EDITORIAL

# Gated Blood-Pool Scanning in the Critically Ill: A Valuable Tool for Clinical Research

The development of the portable, i.e., highly mobile, gamma camera/computer system has made it feasible to perform gated blood-pool scans on critically ill patients in the Intensive Care Unit (ICU). During the past 5 yr, gated blood-pool scanning has proven to be a valuable tool for the evaluation of cardiac performance in critically ill patients. Serial radionuclide studies have, for example, demonstrated reversible left ventricular dysfunction in patients with septic shock (*1,2*). Gated blood-pool scanning has also proven valuable in the clinical management of critically ill patients with a variety of other disorders (*3*). The techniques of first-pass and equilibrium gated blood-pool imaging using technetium-99m ($^{99m}$Tc) have been well documented for evaluating left ventricular function and wall motion, and are generally accepted as reliable and reproducible (*4,5*).

The gated blood-pool scan has been used in our Critical Care Unit to evaluate a number of critical illnesses (*3*), especially septic shock, the most common cause of death in ICU. Survivors of septic shock most commonly demonstrated a profound decrease in left ventricular ejection fraction (LVEF) at the onset of shock due to sepsis, and serial scans demonstrated that surviving patients usually recovered to a normal ejection fraction by 7 to 10 days postshock. The scan can be used in conjunction with conventional hemodynamics to calculate ventricular volumes. An important application of this principle is to determine the end diastolic volume of the left ventricle; by performing the gated scan and a thermodilution cardiac output simultaneously, one can calculate accurately the end diastolic volume. The end diastolic volume of the left ventricle equals the stroke volume (from the thermodilution cardiac output) divided by the LVEF. Using this calculation, the septic shock survivors were found to have very dilated left ventricles at the onset of septic shock, and the ventricle decreased toward normal size by 7 to 10 days. This hemodynamic pattern of decreased ejection fraction with left ventricular dilatation has been confirmed by another group of investigators (*2*), and two-dimensional echocardiography studies have further confirmed this cardiovascular dysfunction and dilatation in human sepsis (*6*). Recently, the pathogenesis of this reversible left ventricular cardiomyopathy and dilatation has been studied, and evidence suggests that a circulating myocardial depressant substance is the likely mechanism (*7*). A canine model of septic shock with a cardiovascular pattern very similar to humans has been evaluated with gated nuclear scans and thermodilution outputs. The canine model also shows reversible myocardial depression as well as a profound abnormality of diastolic left ventricular compliance (*8*). Thus, the left ventricular gated scan has been a very valuable clinical investigatory probe to evaluate left ventricular function in critically ill patients.

Right ventricular function, while of considerable interest in septic shock, severe pulmonary failure, and in a variety of other severe illnesses, has been considerably more difficult to assess. The right ventricle is more difficult to isolate from the other cardiac chambers, especially the right atrium. These and other technical difficulties encountered in imaging the right ventricle are magnified in the critical care setting. Positioning the camera is made awkward by the support equipment necessary at the patient's bedside (e.g., ventilators, i.v. poles, etc.), as well as by the inability of many critically ill patients to lie flat or still during the study. Methods of evaluating right ventricular function using $^{99m}$Tc have been described, using both the first-pass and equilibrium techniques (*5,9*), but these techniques have not achieved the degree of universal acceptance accorded the assessment of left ventricular function. The equilibrium method of studying right ventricular performance has been used in clinical studies of septic shock in critically ill patients; right ventricular dysfunction was demonstrated by Kimchi et al., in a subset of patients with septic shock (*10*). Further studies of right ventricular performance in septic shock, as well as in acute pulmonary and cardiac disease would be of great interest to clinicians and researchers alike. Ideally, such studies

would be performed using an isotope with a short biologic half-life to prevent the isotope from reaching the left heart, thus preventing right-left chamber overlap, and to permit repeated assessment of the right ventricular response to therapeutic interventions.

Three studies in this issue of the Journal address the difficulties inherent in trying to establish a reliable, reproducible method for determining right ventricular ejection fraction (RVEF). Ham et al. (*11*) present an analysis of the sources of error in calculating RVEF using the steady-state krypton-81m ($^{81m}$Kr) method. They examine the questions of mixing of the isotope in the right ventricle, the importance and accuracy of background correction, and the difficulty of defining the right ventricular region of interest (ROI) at end systole and end diastole. They conclude that careful analysis can minimize these sources of error and that the steady-state $^{81m}$Kr method should provide an accurate measure of right ventricular function.

Caplin et al. (*12*) compared four different methods of analysis of the steady-state $^{81m}$Kr method with the first-pass method using $^{195m}$Au. They examined fixed and variable ROIs with and without background correction and demonstrate that the magnitude of the calculated value of RVEF may vary significantly depending on which technique is used. They caution, appropriately, that measures of right ventricular function from different centers may be difficult to compare.

The study by Caplin et al. sought primarily to define which of the four calculated methods of RVEF they investigated would give the closest absolute agreement with a $^{195m}$Au first transit RVEF. Their principle concern was agreement of absolute value, not intraobserver or intrastudy variability. Ham et al., on the other hand, investigated the various factors which could lead either to systematic error or to increased variability. They give strong evidence suggesting that the $^{81m}$Kr method should, under the circumstances they discussed, yield a RVEF measurement which may or may not be unbiased (lacking a reliable standard for comparison) but which surely may be made precise. In the critical care setting, the absolute measure of right ventricular function (i.e., its unbiasedness) is obviously important, but perhaps more so is the reproducibility (i.e., its precision) of the method. In many critically ill patients, the ability to reliably measure changes in right ventricular function with time, or in response to therapeutic interventions, may be more important than the accuracy of the absolute value obtained for a measure of right ventricular function (e.g., ejection fraction). Serial assessment of right ventricular performance would demand a method of evaluation that is highly reproducible, so that relative changes in right ventricular function could be determined accurately. Just as serial studies of left ventricular function are essential to demonstrate the cardiovascular response to septic shock (*1,2*), so serial right ventricular studies are of equal interest and probably of equal importance.

One point that at this time limits the potential usefulness of $^{81m}$Kr as an isotope to determine right ventricular function in the ICU is its very short half-life, that requires placing the isotope generator at the patient's bedside. The large amount of equipment required at the bedside of most critically ill patients will necessitate a very compact and portable generator to make the use of the $^{81m}$Kr in the ICU practical.

The difficulties of obtaining and using $^{81m}$Kr have led Martin et al. (*13*) to examine the accuracy and reproducibility of gated xenon-133 ($^{133}$Xe) imaging of the right ventricle. A number of characteristics of $^{133}$Xe make it attractive for use in the critical care setting. Its relatively long half-life makes it easier to obtain and more practical for use in the critically ill patient. In addition, the amount of time required to complete a study is very short (20 sec in Martin's study, as opposed to 15–20 min when using $^{81m}$Kr). Critically ill patients are often unable to lie flat or still for very long, so the short imaging time would improve the likelihood of obtaining a high quality scan. Despite these advantages, $^{133}$Xe is not the ideal isotope. The attenuation problems mentioned by Martin are important. In addition, the long half-life of $^{133}$Xe may lead to problems of environmental contamination in the ICU, where patients commonly require mechanical ventilation and where the ventilation system of the unit may not be adequate to remove the radioactive gas.

Xenon-127 ($^{127}$Xe) was mentioned by Martin et al. as a possible alternative to $^{133}$Xe. Its higher energy gamma, although requiring a medium-energy collimator, does have significantly improved imaging qualities. In addition to the drawbacks of $^{127}$Xe mentioned by Martin et

al. it should be pointed out that the high-energy collimator necessitated by the use of $^{127}Xe$ (and, some would argue, $^{81m}Kr$) is often not available for mobile cameras. Furthermore, the thin crystal (usually ¼ in.) employed in most Anger-type mobile cameras has a markedly reduced efficiency for detecting the high energy radiation emitted by either $^{127}Xe$ or $^{81m}Kr$. At 191 keV a ½-in.-thick crystal has almost 50% greater total efficiency than a ¼-in. crystal. The image quality, therefore, may be measurably poorer in a mobile camera/ICU study as compared with a study in a conventional nuclear medicine setting.

It is clear that the right ventricle is, and will continue to be, the focus of considerable interest. Measurement of its function is important both in clinical research, and in the clinical management of the critically ill patient. The lack of consensus as to how best to perform this measurement is apparent from the wide variety of different techniques described for measuring right ventricular ejection fraction. As yet, no ideal method for performing these studies in critically ill patients is available. Right ventricular function will be an important area of clinical research when a practical, accurate, reproducible method of evaluating the right ventricle becomes available. The current interest in the technical aspects of this problem will undoubtedly contribute to the development of such a method in the near future.

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