Measurement of Left Ventricular Ejection Fraction in Pediatric Patients Using the Nuclear Stethoscope

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Left ventricular (LV) ejection fraction (EF) was measured in 25 patients, aged 2 weeks to 20 years (mean 8.6 years), using a portable nonimaging scintillation stethoscope. Technically satisfactory studies were obtained in 23 patients. LVEF was validated by cineangiography in 19 patients and by standard gated blood pool scintigraphy in 4. EF measured by the nuclear stethoscope correlated well with values obtained by cineangiography or scintigraphy ($r = 0.869$, $p < 0.001$) over a wide range of EF values (18 to 79%). In children younger than 5 years ($n = 11$), the correlation ($r = 0.728$, $p < 0.02$) was less satisfactory than in those older than 5 years ($r = 0.926$; $p < 0.001$). Although modifications in the instrument and further clinical trials with the stethoscope are needed before the device becomes clinically useful to pediatric cardiologists, our data indicate that the nuclear stethoscope can provide reliable assessment of LVEF in pediatric patients. **(Am J Cardiol 1984;53:211-214)**

Recent advances in radiopharmaceuticals, imaging systems and computer capabilities have allowed application of many nuclear cardiology techniques to pediatric patients. Radionuclide angiography has been applied to left and right ventricular function analysis in children with structurally normal hearts and those with congenital defects.[1-5] Since the first report on the use of a nonimaging scintillation probe to develop left ventricular (LV) time-activity curves in 1976,[6] the nuclear stethoscope has been shown to determine LV ejection fraction (EF) accurately at rest[7,8] and with exercise[9] in the normal[8,9] and abnormal[7-11] heart. The present study determines the accuracy and utility of the nuclear stethoscope in assessing LVEF in children and adolescents with cardiovascular disease.

Methods

Patients: Twenty-five patients, aged 2 weeks to 20 years (mean 8.6 years), with a variety of congenital and acquired cardiac defects were studied with the nuclear stethoscope (Table I). Among the group with congenital defects, 11 had prior palliative or corrective surgery for the defect and 10 had no prior cardiac surgery. Twenty-one patients were studied during cardiac catheterization and LV cineangiography was performed in each. In 4 patients studied on the ward or intensive care unit, a standard gated blood pool acquisition scintigraphy was performed. Two of 21 patients catheterized were excluded because of technical difficulties in achieving red blood cell labeling with the radiopharmaceutical. The 23 patients with adequate stethoscope studies and either scintigraphic ($n = 4$) or angiographic studies ($n = 19$) comprise the study group.

Radionuclide imaging technique: All patients underwent in vivo red blood cell labeling using i.v. stannous pyrophosphate (10 μg Sn^{+2}/kg) followed 15 to 20 minutes later by the administration of technetium-99m pertechnetate. The dose of technetium was calculated using a body surface nomogram adjusting the adult dose of 20 mCi/1.7 m^2 to the child's body surface area. The commercially available computerized nuclear probe (Nuclear Stethoscope®, Bios) was used for all studies. The probe device, which has been described extensively in previous reports,[7,9] consists of a 2-inch sodium iodide crystal detector with a microcomputer which measures and displays a high temporal resolution (10 ms) image of the LV time-activity curve. The position/monitor mode of the device displays beat-to-beat time-activity curves and allows localization of the optimal LV and background positions with a series of computer-assisted algorithms. Using the position-monitor mode of the stethoscope, 10 to 20 consecutive cardiac cycles were identified using manually controlled cursors and then analyzed by the microprocessor. The microprocessor determination of ejection fraction was made using the formula (end-diastolic counts − end-systolic counts)/(end-diastolic counts − background counts).

The 4 patients studied using gated blood pool techniques were imaged using a computerized single-crystal scintillation camera (Technicare Sigma 420®). EF was calculated by an

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TABLE I Cardiac Diagnoses in 25 Children with Nuclear Stethoscope Studies

Congenital heart defects (n = 21)		
Nonoperated		10
Ventricular septal defect	3	
Pulmonary valve stenosis	2	
Cardiomyopathy	2	
Tetralogy of Fallot	1	
Mitral incompetence	1	
Endocardial cushion defect	1	
Postoperative		11
Repaired		
Tetralogy of Fallot	2	
Endocardial cushion defect	2	
Ebstein's anomaly s/p tricuspid valve replacement	2	
Ventricular septal defect	1	
Total anomalous pulmonary venous return	1	
Tricuspid atresia s/p Fontan	1	
Aortic stenosis s/p valvotomy	1	
Palliated		
Tricuspid atresia s/p aortopulmonary shunt	1	
Acquired heart disease (n = 4)		
Osteosarcoma	1	
Myocarditis	1	
Complete heart block	1	
Kawasaki disease	1	

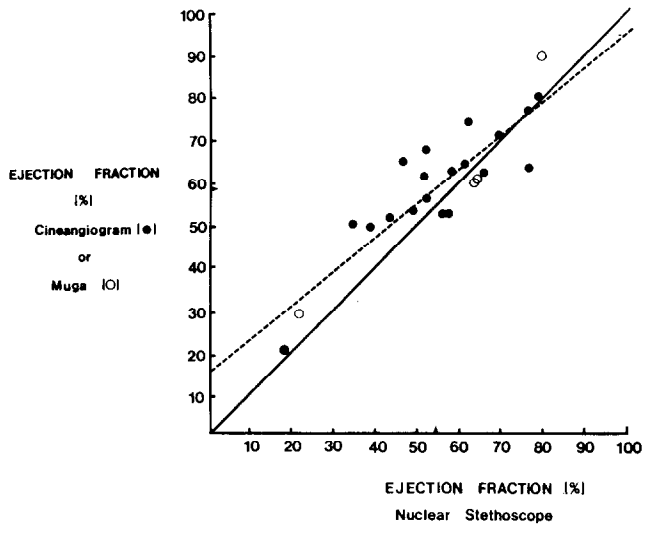

FIGURE 1. Comparison of left ventricular injection fraction determined by the nuclear stethoscope and by cineangiography or gated blood pool scintigraphy (Muga) in 23 pediatric patients (y = 0.78x + 16.6; r = 0.869; p <0.001; n = 23).

independent observer who was unaware of stethoscope results, using a semiautomatic edge-detection computer program on images obtained in the left anterior oblique projection which provided optimal separation of the atria and ventricles. Regional wall motion abnormalities were analyzed using cinematic closed-loop display. In 3 of the 4 patients studied by gated blood pool scintigraphy, studies were performed within 1 hour of the stethoscope study; in 1 patient the scintigraphic scan was performed 3 weeks after the nuclear stethoscope study.

Cineangiography: LV cineangiograms were obtained using 1 to 1.5 ml/kg body weight of diatrizoate meglumine (Renovist II®, Squibb) injected within 1 second. LVEF was measured using the area-length method[12] on digitized biplane (anteroposterior/lateral or anteroposterior/left anterior oblique) views of the heart. Measurements were made by independent observers not involved in the study, who had no knowledge of stethoscope study results. Stethoscope studies were performed 30 minutes or more after (n = 16) or immediately before (n = 3) LV angiography.

Comparison of the ejection fraction determined by the nuclear stethoscope with that determined by cineangiography and scintigraphy was made using standard linear regression analysis, correlation coefficient and paired *t* test. Group data are presented as mean ± standard deviation. Statistical significance is at the p <0.05 level.

Results

LVEF measured by cineangiography in 19 patients ranged from 20 to 80% (mean 59 ± 12) and in the 4 patients studied by scintigraphy from 30 to 89% (mean 58 ± 21). EF determined by the nuclear stethoscope in the same 23 patients ranged from 18 to 79% (mean 54 ± 16%) (difference not significant). There was a direct relationship between LVEF determined by the nuclear stethoscope and cineangiography or scintigraphy (r = 0.869; p <0.001) (Fig. 1).

In the 12 patients >5 years of age, whose body surface areas ranged from 1 to 1.83 m^2 (mean 1.42), the EF measured by stethoscope correlated more closely to cineangiography or scintigraphy (Fig. 2) than in younger patients (Fig. 3). In children younger than 5 years (BSA 0.23 to 0.74 m^2; mean 0.43 m^2) the EF measured by the nuclear stethoscope underestimated the values obtained by angiography (Fig. 3). However, the difference in mean EF calculated in these patients (53 ± 12% vs 58 ± 7%) was not statistically significant.

Discussion

The present study demonstrates that the nuclear stethoscope can accurately estimate LVEF in the pediatric population. The stethoscope values correlate well with both cineangiogram and gated blood pool studies over a wide range of ejection fractions. The data are in agreement with previous studies reported in adults.[7,9] However, EF values measured by the nuclear stethoscope are not as accurate in smaller children. The explanation for this disparity may lie in the size of the collimator, which is designed for adults. If the field of view of the collimator is too large for the relatively small size of the pediatric heart, an overestimation of systolic and, to a lesser degree, diastolic counts will be made, resulting in underestimation of the "real" EF.[7] Although decreasing collimator diameter could result in an appropriately limited LV field of view, the very small chamber volume will limit the count rate response of the probe.[8] Patient cooperation, which might be expected to be less in younger patients, was not a factor in that it did not adversely influence the measurements in our study. All patients younger than 5 years of age were studied after being sedated for cardiac catheterization. Alterations in the LV field of view occurring with respiratory motion[7] were not observed in our patients at

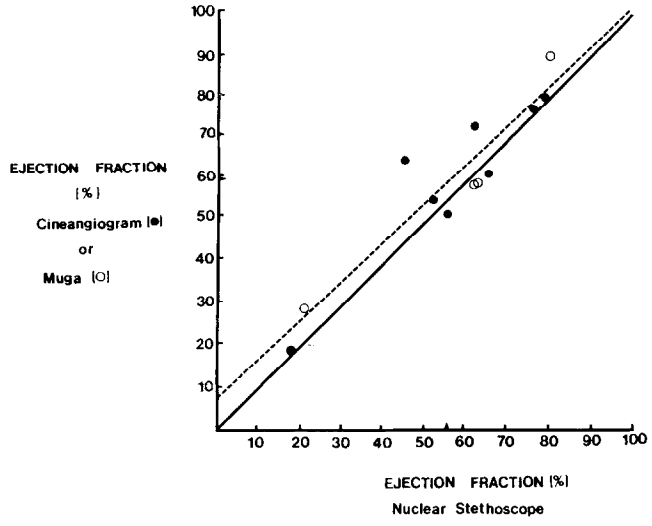

FIGURE 2. Comparison of left ventricular ejection fraction determined by the nuclear stethoscope and by cineangiography or gated blood pool scintigraphy (Muga) in 12 patients older than 5 years ($y = 0.92x + 8.2$; $r = 0.926$; $p < 0.001$; $n = 12$).

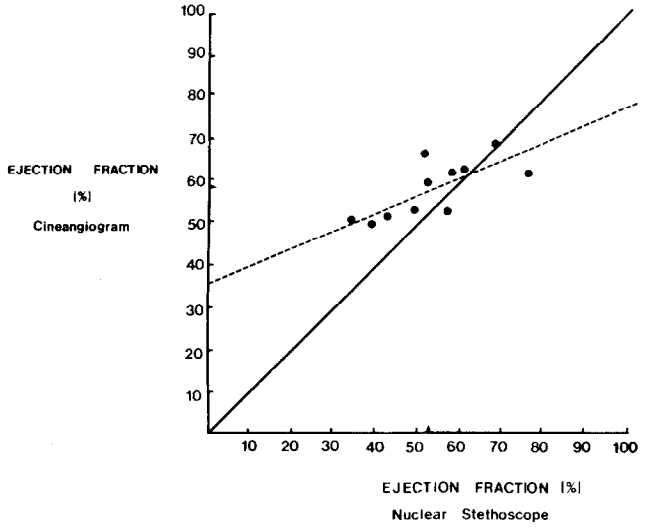

FIGURE 3. Comparison of left ventricular ejection fraction determined by the nuclear stethoscope and by cineangiography in 11 patients younger than 5 years ($y = 0.41x + 36.6$; $r = 0.728$; $p < 0.02$; $n = 11$).

rest. Although wall motion abnormalities may cause erroneous stethoscope values,[10] none of our patients demonstrated wall motion abnormalities detectable by cineangiographic or gated blood pool studies. None of our patients had an abnormal spatial configuration of the left ventricle (dextrocardia, L-looping of ventricles), which may result in difficulty in identifying LV activity.

In addition to potential sources of error in stethoscope studies, a further concern is the time involved in performing the examination. Whereas the red cell labeling technique is identical to that used in standard blood pool studies, the computer-assisted algorithms for determining optimal ventricular and background counts are tedious and time consuming. Small changes in probe position relative to the chest wall and heart can result in major alterations in total counts over the ventricle and background, altering results. Painstaking patience, deliberately slow movements and a nonhurried environment are critical for performing accurate studies. A good correlation has indeed been demonstrated between tests performed by 2 experienced operators.[7]

The nuclear stethoscope has several advantages over other methods of LV function analysis. The first is the relatively low cost of the stethoscope, especially compared with any angiographic or standard gamma camera equipment. Second, the camera can be easily transported to a clinic, intensive care unit or catheterization laboratory setting. Third, the ability of the stethoscope to monitor beat-to-beat function allows detection of rapidly changing hemodynamic events. The rapid determination and display of these events is useful in the evaluation of arrhythmias,[11,13] and may be helpful in monitoring acute changes in LV function during pharmacologic intervention or cardiac pacing in critically ill or postoperative patients. Gated studies of LVEF can be obtained using the stethoscope and correlate well with standard gamma camera techniques.[10] Recent applications of the nuclear stethoscope in adults include diastolic function studies,[14] pressure-volume analysis[15,16] and LV dysfunction in patients with coronary artery disease[9] or adriamycin toxicity.[17] The clinical usefulness of these applications in a pediatric population has not been explored.

Our results suggest that the nuclear stethoscope can be used to monitor resting LVEF in pediatric patients. Problems with operator expertise, motion artifact and patient size appear to limit advances with the present device. Modifications in the instrument, use of different isotopes and further clinical investigations are required before this device can be considered a standard tool for pediatric cardiologists.

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