RADIOISOTOPIC EXAMINATION OF THE HEART

REVIEW

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Presented

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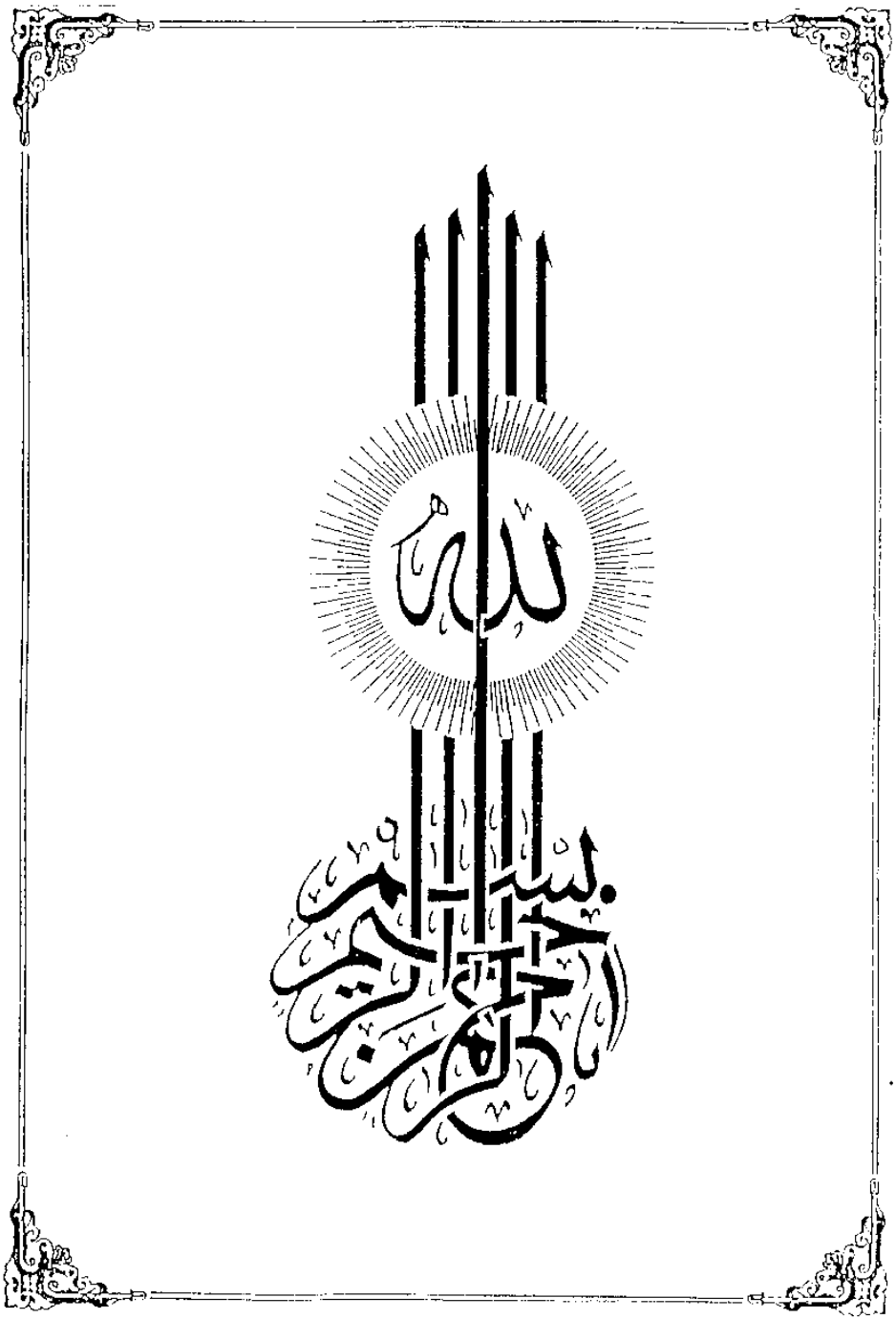

CONTENTS

ABREVIATIONS

^{201}Tl	Thallium-201
^{99m}Tc	Technetium-99m
^{111}In	Indium-111
^{11}C	Carbon-11
Rt	Right
Lt	Left
LAO	Left anterior oblique projection
RAO	Right anterior oblique projection
L.L.	Left lateral view
ECG	Electrocardiography
Echo	Echocardiography
2D-echo	Two-dimensional echocardiography
SPECT	Single-photon emission computed tomography
PET	Positron-emission computed tomography

INTRODUCTION
AND
AIM OF REVIEW

INTRODUCTION AND AIM OF THE REVIEW

Recent developments in cardiology have centered on the noninvasive diagnostic evaluation. The application of nuclear medicine techniques to diagnostic cardiology is one such area of rapid advancement in noninvasive assessment.

The application of radionuclides to the study of the heart has grown with dramatic pace during the past decade, this is because of the need for accurate noninvasive techniques to assess cardiac function and perfusion. This growth is also the result of dramatic improvements in technology and the application of these improvements to the development and refinement of diagnostic techniques.

Cardiac nuclear medicine (with only an intravenous injection of radionuclides) provides information comparable to that obtained with more invasive techniques, and also provides relevant physiologic data concerning regional cardiac function, myocardial perfusion, viability and metabolism which cannot be examined by other techniques, whether they are invasive or noninvasive.

Because most of the parameters of cardiology are quantitative, cardiologists are disciplined to require quantitative data, and have to expect and require precise, calibrated, error-limited measurements. Perhaps the most exciting development in nuclear medicine in the 1970 s, is the achievement of a quantitative capability in the recording and interpretation of nuclear medical studies.

Hence, radionuclide techniques have taken their place for the routine day-to-day assessment of patients with known and suspected cardiac disease.

Nuclear cardiology techniques involve the injection of specially prepared radioactive materials and the detection, definition and quantification of radiation emanating from cardiac structures with externally placed radiation detection instrumentation.

As these techniques rely on expensive equipment and there are some difficulties in supplying the tracers, one may ask whether these techniques are clinically efficacious and whether they have a meaningful effect on patient diagnosis and therapy, and if they add to other noninvasive procedures. Such important questions will be discussed in this review.

NOMENCLATURE

Isotopes (Nuclides) :

Individual atoms of the same element having the same proton number but different mass number, i.e. they have the same number of protons but different number of neutrons in their nuclei.

Most naturally occurring elements exist as a mixture of two or more isotopes. e.g. carbon $C^{11}, C^{12}, C^{13}, C^{14}$. The isotopes of the same element may be stable or unstable.

Radioactive Isotopes (Radionuclides) :

These are isotopes having unstable arrangements of neutrons and protons and such nuclei tend to assume more stable configuration by gaining or loosing a unit of positive electrical charge and disposing of excess energy by the emission of radiation "spontaneous decay". This disintegration is known as radioactive decay. Examples of these isotopes include thallium-201 and technetium-99m.

Radioactive Half Life :

It means the time taken for the radioactivity to decrease to half its initial value, for example, for thallium-201 it is 73.1 hours, but for technetium-99m it is 6 hours.

The rate of disappearance of radioactivity from the body depends on the physical half life of the nuclide and the rate at which metabolism and elimination occur. Thus, the time taken for the body rate activity to fall to half is called the biological half life.

Physical Half Life :

The time necessary for the activity of a nuclide to decay to one-half its original activity.

Biological half life :

The time necessary for the concentration of the tracer to fall to one-half its original concentration. It depends on the physical half life, the rate of its metabolism and elimination from the body. Most isotopes in clinical use have half-lives of hours or days.

Types Of Radiation from Radioactive Isotopes : these are classified as alpha, beta and gamma.

Alpha radiation : is of little importance in clinical tracer work.

Beta radiation : a radioactive nucleus tends to become more stable either by gaining or loosing a unit of positive electrical charge so that in effect one of the neutrons is transformed into a proton or vice versa. In the majority of cases this process is characterized by the emission of charged particle having a mass equal to that of the electron-the beta radiation-this may be either negatively charged, beta-negative radiation (electron) or positively charged, beta-positive radiation (positron). These are penetrating radiation.

In many cases the energy of the radioactive nucleus is not accounted for completely by the process of beta decay and the excess energy is then emitted as a quantum of gamma radiation. Also, all positron emitters can be regarded as sources of gamma radiation since when a positron ultimately comes to rest it immediately combines with an electron and the two particles are then transformed into gamma irradiation, giving rise to two

photons which are given off in exactly opposite directions, and the detection of this form of annihilation radiation has application in cardiac diagnosis (Holman, 1980).

Gamma radiation : electromagnetic waves with short wavelengths that originate from nuclear transitions, made up of photons capable of giving up energy in discrete interactions with matter. It is similar to the radiation produced by high voltage X-ray apparatus. This type of radiation is highly penetrating.

Unit of Radioactivity: The unit of radioactivity is called the Curie, after Marie Curie and her husband Pierre. Its symbol is Ci and it is defined as that amount of radioactive material in which the number of disintegrations per second is $3.7X10^{10}$ (the disintegrations in one gm of radium). Since this is a large quantity, clinically we use microcuries (one millionth of a curie "μci") or millicuries (one thousandth of a curie "mci"). It is possible to detect quantities of radioactivity of the order of one millionth part of a millicurie.

HISTORY, INSTRUMENTATION AND TECHNIQUES OF RADIOISOTOPES IN CARDIOLOGY

HISTORICAL BACKGROUND

The use of radioactive tracers to study cardiovascular dynamics was reported initially by Blumgart and Weiss in 1927 who used radon gas injected intravenously to measure circulation time in humans (Jaret & Berger, 1982). Twenty years later, Prinzmetal et al. (1949) described the gross characteristics of the first pass radiocardiogram using sodium-22 and a Geiger-Muller counter positioned over the precordium.

Donato (1973) analyzed the quantitative aspects of the radiocardiogram using a newly developed shielded and collimated scintillation probe. This allowed definition of both cardiac dynamics and myocardial blood flow.

In the same decade, prototype scintillation cameras were used by Bender & Blau (1963). Anger et al. (1965) demonstrated the ability to define cardiac transit with analogue images obtained from the prototype single-crystal scintillation camera.

In the early 1970s, the concept of electrocardiographic gating of the equilibrium cardiac blood pool was proposed as a means of evaluating both regional wall motion and global left ventricular performance as measured by ejection fraction (Strauss et al., 1971). At roughly the same time, Van Dyke et al. (1972) described the first transit technique using the scintillation camera for measuring left ventricular function.

In the late 1970s, additional advances involved the application of computer techniques to the equilibrium cardiac blood pool and first transit studies and the addition of exercise stress to the assessment of ventricular performance.

The assessment of myocardial perfusion and viability has followed a parallel development course in radiotracers.

Carr et al. (1963 4) were the first to demonstrate that potassium analogues would be suitable for imaging myocardial perfusion. Initial studies were performed with radioactive cesium. Following this demonstration, radioactive potassium and rubidium were employed (Martin et al., 1974). In 1973, exercise myocardial perfusion imaging using potassium-43 for assessing transient ischemia was introduced (Zaret et al. 1973). In 1973, thallium-201 was introduced as a potassium analogue with physical characteristics more suitable for conventional scintillation camera imaging (Lebowitz et al., 1973).

Within the past few years, tomographic imaging employing thallium-201 have also been developed and is currently in its initial prototype application (Vogel et al., 1978).

The concept of imaging myocardial infarction as a zone of increased radioactivity was first reported by Carr et al. (1962) using radiolabeled chlormerodrin. Holman et al. (1974) reported on the efficacy of technetium-99m-labeled tetracycline imaging as a means of demonstrating acute myocardial infarction in humans. Shortly thereafter, Bonte et al. (1974) demonstrated the applicability of pyrophosphate imaging for defining acute myocardial infarction in animals and humans.

INSTRUMENTATION

Nuclear cardiology techniques are based upon the ability to detect, define and quantify radiation emanating from cardiac structures with externally placed radiation detection instruments. Radiation detection devices determine the location and quantity of radionuclide activity in the heart by producing images. The clinical accuracy of radionuclide cardiac studies depends upon the initial quality of the observed and recorded data, which is determined in large part by the performance of instruments used.

NOMENCLATURE

A Crystal :

A high-density photon absorber that converts the energy of the incident photon to a number of light photons. It is formed of sodium iodide.

Collimator :

The lens of the imaging system, absorbing photons travelling in inappropriate directions and originating from parts of the body other than the region under investigation. Collimators are usually made of lead with holes to allow desired photons to pass through to the crystal (Holman, 1980) (Fig.1).

There are different types of collimators according to the holes they carry.

(a) Parallel-hold collimator: With thousands of holes in a lead absorbing sheet. The holes are parallel to each other and perpendicular to the crystal or at some other angle. Standard high-sensitivity and high-resolution collimators are types of