

Methods and Devices

Paediatric Nuclear Cardiology in Intensive Care

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Abstract. The role of non-invasive nuclear medicine procedures in the management of paediatric cardiac abnormalities is reviewed. These studies can be performed at the bedside of the very sick infant using a mobile gamma camera computer system, and provide functional and structural information essential for management.

Key words: Nuclear cardiology – Paediatric cardiac abnormalities

Introduction

Non-invasive diagnostic nuclear medicine procedures are having an increasing and beneficial role in the diagnosis and management of many paediatric cardiac abnormalities both congenital and acquired. In conjunction with other non-invasive modalities such as echocardiography, both functional and structural information can be obtained which was only previously determined by cardiac catheterization and contrast angiography. In very sick infants with known or suspected heart disease catheterization has significant morbidity and mortality, and in these cases physiological and anatomical information, essential for management, can be obtained by radioisotopic methods. Mobile (and in the future, portable) gamma camera computer systems permit the performance of these studies at the bedside of the severely ill patient in the intensive care unit, particularly premature and newborn infants and children during the early post-operative period. The newer detection devices interfaced with data loggers and computers provide continuously expanding data processing capabilities and improved detector performance [2].

Paediatric nuclear cardiology procedures applicable to intensive care are: 1) the radionuclear angiogram, 2) studies of ventricular function, 3) myocardial perfusion imaging and 4) perfusion lung scanning.

1. Radionuclide Angiogram

This consists of serial imaging of the passage of a radioactive tracer through the cardiovascular system with a gamma scintillation camera [10]. This camera is interfaced with a computer system for data analysis. The nuclear angiogram is performed by injecting a small bolus of 99m-Technetium Albumin or Pertechnetate into an external jugular vein via a 19 or 21 gauge scalp vein needle. The scalp needle is attached to a 3-way stopcock and extension tube and the dose is flushed with 10 cm$^3$ of saline. A small, compact bolus results; fragmentation of the bolus must be avoided as this leads to erroneous results. The bolus may be delayed when there is obstruction to the venous return to the heart, elevated pulmonary venous pressures or obstructive valvular disease. Both analogue and computer images are obtained by the mobile gamma camera. Numerous (20 – 30) analogue images are recorded on videotape or cine film and the transit of the bolus is recorded on a computer disc. This on-line computer system permits storage, display and analysis of the dynamic data acquired. The analysis of the nuclear angiogram is divided into several components:

i) Qualitative Analysis

Qualitative analysis or visual inspection and assessment of the analogue and flow patterns produced by the gamma camera. This is a very important aspect...
of the study as often a peculiarity of anatomy may be demonstrated by an abnormal flow pattern. For example, interruption of the flow of the radionuclide into the right atrium by mediastinal compression can be readily detected. Conditions which cause left to right shunting like atrial or ventricular septal defects or patent ductus arteriosus, cause early recirculation and persistence of activity in the lungs. Early appearance of the tracer in the laevophase before or simultaneous with its appearance in the pulmonary circulation is evidence of right to left shunting. The level of the shunting and associated structural abnormalities (like tricuspid or pulmonary atresia) can be detected. Obstructive lesions like hypoplastic left heart syndrome or aortic atresia also cause characteristic flow patterns.

ii) Quantitative Analysis

a) Shunt quantification is one of the most important applications of these techniques. This is derived from the time-activity histogram generated from the first transit and recirculation curves of the radionuclide bolus through the lungs [5]. Based on the indicator-dilution principles, it provides an extremely accurate determination of the left to right shunting (Qp:Qs) [1].

b) Cardiac output can also be determined by radionuclide methods using the indicator-dilution principle, in which the dilution time-activity curve is recorded over one or more cardiac chambers after the bolus injection of Technetium-labelled albumin has labelled the blood pool. A semilogarithmic extrapolation of the downslope of the left cardiac phase is used to calculate the area under the curve at equilibrium after complete mixing of the radioactive material. Exact quantification requires an estimate of total plasma volume.

c) Ejection fraction. After defining systolic and diastolic frames with electrocardiographic ‘gating’, left ventricular ejection fraction can be computed by monitoring the activity within the ventricles as the tracer passes through it [3]. The use of multiscrystal cameras in the ‘first pass’ study of ventricular function is referred to later; ejection fraction estimates can also be obtained using a non-imaging single crystal scintillation probe [11]. The latter method requires that accurate estimation of the position of the left ventricle be made before the study to obtain reproducible results.

2. Studies of Ventricular Function

Once the tracer has equilibrated in the blood stream, ventricular function can be studied by synchronising (‘gating’) the computer to the patient’s electrocardiogram [7]. The ‘gate’ is triggered on the patient’s R wave and each R to R interval is divided into numerous sections and a set count or time period number of cycles collected (usually 800 – 1000 cycles). This is viewed in a cine film format and the wall motion of the heart chambers can be observed. The gated study is usually performed in 2 views: a left anterior oblique view angled down the septum gives the best delineation between right and left ventricles; the other view is anterior. From the gated study ventricular wall motion is studied and dyskinetic or akinetic segments visualized. This is of particular value in those conditions in which ventricular function is abnormal, such as cardiomyopathies, anomalous left coronary artery disease, obstructive lesions, transposition of the great arteries, etc. Besides the wall motion, quantification of left ventricular function (ejection fraction, stroke volume and diastolic volumes) can be readily obtained [4]. These are important parameters in determining the extent or severity of the disease and are a rapid, non-invasive method of following the patient’s clinical course as ventricular function can be monitored over a period of days or weeks. The side effects of cardiotoxic drugs like adriamycin can be diagnosed early with this technique.

The ‘first pass’ studies of ventricular function involve imaging of the cardiac blood pool immediately after the introduction of tracer into the venous blood. To correctly judge ventricular wall motion from these first pass studies requires the use of a highly efficient scintillation camera (i.e. a multiscrystal rather than Anger camera). These studies are specially suitable for the rapid non-invasive assessment of right ventricular performance in children with cardiopulmonary disease.

3. Myocardial Perfusion Imaging

The myocardial uptake of 201 Thallium depends on the regional blood flow and ischaemic areas appear as zones of decreased perfusion ('cold spots'). Prior administration of a coronary vasodilator like Dypiridamole appears to increase the resolution of the images. Ten minutes after the injection of the isotope, scanning is performed with a high-resolution mobile camera and converging collimator. Usually three views of the heart are obtained; the computer images are later quantified for tracer uptake.