovascular magnetic resonance assessment

A Philips ACS Gyroscan of 1,5 Tesla system was used. The CMR scans were performed in a ViewForum 2003, from Philips, release 3.4, with cardilogic software. Localizing sequences were performed to program the study cuts.

Resonance sequences: electrocardiography-gated sequences were performed. In order to obtain the images pondered in T1 a visual field of 400 mm was used, with an 8 mm slice width and a 256 x 256 mm matrix, which allowed a spatial resolution of 1.56 x 1.56 x 8 mm. The echo time was 20 ms and the repetition time depended on the patient's heart rate. Cine-resonance images were obtained with fast field echo (FFE, Philips) sequences, with retrospective electrocardiography gated and respiratory compensation. The acquisition matrix was of 400 mm, interpolated at 256 x 256 mm, due to the video. The echo time was 4 ms, with a

15° *flip* angle. The slice width was 8 mm. For the quantitative flow analysis a sequence called phase contrast was used. A variable matrix of 350 to 400 mm, with a 6 mm slice width was used.

Sequence for flow quantification: quantification of aortic and pulmonary flows was performed by means of acquiring the images transversal to the flow at the ascending aorta and at the pulmonary artery trunk, at the beginning of the pulmonary branches. Acquisition velocities were codified in 3 meters per second for the pulmonary and aortic flow.

Technique for ASD acquisition and measurement: localizing images were obtained at the transversal, coronal and sagittal planes. Subsequently, T1 (*turbo spin echo*) transversally oriented sequences were obtained. The oblique images were programmed on these and the heart short axis was obtained. Particular attention was paid to the inclusion of both atria. Transversal slices were useful to visualize the interatria septum throughout its extension. On these views of the fast field echo gradient sequences were programmed and 4-chambers view were obtained. Using these last images, and with phase-contrast images (previously described), the septum was "cut" parallel to ASD in its middle section (Figure 1). Velocity codification to measure transeptal flow was 2 meters per second. On the front images of ASD, in a "velocity map" the communication planimetry was performed and its diameter and flow were obtained, as well as the cephalocaudal and anteroposterior measures. (Figure 1, right)

Statistical analysis

The statistical analysis was performed with the statistical packages of the GB.Stat v6.5 and SPSS Interactive Graphics, v10-0.6, SPSS Inc, Chicago, IL programs. Data are expressed as mean with their standard deviations. For the primary comparative analysis of the continuum variables between DE and CMR (ASD size and aortic and pulmonary flows) in accordance with the normal tests results, the two-tails correlation statistical model was used for paired samples with Pearson or Spearman correction. To analyze the association between the ASD area measured by planimetry with CMR (dependent variable Y) and to determine which of the echocardiographic variables (independent variable X)

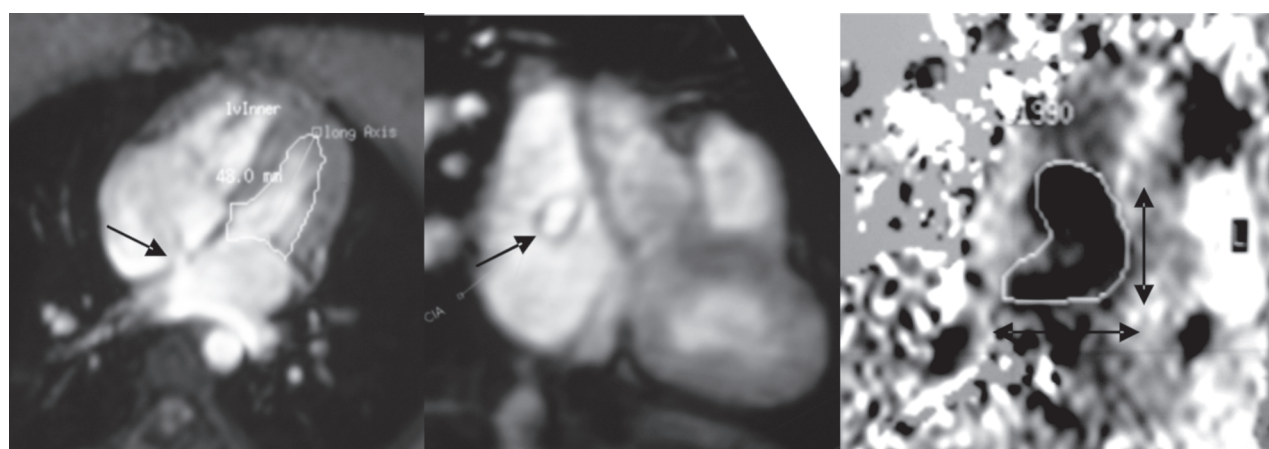


Fig. 1. Left: Cross section of CMR at a four-chamber view showing a solution of continuity at the mid-interatrial septum (arrow). Turbulent flow from left to right across the defect can be noticed. Center: frontal section of the interatrial septum. An ostium secundum ASD is seen (arrow). Right: Phase-contrast images of an ASD, with an irregular shape according to the measurements performed (arrows).

were associated with the ASD area, a multiple regression analysis with successive steps was performed. To compare both variables, the linear regression method was used. In order to assess the concordance between the same variables analyzed with both methods, the Bland-Altman analysis was performed. For the qualitative variables analysis the chi-square test was used. P values < 0.05 were considered significant differences.

Baseline characteristics of the studies population

Of the 30 patients enrolled in the study, 11 (37%) were males and 19 (63%) females, average age was 42 ± 19 years (range from 9 to 82 years). No differences were noted in regards to ages by sex. All the patients showed dilation of the right cavities. Of the 30 ASD, 23 (82%) were *ostium secundum* type; 6 (20%) of the sinus venosus type and 1 (3%) was *septum primum* type. During the recruitment period, defect closure with Amplatzer type device was performed to four patients. One patient showed multiple ASD. The defect was *septum secundum* type with a thin wall. This was suspected by the surface echocardiogram and confirmed later by the CMR and the TEE performed during the closure procedure. In this case, before placement of the device, both orifices were unified by breaking the thin wall that separated them.

RESULTS

Comparison between DE and CMR

In the comparative analysis of the aortic and pulmonary flows, a total of five patients were excluded due to CMR problems: three showed inadequate images for the analysis and two showed electrographic-gated bad signal. Two patients were excluded due to DE problems since flow measurements were non confident, obtaining extreme discordant values. In the latter, Qp/Qs was higher than 5, whereas the median for DE was 2.20 and for CMR was 2.38. When including these values in the regression analysis, a correlation was obtained between methods of $r = 0,56$, $p < 0,002$, and when they were excluded from the analysis, the obtained correlation was $r = 0,55$, $p < 0,004$, without influencing the final results.

In Table 1 the ventricular diameters and volumes are shown measured by DE and CMR. No significant differences were found between ventricular volumes measured with both methods. Aortic and pulmonary flows measured by CMR were 18% higher than those obtained with DE. This same trend was observed with the resulting Qp/Qs, but the difference in the assessments was 6%. ASD perimeter and the crossing flow were measured only with CMR.

Morphology and ASD flows

Differences were observed in ASD dimensions as measured by DE and CMR; lower values were found with DE in regards to CMR (see Table 1). In half of the patients, the anteroposterior diameters were greater than the cephalocaudal, giving them a horizontal, ovoid morphology; the other half showed similar form, but vertical. Good correlations were observed between the ASD diameter measured with DE and

Table 1. A comparison between DE and CMR measurements

Ventricular volumes and ventricular flows			
	Echo	CMR	p
EDV (ml)	72 ± 21	88 ± 20	0,10
ESV (ml)	25 ± 18	32 ± 15	0,51
EF (%)	67 ± 13	63 ± 11	0,53
Aortic flow (ml)	49 ± 10	57 ± 12	0,009
Pulmonary flow (ml)	108 ± 55	135 ± 48	0,002
Qp/Qs	2,30 ± 0,63	2,43 ± 0,75	0,001
ASD dimensions			
Cephalocaudal diameter (cm)	-	2,67 ± 1,28	-
Anteroposterior diameter (cm)	2,19 ± 0,81	2,69 ± 0,99	0,006
ASD area (mm ²)	-	586 ± 386	-

EDV: End-diastolic volumen. ESV: End-systolic volumen. EF: Ejection fraction

the anteroposterior diameters ($r = 0,69$, $p < 0,001$), cephalocaudal ($r = 0,44$, $p < 0,003$) and area ($r = 0,64$, $p < 0,001$) measured with CMR. Qp/Qs determined by CMR was directly related to the anteroposterior diameter of ASD measured with DE ($r = 0,52$, $p < 0,009$), whereas it was not correlated with any other parameter of the DE. In CMR measurements, ASD areas were directly correlated to the pulmonary flow ($r = 0,42$, $p < 0,05$), as well as with the flow throughout the defect ($r = 0,62$, $p < 0,002$). The only difference found with CMR between the different types of ASD was that the sinus venosus type defect had an anteroposterior diameter greater than the ostium secundum type ($3,64 \pm 0,82$ versus $2,38 \pm 0,84$, $p < 0,021$).

In Figures 2 to 4 the Bland-Altman analysis is shown comparing the aortic, pulmonary, and through ASD flows between DE and CMR. In the Bland-Altman analysis a good coincidence between the resulting aortic, pulmonary and Qp/Qs flows, measured with both methods ($r = 0,71$, DEE: 6,1 ml, $p < 0,007$; $r = 0,62$, DEE: 16 ml, $p < 0,013$ y $r = 0,53$, DEE: 0 ml, $p < 0,003$, respectively). Despite the good correlation between both methods, DE showed values lower than CMR in the quantification of the lower aortic, pulmonary and Qp/Qs flows: 21%, 10% and 4%, respectively. When analyzing the CMR results, an excellent correlation between the flow throughout the ASD and the pulmonary flow was observed ($r = 0,83$, $p < 0,0001$), which showed a strong association between these two parameters.

Comparison between DE and CMR

In the comparative analysis of the aortic and pulmonary flows, a total of five patients were excluded due to CMR problems: three showed inadequate images

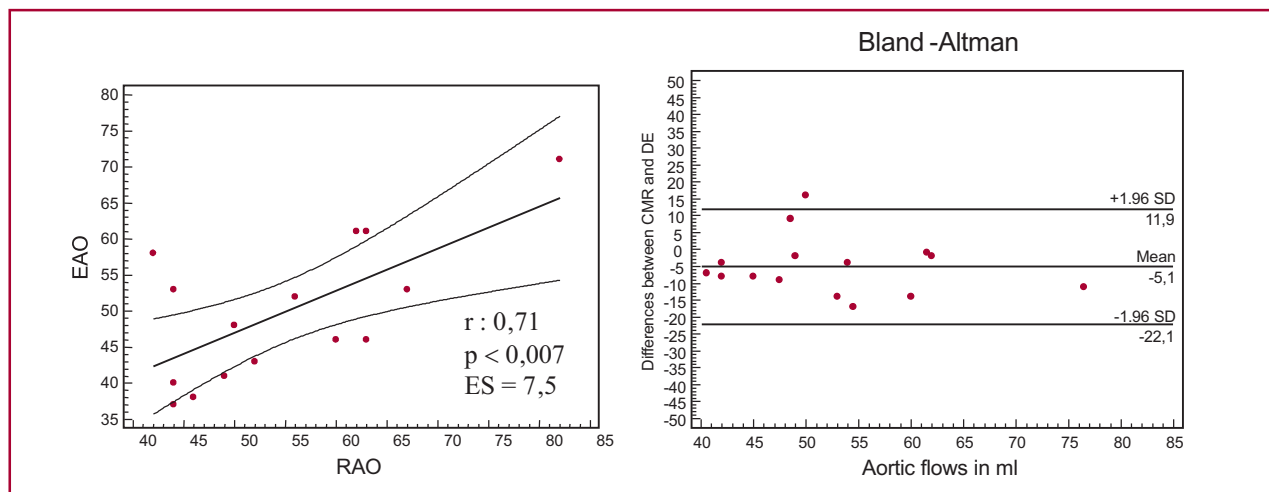


Fig. 2. Left: regression line comparing aortic flow measured by DE and CMR. Right: comparative analysis of Bland-Altman with mean differences in the measurements of the aortic flows.

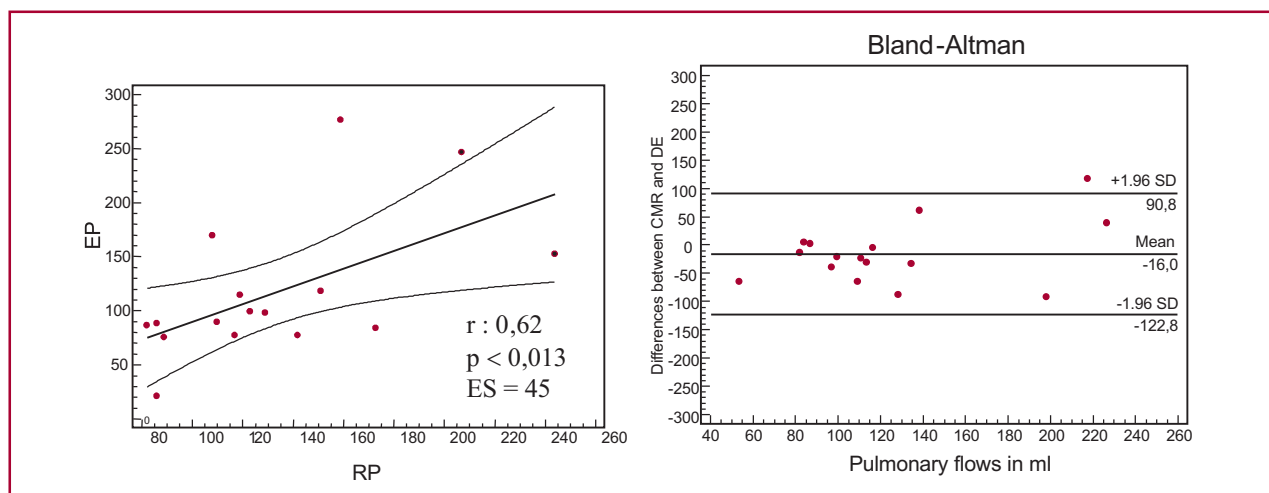


Fig. 3. Left: regression line comparing pulmonary flow measured by DE and CMR. Right: comparative analysis of Bland-Altman with mean differences in the measurements of the flows.

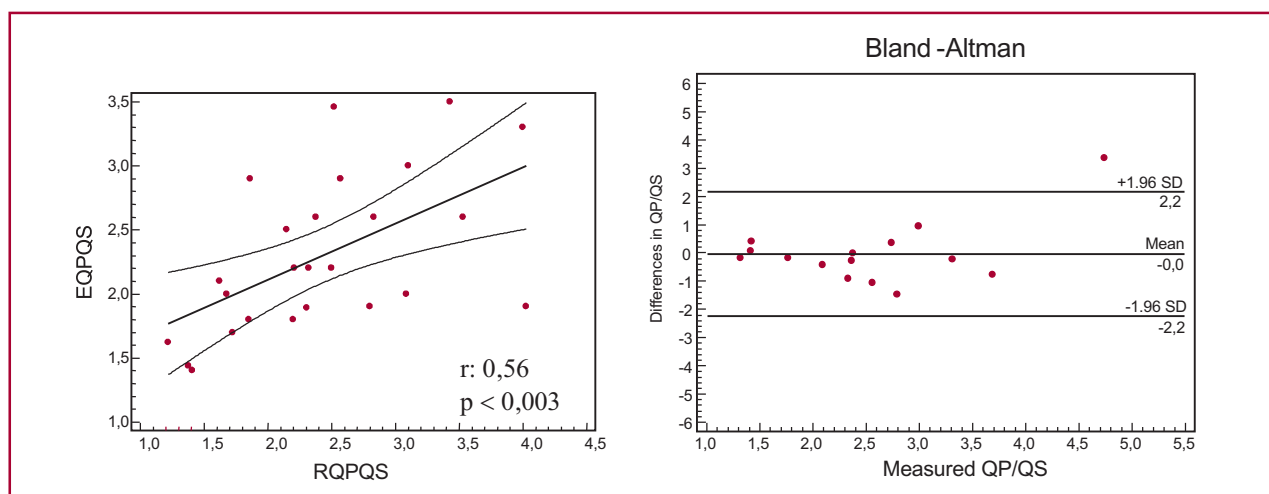


Fig. 4. Left: regression line comparing Qp/Qs measured by DE and CMR. Right: comparative analysis of Bland-Altman with mean differences in the measurement of this ratio.

for the analysis and two showed electrographic-gated bad signal. Two patients were excluded due to DE problems since flow measurements were non reliable.

DISCUSION

ASD is one of the congenital heart diseases habitually diagnosed in clinical practice. With a frequency of 3.8/10,000 born alive, (12) ASD appears as the septum disease most prevalent in adult age with 5.6. (13). In our service, ASD was diagnosed in 1.2% of the Doppler assessments consecutively performed in adult patients. At present, the therapy of choice, whenever anatomy allows, is percutaneous closure with Amplatzer. TEE has proved to be extremely useful in these procedures, to the extent of being considered an essential guide in its performance. (14). CMR and Multi-detector row computed tomography are the only methods able to provide front views of the ASD (Figure 2). It is vital to determine the relation between its borders and the adjacent structures (aorta, mitral valve, and vena cava) in the adequate selection of the size and positioning of the closure device. (15). In this study, the anteroposterior diameter of the ASD measured by DE had good correlation with the same measurement with CMR. The front view of the ASD provided by the CMR appears as a very useful tool for its study as it allows analyzing not only its shape but also to observe the relationship with the vena cava, the atria posterior wall and the atrioventricular valves.

This peculiar way of visualizing the defect allowed us to observe that its morphology is not always regular and provided us with a more anatomical approach. With the front view of the ASD, CMR can estimate, easily, the caudal flow that passes through. Previous studies had already noted the important diagnostic ability of CMR over DE for diagnosing ASD; (16) also, Durongpisitkul et al, (17) assessing patients subjected to Amplatzer closure observed that with CMR it was possible to obtain more information than with transesophageal echo in the evaluation of ASD. In our study, comparing CMR with DE, we obtained more information with CMR in the overall assessment of the defect. In our study, good correlations between flows measured by DE and CMR. Direct quantification of the flow through the defect showed a high correlation with the pulmonary flow measured with CMR ($r = 0,83$, $p < 0,0001$). This strong association leads us to speculate that flow measurement through the defect could be used alternatively to the volumetric pulmonary quantification. This measurement would be useful in patients with moderate to severe pulmonary failure, where there is pulmonary hyper-flow due to the additional regurgitating volume. On the other hand, it is worth remembering that the flow through the ASD depends on the right ventricular distension and pulmonary resistances; in patients where these are increased, direct measurement of ASD diameter would be helpful in defining therapy.

CONCLUSIONS

CMR allows fast, complete, and safe study of ASD. When compared to DE, good correlations in flow quantification were obtained. CMR has the additional advantage of allowing that the defect be observed through front images, and it is to date the only method that is able to directly quantify the crossing blood flow. Due to its harmless characteristics as well as its wide capacity of analysis, CMR should be considered a non invasive, alternative and complementary to DE method for the study of ASD.

RESUMEN

Comunicación interauricular evaluada por resonancia magnética cardiovascular: comparación con ecocardiografía Doppler

La comunicación interauricular (ASD) es uno de los defectos congénitos que se diagnostica con más frecuencia en el adulto. La ecocardiografía Doppler (ED) es el método de primera elección para su diagnóstico y seguimiento. La resonancia magnética cardiovascular (CMR), con sus múltiples aplicaciones, puede ser una excelente alternativa para su estudio. Para analizar la utilidad de la CMR en esta patología, se estudiaron 30 pacientes con ASD y se compararon los resultados con la ED. Veintitrés pacientes tenían ASD de tipo *ostium secundum*, 6 de tipo seno venoso y 1 de tipo *ostium primum*. Se observó buena correlación entre la CMR y la ED en los flujos aórticos ($r = 0,67$, $p < 0,007$), pulmonar ($r = 0,62$, $p < 0,01$) y Qp/Qs ($r = 0,56$, $p < 0,003$). Únicamente con la CMR se pudo visualizar el defecto en visión frontal y cuantificar el flujo que lo atraviesa. La planimetría directa de la ASD se correlacionó adecuadamente con el flujo cuantitativo pulmonar y a través del defecto interauricular, corroborándose los resultados obtenidos por estas dos técnicas en el estudio de CMR.

Se concluye que la CMR presenta buena correlación con la ED y que es una alternativa válida para el estudio de la ASD. La visualización frontal del defecto con la cuantificación de su flujo es una ventaja de la CMR sobre la ED.

Palabras clave ➤ Resonancia Magnética Nuclear, Comunicación Interauricular, Ecocardiografía.

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