1. Introduction to imaging of the heart: Contrast angiography, digital angiography, nuclear imaging, echocardiography

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Introduction

Recent developments in cardiovascular imaging and signal analysis offer the physician a wide range of methods to evaluate the anatomy and function of the cardiovascular system. These include contrast angiography, echocardiography, nuclear imaging, digital subtraction angiography, and in the near future nuclear magnetic resonance. The cardiologist, internist or radiologist must then choose the technique(s) which provide the most useful diagnostic information in a given patient. Such decisions should be based on precise understanding of the strength and limitations of each method. Excellent reviews and books are available which describe the various imaging techniques. However, these focus mostly on the value of one particular technique and to a lesser extent on the questions which should be resolved in clinical practice. In this chapter the value of the various methods to provide clinically useful information on the anatomy and function of the heart, such as cardiac output, ventricular function, ventricular and atrial dimensions, intra-cardiac shunts, coronary anatomy and myocardial metabolism will be analyzed.

It should be realized that in addition to the general aspects as discussed below, the choice of a given investigation will depend also on the availability and costs of various methods and certainly on local expertise.

Cardiac output

Cardiac output, the product of heart rate and stroke volume, is a measure of performance of the circulation as a whole. A wide range of regulatory systems can change cardiac output and, equally important, the distribution of regional bloodflow. Accordingly, determination of cardiac output provides little insight in cardiac performance in a given patient. Actually, cardiac output can be maintained at normal or near normal levels in the
presence of even severe heart disease. Nevertheless, measurement of forward cardiac output in conjunction with other data such as blood pressure, ejection fraction and total stroke volume can provide vital information on systemic and pulmonary vascular resistance, left and right ventricular volumes and the presence and degree of valvular regurgitation. Furthermore, repeated determination of cardiac output aids the analysis of the cardiovascular response to stress and other interventions as well as evaluation of the action of drugs in a given patient.

Most methods for determination of cardiac output are based on the indicator-dilution principle. The indicator can be administered continuously or as a bolus. The most widely used invasive method is thermodilution with a Swan-Ganz catheter in the pulmonary artery. This method is particularly useful during cardiac catheterization procedures and in the intensive care unit [1, 2]. Dye dilution is an older method which is still used for calibration of other techniques. This method requires a central venous or preferably pulmonary artery catheter as well as arterial determination of dye concentration [3]. The Fick method is an indicator dilution technique using oxygen as an indicator which is continuously administered to the circulation in the lungs. Here measurement of O₂ uptake is required as well as determination of the oxygen content of mixed venous and arterial blood. This method is most useful if O₂ uptake is also needed for other purposes such as in exercise physiology [4]. Radioisotopes can be used as indicator and detected with a gamma camera or nuclear probe. A “first pass technique” can be used which requires a bolus injection in a large central vein or a continuous infusion of a short living isotope such as Kr-81m can be used. [5, 6]. Furthermore, this method can be adapted in the nuclear cardiology laboratory in connection with measurement of ejection fraction to check the determination of ventricular volume. Changes of cardiac output, for example during a stress test, can be determined from “stroke counts” in gated bloodpool studies.

Truly noninvasive methods for determination of cardiac output are the CO₂ rebreathing method [7], which is again used in exercise physiology, and impedance plethysmography. The latter method has not been accepted widely, probably since its reliability in patients with heart failure or during stress has not been established.

Finally, cardiac output can be derived if stroke volume is measured by echocardiography, contrast angiography or radionuclide angiography as discussed below.