Isotopic assessment of regional abnormalities of myocardial perfusion

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Nuclear cardiology comprises four different areas that include (1) regional myocardial perfusion with the use of potassium analogues, namely thallium-201; (2) evaluation of left ventricular function both at rest and at exercise with blood pool agents, primarily Tc-99m-labeled red blood cells and human serum albumin; (3) shunt analysis and semiquantification with first pass bolus technique using primarily technetium preparation, (4) myocardial infarct imaging or "hot spot" imaging with Tc-99m pyrophosphate and occasionally tetracycline preparations.

There are several different tracer methods available for studying myocardial perfusion. These include labeled metabolic substrates, particulate regional blood flow, direct injection of diffusible tracers, and potassium analogues including thallium-201. The metabolic substrates include I-131-labeled fatty acids, carbon-11 tagged to palmitic acid as well as to carbon monoxide and nitrogen-13 to ammonia.

Carbon-11 and nitrogen-13 are short-lived cyclotron-produced isotopes not commercially available. They produce images by annihilation radiation that require special detecting devices. They do offer promise in the future when they become more readily available.

Particulate regional blood flow with either human albumin microspheres or macroaggregates of albumin attached to different isotopes is another method of studying myocardial perfusion. With this method, one injects two isotopes with different photon energies into the right and left coronary arteries, respectively. One is then able, by taking multiple views, to generate the isotopic geographic distribution of the territories supplied by each of the two vessels.

The use of xenon-133, an inert gas, is another method of evaluating regional perfusion. By injecting the xenon directly into the coronary artery, one is able to identify not only the fractional distribution of the blood flow to different regions in the heart, but also specific blood flow, namely blood flow per unit mass by the rate of elimination. The particulate regional blood flow and inert gas studies both require invasive coronary catheterization.

Thallium-201 imaging appears to be the most accepted perfusion-imaging technique available today.

Rubidium as well as cesium and potassium have been used in evaluating myocardial perfusion, but have not obtained widespread use since either the photon emission or the half-life of the radionuclides was not optimal for radionuclide imaging. Although thallium has not become the diagnostic panacea that everyone had hoped, it is helpful in assessing both fixed and transient myocardial defects that represent areas of decreased myocardial perfusion.

Introduced as an imaging agent in the mid-1970s, thallium has only been in widespread clinical use since January 1978. Although this technique has been accepted as a diagnostic tool, there have been pitfalls identified in the interpretation of such scans. It is the purpose of this paper to help point out some of the limitations of thallium. Several investigators have reported on the increased sensitivity of thallium myocardial perfusion studies when compared to electrocardiographic results.

It is important to have close clinical supervision and a well-designed protocol carefully outlining the individual steps. A dose of 1.5 mCi or more of thallium is highly desirable to improve statistical analysis and also image contrast, since only approximately 4% of the injected dose goes to the heart. Thallium-201 basically follows the Sapristein principle with approximately 80% of the eventual dose going to the heart being extracted on the first pass, thereby giving a reasonable representation of regional myocardial blood flow. It is also important to have the patient, when being stressed, achieve peak exercise and to maintain that for at least 30 seconds after thallium has been injected.

After the stress has been completed, the patient is imaged as soon as possible with a 37-photo tube gamma camera with a parallel hole, medium sensitivity, low energy collimator. A 20% window is centered at approximately 80 keV, and 10 minutes are required to view the heart in the 45° left anterior oblique, 60° left anterior oblique and anterior views, respectively. Equilibrium studies are performed approximately 3 hours or longer after the completion of the stress. I believe that a small computer is critical for optimal interpretation, as this allows one to normalize data and to compare more objectively counting rate ratios between stress and equilibrium.

Thallium demonstrates both fixed changes in the perfusion, namely scarring and fibrosis, as well as regional reserve changes, namely areas of ischemia related to critical lesions, which under stress are identified as relative areas of decreased perfusion, but at rest

appear normal. Gould et al several years ago showed that there can be normal flow patterns at rest with lesions in the vicinity of 80% to 85%. When, however, there is increased work demand, the region distal to the obstruction will not be able to keep up with the demand and, therefore, will be identified as a relative area of decreased activity, a cold spot, on the scan. Since thallium interpretation relies on regional myocardial blood flow, one must be careful not to misdiagnose triple-vessel disease on the basis of a regional area of myocardium showing relatively good uptake when, in fact, there is disease in that area but less so than is present in the rest of the myocardium.

The normal heart to lung counting rate ratio is in the range of 2 to 1 at rest and increases to approximately 3 to 1 at exercise. With a computer available, triple-vessel disease can be identified by examining the target to background ratio and semiquantitatively regions of decreased activity can be identified in the heart, which, although they appear in relationship to the rest of the myocardium to show adequate perfusion, are in fact, absolutely decreased. One must, therefore, be aware that thallium evaluates regional relative myocardial perfusion only. This is a severe limiting factor, since generally only one half to two thirds of all vessels involved in patients with coronary artery disease that have been studied will show up as areas of decreased activity on the thallium study.

Thallium, however, has been shown to be more sensitive in identifying areas of scarring secondary to remote infarction when compared to electrocardiograms. The posterolateral wall is an area familiar to all cardiologists where the electrocardiogram is markedly limited and where thallium can be helpful in identifying scarring.

There has been interest since Pohost et al described their experience with equilibrium views in 1976 regarding the substitution of an equilibrium study for a rest study. This obviously decreased the cost, radiation, and time involved for the patient. A recent study, however, shows that although the equilibrium examination did provide a reasonably good facsimile of a resting study, nonetheless, 45% of the patients did not have a return to the resting images that were performed one week later. In two patients, there was no improvement; this would suggest scar, but the resting study performed one week later showed symmetric uptake. It was concluded that equilibrium studies frequently did not show the true extent of viable myocardium seen on the resting studies and, therefore, if thallium was used to assess myocardial viability, a resting study would be the best examination.

The amount of total body radiation that the patient receives from an average dose of 1.5 mCi of thallium is approximately .11 rads. The dose to the kidney, which is the critical organ, is about .75 rads, and to the testes is about .375 rads per 1.5 mCi dose.

In summary, I have attempted to outline the various ways that radionuclides can evaluate regional myocardial perfusion. Concentrating on thallium-201 imaging, I have tried to point out the necessity of following a well-established protocol, the usefulness of thallium in certain clinical situations and also some of the limitations related to its physical and biological characteristics. By being aware of the assets as well as the limitations of this study, information useful in patient management can be obtained.