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Appropriate diagnostic technology in the management of cardiovascular diseases

Report of a
WHO Expert Committee

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DIAGNOSTIC TECHNOLOGY IN THE MANAGEMENT OF
CARDIOVASCULAR DISEASES**

Geneva, 23–30 November 1987

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APPROPRIATE DIAGNOSTIC TECHNOLOGY IN THE MANAGEMENT OF CARDIOVASCULAR DISEASES

Report of a WHO Expert Committee

1. INTRODUCTION

The WHO Expert Committee on Appropriate Diagnostic Technology in the Management of Cardiovascular Diseases met in Geneva from 23 to 30 November 1987. Dr Lu Rushan, Assistant Director-General of WHO, opening the meeting on behalf of the Director-General, said that, while the overall objectives of the WHO Cardiovascular Diseases Programme were to prevent and control cardiovascular diseases in the community, one of the specific tasks of the Programme was to monitor advances and developments in technology for management of cardiovascular diseases. Major advances in cardiological diagnostic and therapeutic techniques had taken place in recent years, and an authoritative statement was needed on their appropriateness at different levels of health care. The Expert Committee had therefore been convened to assess the indications for, and the limitations, costs and effectiveness of, various diagnostic techniques in the management of cardiovascular diseases in both developing and developed countries, with particular attention to the primary health care level.

2. GENERAL CONSIDERATIONS

Appropriate health technology means methods, procedures, techniques, and equipment that are scientifically valid, adapted to local needs, and acceptable both to those who use them and to those for whom they are used, and that can be acquired, maintained and utilized with resources the community or the country can afford.

Appropriate diagnostic technology means the equipment and methods whose application in disease recognition and evaluation satisfies the same criteria. Thus, the designation of a diagnostic technology as "appropriate" is conditional upon (1) its

characteristics and value in ideal circumstances, (2) the specific goals and actual circumstances of its use, and (3) its costs, how funds might otherwise be utilized, and the availability of resources.

Since it is rarely possible to make universal recommendations about the appropriateness or inappropriateness of a diagnostic technology, it is more reasonable to describe the factors that go into the "appropriateness" calculation. Some general guidelines are applicable to many diagnostic technologies, but each health care facility or system must base its analysis on realistic assessments of various factors.

Diagnostic technologies have a variety of uses:

- diagnosis, assessment and management of acute or chronic illness;
- identification of asymptomatic disease or risk;
- population studies;
- assessment of disability;
- teaching and training physicians and other health care personnel about disease and health care; and
- research.

The present report focuses only upon the first four of these uses.

From the standpoint of the physician who must consider the interests of an individual patient, the appropriateness of a diagnostic technology can be assessed on the basis of the following factors:

- (1) the additional information that is produced (and the alternative diagnostic procedures that may be avoided);
- (2) the importance of the information it yields, e. g., in establishing diagnoses, assessing disease severity, instituting or modifying treatment, recommending an alteration of life-style, or providing a statement of work capacity or an assurance of good health, and the importance of this expected utilization;
- (3) the accuracy and reproducibility of the results in the circumstances of actual use;
- (4) the sensitivity and specificity of the results in the circumstances of actual use;
- (5) the ability to act upon the information provided, for example, the availability of and access to the therapeutic procedures indicated by the clinical findings;
- (6) the possible hazards of the diagnostic procedure;
- (7) the possible consequences of erroneous or misleading information;

- (8) any burdens on the patient and family, including possible financial burdens.

From the standpoint of a health care facility or system, the following additional considerations are relevant:

- (9) the frequency with which the technology is needed, which is affected by the incidence and prevalence of the disease or diseases for which it is used;
- (10) the frequency and reliability with which the technology can and will actually be used;
- (11) the professional expertise necessary for use of the diagnostic technology and interpretation of its results;
- (12) the necessary support staff;
- (13) adequate ruggedness to withstand essential transportation and conditions of actual use (e.g. humidity, temperature, inadvertent misuse, line voltage fluctuations) and the type of breakdowns that might occur;
- (14) the ability of in-house or local technical staff to provide maintenance and service;
- (15) the ease, speed and cost of getting spare parts and manufacturer-supported service, and the period for which these are guaranteed;
- (16) the availability of supplies and disposables;
- (17) other services that may be necessitated by or associated with the technology, and their availability;
- (18) possible uses for the technology outside the field of cardiovascular disease;
- (19) initial and continuing costs, and anticipated changes in costs;
- (20) expected rate of obsolescence;
- (21) the potential alternative uses of the requisite resources, i.e., the opportunity costs.

The costs and cost-effectiveness of a diagnostic technology are essential factors in these considerations. Costs—of equipment, supplies, professional and technical support, and maintenance—may vary widely in different settings.

A further element in the cost-effectiveness calculation is actual effectiveness. For some purposes, a single index of effectiveness may be satisfactory, but for considerations of overall appropriateness many different indices must be considered; the above listing is illustrative of this.

Among the most critical factors are the increase in, and clinical significance of, the information obtained, the capacity for acting upon that information, the reliability of the information, the likelihood of the technology operating successfully in the circumstances of actual use, and the costs and opportunity costs. The relative weight accorded to these various factors, however, will vary according to the proposed setting for the technology.

Whether or not a particular diagnostic technology is appropriate is thus dependent partly upon the health care level—primary, secondary or tertiary—of the proposed setting, and partly upon the degree of development of, and the availability of resources for, the overall health care system.

3. SPECIFIC CARDIOVASCULAR DIAGNOSTIC AND EVALUATIVE TECHNOLOGIES

3.1 Clinical history

A careful and detailed clinical history is one of the most important components of cardiovascular diagnosis and evaluation and one that requires training, knowledge and practice to compile. The complexity and completeness of any clinical history will vary according to its purpose (to screen for disease, decide upon referral, establish a diagnosis, or institute therapy) and according to the level of the health care facility.

Clinical history, together with physical examination, is an obligatory part of cardiovascular diagnosis. It may provide information about the nature and severity of cardiovascular disease, give insight into the role of psychological, familial, environmental and social factors in causing or aggravating the disease, indicate the presence of other non-cardiovascular disorders that may be responsible for some of the patient's symptoms, and provide prognostic information. Most importantly, it serves as the basis for selecting diagnostic studies and for identifying possible therapeutic options.

History recording has its limitations, however, as do all diagnostic methods. Some symptoms may be highly subjective; their appreciation as well as narration is patient-dependent and may be difficult to quantify. Many symptoms of cardiovascular disease are common to those of disease in other organ systems, and thus are of

variable specificity. Moreover, cardiovascular disease may be severe in the absence of symptoms, while severe symptoms may be present where disease is mild or even non-existent.

The importance of a careful history cannot be overemphasized. It costs little to compile and can be used at all levels of care and for all types of health care system.

Standardized questionnaires, appropriate to the cultural system of the patient, can be used even by non-physicians to identify certain common symptoms and in some cases to grade their severity. They are especially effective for history recording by non-physicians in field settings.

3.2 Physical examination

The basic techniques of physical examination are inspection, palpation, percussion and auscultation, which are complementary to each other and to the clinical history. Auscultation of the heart and blood vessels is of particular importance in the diagnosis of valvular, congenital and myocardial disease, as well as of peripheral arterial disease, systemic and/or pulmonary arterial hypertension, pericarditis, and some cardiac rhythm disorders.

Physical examination, including measurement of blood pressure, is required in all patients, at all levels of medical care and in all types of health care systems. In infants and children, it is important to document height and weight and to assess the rate of growth and development in general. The information gleaned from a sound physical examination is critical in assessing whether or not there is a need for additional diagnostic procedures or for the institution or modification of treatment.

Physical examination is cost-effective. Some procedures (e.g., measurement of heart rate, blood pressure, height and weight, and even screening for some abnormalities) may be carried out by non-physicians. Although an appropriate stethoscope and sphygmomanometer are required, the unit cost of these instruments is low and maintenance needs, except for periodic calibration of the sphygmomanometer, are limited.

3.3 Electrocardiography and related techniques

The *electrocardiogram* (ECG) is a time-based graphic record of voltage changes produced by activation of the heart muscle and

detected at the body surface. Its value for the differential diagnosis of cardiac arrhythmias and conduction disorders is unsurpassed, and it is essential in the diagnosis and evaluation of myocardial infarction and other syndromes of myocardial ischaemia. It is also useful for identification of ventricular and atrial hypertrophy, various other anatomical abnormalities of the heart, pericarditis, systemic diseases affecting the heart, drug effects on the heart, and disturbances of electrolyte balance, as well as for pacemaker follow-up. Moreover, the ECG may provide prognostic as well as diagnostic information. Specificity and sensitivity of the ECG vary according to use.

A 12-lead ECG is standard, consisting of leads I, II and III, aVR, aVL and aVF, and V1, 2, 3, 4, 5, 6, recorded by single channel or multi-channel recorders.

Electrocardiographs are generally relatively inexpensive (of the order of US \$1000 per channel) and sturdy. Consumables, including the ECG recording paper and electrode jelly, are also relatively inexpensive. Electrodes, electrode straps, and patient cables require occasional replacement. A suitable power source (line voltage or disposable or rechargeable batteries) is necessary, and technical manpower is needed to carry out periodic maintenance and repairs.

The ECG can be recorded by suitably trained technical and nursing staff as well as by medical staff, but its analysis requires specialized training and is generally carried out by physicians. Automated computer ECG reading systems are available; their accuracy is not uniform, however, and must be validated for any system that is used. In general, the indication of a normal reading is reliable, but the presence of abnormal findings requires confirmation or over-reading by a physician. Nevertheless, for a facility that must interpret a large number of tracings, such a system may be appropriate.

In some instances, telephone or radio transmission of the ECG and communication of clinical data may be useful. Examples include supervision by physicians of emergency care in mobile units, expert consultation on ECGs from remote sites, distant monitoring of pacemaker function, and monitoring of patients during exercise rehabilitation programmes.

Vectorcardiography is the recording of the mean direction and magnitude (vector), in two or three planes, of the instantaneous electromotive forces of the heart during one complete cardiac cycle. The vector concept is valuable in the teaching and understanding of

ECGs, but vectorcardiography itself does not add to the information provided by the ECG. The apparatus is expensive and special expertise is required for the interpretation of its results.

Ambulatory ECG monitoring refers to the continuous detection of the ECG signal, typically for a 24-hour period. The signal may be recorded for subsequent playback, or continuously monitored with only abnormal events being recorded.

The technique is utilized in the diagnosis of suspected cardiac arrhythmias, in assessing the effectiveness of anti-arrhythmic therapy, and for identifying clinically "silent" or asymptomatic myocardial ischaemia. Recording systems that are adequate for monitoring cardiac rhythm do not necessarily have an adequate low-frequency response for faithful recording of the ST and T-wave changes characteristic of myocardial ischaemia. The sensitivity of automatically actuated recording systems must be validated.

Ambulatory ECG monitoring equipment is expensive (approximately US \$40 000, including the relatively expensive playback and analysis system), although newer systems (event recorders/real-time analysis equipment) may be less costly. Consumables include batteries for the recorder and disposable electrodes for each study. Patient cables require frequent change and the recording unit carried by the patient, which costs about US \$2500, is susceptible to damage and even loss. The technique requires specially trained technical or nursing and medical manpower to obtain optimal results.

3.4 Chest radiography and fluoroscopy

The *standard chest radiogram* provides information about heart size, chamber enlargement, other abnormalities of the cardiac and vascular images, calcification in the pericardium and other cardiac structures, and abnormalities in the lung fields or the rib cage. The equipment required is simple and satisfactory chest radiograms can be produced cheaply. The WHO Basic Radiological System X-ray machine will satisfy requirements for chest radiography for the management of cardiovascular disease. There must, however, be adequate expertise for the interpretation of the radiogram. A regular and steady electric supply is necessary but, where this is unavailable, apparatus with rechargeable batteries can be used.

Fluoroscopy, with image intensification, may be used selectively for specific purposes, e.g., recognition of calcification of the cardiac

valves, coronary arteries and pericardium, evaluation of prosthetic valve function, documentation of hilar dance, and insertion of pacing (and other) catheters.

3.5 Phonocardiography and mechanocardiography

Mechanocardiography is the graphic recording of externally registered low-frequency pulsations produced by the heart; *phonocardiography* is the recording of audio-frequency signals, i.e., heart sounds and murmurs. Although these techniques illustrate a number of cardiac functions and malfunctions and provide some index of their severity, as clinical tools they have been overtaken by other technology, particularly echocardiography. They may still have useful roles in the teaching of physicians, but they require expertise in their application and interpretation and no longer play a significant role in the diagnosis, assessment or management of cardiovascular disease.

3.6 Echocardiography

Echocardiography (or ultrasound examination) involves the direction of beams of ultrasonic waves through the chest wall and the detection and analysis of the returning echoes. Ultrasonic waves are generated by a transducer, typically with a frequency range between 2.5 and 7 MHz (the lower frequencies being used for large body sizes, the higher frequencies for small). The incident beams of ultrasound are deflected, absorbed or reflected by the tissues and structures in and around the heart, then detected by the same transducer. These returning signals can be observed and recorded by cathode ray tube, polaroid film, heat- or light-sensitive paper or video recorder, thus providing an image of the position and motion of heart walls, internal structures of the heart and neighbouring tissues. Direct measurements can be made from the images thus obtained or further interpretation may be undertaken by computer.

Moving objects alter the frequency of any sound they reflect. *Doppler echocardiography* utilizes this to recognize blood flow and to characterize its pattern.

In *M-mode echocardiography*, anatomy is characterized along the line of the narrow probing beam; movement of structures along that axis can be depicted over time. The technique provides dimensional information on heart cavities, walls, valve structure and function,

intracavitary structures, and the pericardial space. However, certain sections of the heart are not accessible, and the usefulness of the procedure is therefore limited.

In *two-dimensional echocardiography*, signals are sent out along a fan-shaped sector so that the returning signal continuously depicts a cross-section. Two-dimensional echocardiography can be used to study valvular structure and function, subvalvular structures, global and regional ventricular function, ejection fraction, the pattern of heart wall thickness, aneurysm formation, congenital malformations, intracavitary masses, pericardial diseases, aortic aneurysms and other structures. Adding a pulsed Doppler signal to two-dimensional echocardiography allows the study of patterns of blood flow, including the detection of abnormal flows, shunts and cardiac output. The patterns of blood flow can be more readily identified through colour enhancement. Continuous Doppler, combined with two-dimensional echocardiography, adds the possibility of studying pressure gradients across valves from flow and valve area observations.

The data from echocardiography are such that in some settings patients can be sent to surgery for congenital or valvular disease without cardiac catheterization. However, the technique is currently inadequate for assessment of the coronary vasculature.

Use of an intra-oesophageal transducer allows examination of additional structures such as the atria and better examination for aortic dissection, but it is a technique used by only relatively few clinicians.

Colour enhancement of the Doppler signal greatly facilitates the interpretation of the results of echocardiography but it is certainly not indispensable.

Computerized processing of the signal for chamber dimensions, wall thickness, and ejection fraction has been found useful, but such data can also be calculated manually. On an experimental basis, computerized analysis is also being attempted for tissue characterization.

“Contrast echocardiography”—the injection into the blood stream of a marker such as saline, indocyanine or some of the patient’s own blood—may be used as a substitute for the Doppler examination for certain types of flow and shunt visualization.

In many settings, echocardiography is performed by specially trained technicians working under the supervision of a physician, with over-reading of results by the physician.

Echocardiography equipment that provides only the M-mode is relatively inexpensive, costing about US \$4000–8000. Two-dimensional echo equipment costs considerably more, about US \$20 000 to US \$140 000. The cost varies according to the complexity of the instrument and the number of transducers; two transducers should be the minimum, one for paediatric use and one for use in adults.

3.7 Exercise testing

Exercise testing is now established as an essential, non-invasive, diagnostic, prognostic and evaluative technique in cardiovascular medicine.

The bicycle ergometer and the treadmill are widely used and are suitable for routine exercise testing. For special cases where neither of these is appropriate the arm ergometer is also available, although lower workloads are achieved with this apparatus.

Exercise testing includes continuous monitoring of at least three, and ideally 12, ECG leads, as well as regular recording of blood pressure. The following parameters are routinely observed or measured during the procedure: symptoms (chest pain, discomfort, fatigue, dizziness, claudication, etc.), heart rate, blood pressure, ST segment changes, arrhythmias, and work capacity.

Exercise testing is used for diagnosis and prognosis and for control of therapy, principally in patients with coronary heart disease. It helps in establishing the presence of myocardial ischaemia, in assessing its severity and site, and in deciding upon the need for coronary angiography or intervention.

Exercise testing is also used for:

- patients in rehabilitation and training programmes, to establish suitable exercise levels, monitor progress and provide reassurance;
- testing left ventricular function;
- assessing treatment efficacy;
- detecting exercise-induced arrhythmias and conduction defects;
- screening for coronary disease in high-risk individuals in special occupational groups and in other special circumstances.

However, exercise testing is not recommended as a general screening tool for coronary artery disease in those in whom the pre-test likelihood of the disease is small.

Exercise testing is a non-invasive and adequately safe procedure which yields reasonably consistent and reproducible results in any given laboratory. In persons with a substantial risk of coronary heart disease, its sensitivity and specificity are satisfactory. In middle-aged females its specificity is low, i.e., it yields many false positive results. Specificity is also low in persons without a substantial risk of coronary heart disease. The following circumstances may also prevent or impair satisfactory exercise testing: poor patient motivation, non-cardiac limitation of exercise capacity due to pulmonary, orthopaedic or neurological disease; abnormalities in the resting ECG such as left bundle branch block, and left ventricular hypertrophy; and the use of certain drugs, such as digitalis, beta-blockers and barbiturates.

Exercise testing should not be performed in the presence of severe congestive heart failure, unstable angina with persisting pain, life-threatening arrhythmias, severe aortic stenosis, or symptomatic or advanced heart block.

For a variety of reasons, alternative methods of testing the heart by stress—e.g., atrial pacing, hand grip, cold pressure testing and dipyridamole testing—are far less satisfactory.

Exercise testing is relatively inexpensive. The treadmill or bicycle ergometer, with computerized recording equipment, costs between US \$30 000 and US \$40 000; more than half this sum is for the computer system, which is useful but not essential. Other expenses include standby resuscitation equipment (about US \$6000) and the cost of disposables (about US \$15 per study). Necessary personnel include a trained technician and a doctor in attendance during the test.

3.8 Nuclear cardiology

Non-invasive *myocardial perfusion with thallium-201* is widely used in the evaluation of patients with coronary artery disease. Thallium is taken up by tissue in the same manner as potassium, and its distribution in the heart is dependent upon regional perfusion and myocardial integrity.

The technique involves the patient, with an intravenous line inserted, undertaking graded exercise. Once the target level of exercise is achieved, thallium is injected. Exercise is continued briefly, then stopped; clinical imaging, or scintigraphy, using a scintillation camera begins 5 to 10 minutes later. A perfusion defect

reflects a zone of hypoperfused, scarred or impaired myocardium. If a perfusion defect is observed, imaging is repeated 3 to 4 hours later. A persistent defect, apparent at the second imaging, is most likely to be a sign of scarred or impaired myocardium.

Segmental analysis of the scan often permits identification of the stenosed artery. In the presence of multivessel disease, however, since the scan reflects only the relative distribution of thallium, the perfusion defect may reveal only the location of the most severely stenosed vessel. In severe three-vessel disease, the scan will occasionally show homogeneous distribution of the tracer.

The principal drawback of simple planar thallium-201 imaging is the need for the observer to subtract background subjectively and estimate from a two-dimensional image the uniformity of perfusion in a three-dimensional object. Current apparatus routinely provides computer-assisted quantification which reduces some of the problems and eliminates some of the inter- and intra-observer variation. However, newer equipment is now available with a rotating gamma camera and signal processing that yields tomographic images.

Myocardial imaging is currently indicated for the detection of ischaemia in patients with atypical chest pain and/or with electrocardiographic abnormalities that render the interpretation of the exercise test difficult. The technique is also used to determine the site and extent of myocardial ischaemia and necrosis.

Because of the expense of this imaging technique, it is usually employed only after electrocardiographic screening tests including exercise electrocardiograms.

The equipment for planar imaging with computer-assisted quantification costs between US \$100 000 and US \$180 000; the equipment for tomographic imaging costs approximately US \$300 000. The cost of the thallium-201 required for a single test (55–75 MBq or 1.5–2.0 mCi) is about US \$75–300. Specially trained personnel are required to use the equipment. New myocardial tracers with improved tracer characteristics are now being developed and evaluated.

Infarct-avid myocardial scintigraphy, generally performed with technetium-99m stannous pyrophosphate, is now used relatively rarely. The technique has comparatively poor specificity and sensitivity and yields limited information that is needed for clinical management.

Radionuclide angiocardigraphy utilizes techniques in which the tracer remains in the blood. A single columnated gamma probe,

which permits assessment of global cardiac function, is still used in some circumstances by some good clinicians, but it plays a small role in radionuclide angiocardiology.

With a gamma camera (as used for thallium-201 studies, the planar type being adequate), the cardiac chambers can be visualized and ventricular function can be assessed visually and quantitatively. The patient's red blood cells are tagged by intravenous injection of technetium-99m. If this is done as a bolus injection, its first passage from chamber to chamber through the heart can be visualized—*“first-pass radionuclide angiocardiology”*. The signals are obtained over only a few heart beats while the concentration of the tracer is high. After several minutes there is complete mixing and all chambers then contain an equal concentration of the tracer. A different technique—*“multigated imaging”*—is then employed, in which signals are obtained over several minutes, gated according to their timing in the cardiac cycle, and recombined to depict a typical cycle during the imaging period.

Each technique has its advantages. Both allow subjective and quantitative assessment of global and regional ventricular function and may permit identification of certain anatomical abnormalities. The first-pass technique may be used when ventricular function is expected to change rapidly and must be reassessed; it may also demonstrate shunts not seen with multigated imaging.

The planar gamma camera costs between US \$100 000 and US \$180 000 and the isotope about US \$75 to US \$150. If necessary, both first-pass and multigated imaging can be performed with a single dose of the isotope.

Positron emission tomography (PET) is based on the emission by positrons of twin photons, in opposite directions, which can therefore be detected by coincidence circuitry. The technique employs a ring, or rings, of detectors arranged in opposing pairs around the part of the body to be imaged. PET scanning of the heart, which uses short-lived tracers, is currently used in research for the investigation of regional myocardial blood flow and myocardial metabolism. However, because of their short half-life, most of the tracers require a minicyclotron (for carbon-11, nitrogen-17, fluorine-18, etc.) or a rubidium-82 generator at the site of the PET camera. The cost of the equipment is of the order of US \$1.5–2.8 million in addition to the cost of the isotope source (about US \$800 000 for a minicyclotron and US \$35 000 for a ^{82}Rb generator). At present, PET scanning is a research tool.

3.9 Cardiac catheterization and angiography

Cardiac catheterization and related invasive techniques allow a precise evaluation of the cardiocirculatory system in various disease states and under a variety of conditions (e.g., rest, exercise, pacing, and under the influence of drugs). They are among the most powerful methods for diagnosing and quantifying heart disease and related haemodynamic abnormalities, but they require sophisticated equipment and highly trained personnel.

Cardiac catheterization involves introducing a semi-stiff, radio-opaque catheter into a vein or an artery, typically in the antecubital or femoral area, or a soft, balloon-tipped catheter into a vein, and guiding it into the heart and into the pulmonary circulation or coronary arterial system.

Manipulation of semi-stiff catheters requires X-ray control, while the very flexible catheters can be "floated" from a vein without X-ray equipment. The latter technique is more widely applicable, in that it can be used in severely ill patients in intensive care units, but it provides access only to the right side of the heart and the pulmonary arterial circulation, and its usefulness is therefore quite limited. Sterility is an absolute prerequisite for all catheterization procedures.

In conventional pressure measurement, the blood pressure at the tip of the catheter is transmitted through a column of physiological saline to a transducer outside the body. For precise phasic pressure measurement, a micromanometer at the catheter tip is superior to the conventional approach.

Catheterization of the heart allows pressure and oxygen concentration measurements in the central vessels and cardiac chambers, indicator dilution studies, and the introduction of X-ray-opaque materials into the cardiac chambers (ventriculography) and into the coronary arteries and other vessels (angiography). Cardiac catheterization with ventriculography thus allows overall assessment of cardiodynamics and regional ventricular function, as well as the demonstration and quantification of stenotic and/or incompetent valves and of intracardiac and central vascular shunts. With coronary angiography, lesions of the coronary arteries can be identified, precisely localized and assessed in a semiquantitative manner. (Semi-automated quantitative assessment is available for research purposes.)

Cardiac catheterization and invasive cardioradiography have been accepted for several decades. The procedures are not without

risks, but they are valuable for the definitive evaluation of congenital heart disease, acquired valvular disease, and myocardial disease. Coronary angiography is essential for definitive assessment of the coronary arterial system before surgery.

The diagnostic and evaluative strategy employed in the individual patient depends to an appreciable extent on the type of therapy that may follow. If surgery (or percutaneous transluminal coronary angioplasty) is unavailable or would not be tolerated, cardiac catheterization—with rare exceptions—is unnecessary. Careful clinical history and physical examination, often with echocardiography and/or exercise testing, are helpful in reaching appropriate decisions.

In recent years, therapeutic procedures using catheterization have been developed, such as percutaneous transluminal coronary angioplasty, valvular dilatation, intracoronary administration of drugs, and the introduction of transvenous cardiac pacing leads, but these are outside the scope of this report.

Right-heart catheterization with balloon-tipped catheters requires basic apparatus costing approximately US \$15 000, and disposable apparatus for each procedure costing from US \$150 to US \$250. Although this is a bedside procedure, it does require a physician trained in the technique and familiar with intensive care.

Diagnostic cardiac catheterization generally involves the left heart, alone or with the right heart, although in children right-heart catheterization is more common. The technique requires image-intensifier radiographic equipment and, in the simplest configuration, a videotape system to document and replay the images. Monitoring equipment, a defibrillator and an oximeter are all necessary and a wide variety of catheters must be kept in stock. This equipment results in initial costs of about US \$500 000.

A cardiac catheterization laboratory without angiographic facilities is severely limited. Angiography requires varied angulation and positioning of the X-ray source and image-intensifier video-camera system with respect to the patient. A good monoplane cardiac catheterization-cineangiographic laboratory with a 35 mm system involves equipment costing about US \$1 500 000. Biplane cineangiographic equipment may be desirable, but it further increases the cost and it is not essential.

The clinical success and safety of cardiac catheterization are dependent upon well-trained physicians, technicians and nurses, and a sufficiently large number of patients to permit the staff to gain

experience and maintain competence. Equipment must be well maintained and this requires considerable infrastructure and additional costs. For these reasons cardiac catheterization laboratories are appropriate only for facilities that undertake cardiac surgery or for units that have close physical and functional relationships with such facilities.

The appropriateness of a catheterization laboratory also depends upon a number of other criteria—prevalence of specific diseases, population density, ease of travel, and the necessary concentration and clustering of cardiovascular diagnostic and therapeutic facilities to ensure adequate usage. It is impossible to prescribe a standard ratio for the desirable population base per catheterization laboratory. However, to ensure optimum cost-effectiveness, there should be full utilization of existing facilities (for example, 800 or more catheterizations—or catheterizations plus other types of angiographic procedures—per year) before consideration is given to the establishment of an additional laboratory. In general therefore, except where problems of geography and communications justify the expense of new facilities, consideration should first be given to expanding those that already exist.

3.10 Other imaging techniques

In *digital subtraction angiography* (DSA) a digitized video image recorded before introduction of contrast medium is computer-subtracted from a similar image obtained after introduction of contrast medium. This results in enhancement of contrast density in the processed image. The technique may be used with right-sided or even peripheral venous injection of contrast medium for visualization of the pulmonary vasculature, the left heart and the great vessels. For optimal visualization, however, selective injections are preferable and DSA permits the use of smaller amounts of contrast medium and smaller catheters. The technique has been used effectively for volumetric estimation and has also been advocated for imaging of aorto-coronary bypass grafts, the aortic arch and its branches, and peripheral vessels. It is not considered to be of diagnostic quality for investigation of the coronary arterial system.

Digital subtraction angiography equipment is very expensive but yields information that would otherwise require a more complex and hazardous procedure. For specialized third-level facilities in which

such diagnostic procedures are needed with sufficient frequency, DSA is an appropriate technology.

Digital data acquisition, storage and processing of radiographic signals are in the research stage at present but may replace film-based techniques in the future.

Computed tomography provides cross-sectional anatomical displays of the body. It involves the use of a computer to reconstruct an image of a thin slice of the body by recording variations in tissue opacity to X-rays. The apparatus is present in many third-, and in some areas, second-level facilities because of its diagnostic value for non-cardiovascular problems. In its usual form, it is suitable only for relatively stationary objects and the cardiovascular applications of such a device are comparatively limited, except in assessing the consequences of cerebrovascular disease. The apparatus is expensive and its procurement cannot be justified on grounds of its cardiovascular application; when available, however, it is appropriate for selected cardiovascular diagnostic procedures.

Some new computer tomography technology has become available that permits the visualization of moving structures, including the heart. It is appropriate for cardiac research, but its procurement cannot yet be justified on the basis of its use for patient care.

Magnetic resonance imaging (MRI), formerly known as nuclear magnetic resonance, is a non-ionizing method of generating soft tissue contrast without the need for contrast injection. It allows 3-dimensional imaging of the heart and other thoracic organs and may also permit *in vivo* studies of myocardial morphology and metabolism.

This is a costly technique (of the order of US \$1.3–1.7 millions for the equipment and approximately US \$100 000 per year for operating and maintenance costs), but one that appears to be promising. In cardiology, however, it is still a research tool, and its procurement cannot be justified at this time on the basis of what it adds to clinical care and management.

3.11 Intracardiac electrophysiological testing

Intracardiac electrophysiological studies (EPS) are of little value in the diagnosis, assessment and management of patients with conduction disturbances and other bradyarrhythmias.

Patients with recurrent narrow QRS tachycardia may benefit from EPS when a decision has to be made on the type of therapy (surgery, ablation, or implantation of an antitachycardia pacemaker). In patients with sustained ventricular tachycardia and serious symptoms who have failed to respond to a variety of treatment regimens, serial electrophysiological drug testing may be of value in identifying effective drug therapy.

Standardized EPS methods have not yet been established in patients with ventricular tachycardia. Although there is some disagreement, electrophysiologists generally consider that induction of sustained (> 30 seconds) monomorphic ventricular tachycardia provides a satisfactory baseline for evaluating response to drugs in patients with chronic recurrent ventricular tachycardia. Previous studies have indicated concordance in some 80–90% of patients between the results obtained in the laboratory and clinical protection against recurrence of spontaneous episodes. In contrast, the significance of induced unsustained monomorphic ventricular tachycardia, polymorphic ventricular tachycardia, or fibrillation is not clear.

The value of EPS in patients who have suffered a primary ventricular fibrillation or a recent myocardial infarction is not established. Its use for the identification of high-risk individuals with Wolff-Parkinson-White syndrome still needs investigation.

The apparatus required for EPS is expensive. The investigation is not without danger and can only be performed by highly trained physicians.

EPS facilities are not an essential component of even third-level health care institutions. They should preferably be limited to centres that have particular expertise in the pharmacological or surgical handling of resistant cardiac arrhythmias.

3.12 Endomyocardial biopsy

Endomyocardial biopsy specimens are obtained by advancing a guidewire catheter and then a biopsy forceps into the ventricle under fluoroscopic monitoring. In the hands of experienced operators and in the circumstances in which it is indicated, the procedure is adequately safe.

Endomyocardial biopsy is useful only in conditions that affect the myocardium diffusely. Thus it has a role in assessing the possible rejection of a cardiac transplant, in differentiating between dilated

cardiomyopathy and myocarditis, and in recognizing immune-mediated cardiomyopathy, and it can be useful in differentiating between the restrictive types of cardiomyopathy and pericarditis. Expertise is required to interpret the histopathology of myocardial diseases, many of which are outside the experience of most general pathologists.

The biptome and guiding catheters are not major expenses but, as noted, the procedure must be performed in the catheterization laboratory under fluoroscopy and requires particular facilities and skills for the analysis of the specimens.

3.13 Peripheral vascular techniques

3.13.1 Peripheral arterial disease

Investigation of the patient with peripheral arterial disease requires not only accurate diagnosis of the presence of arterial lesions but also a careful assessment of their functional consequences. As diagnostic procedures, clinical history and physical examination have high sensitivity and specificity.

Pressure measurement using the Doppler ultrasound machine to detect arterial blood flow has become a widely accepted diagnostic procedure. Battery-operated, portable devices enable the physician to confirm or rule out occlusive arterial disease with satisfactory accuracy. Occasionally, however, the procedure fails because of the inaccessibility of arteries or because of an inaudible signal (where there are multilevel occlusions with thin collaterals). Basic Doppler equipment costs only about US \$1000.

Exercise tolerance in the lower extremities can be assessed objectively on a treadmill under standardized conditions (e.g., 3.2 km/h at a slope of 7 degrees). The patient must be familiar with the procedure, and his or her cooperation is necessary. The intervals to the onset of ischaemic pain and to the moment when pain forces the patient to stop are measured and expressed in metres as pain-free walking distance and total walking distance. Since the perception of pain is subjective, a more objective evaluation of the walking test by measurement of arterial pressure distal to the lesion has been advocated. The treadmill costs about US \$10 000.

Venous occlusion plethysmography measures the increase in volume of a limb or extremity caused by short-term venostasis; the data obtained allow calculations of blood flow to be made. However,

resting blood flow can remain unimpaired even where severe arterial occlusion exists. Thus, to increase the sensitivity of the procedure and to obtain more information on arterial functional capacity, measurements of hyperaemic flow should be made after a period of exercise or other vasodilating stimulus. The sensors used in this technique are of limited durability and must be replaced regularly. The more sophisticated automatic plethysmographs may cost as much as US \$20 000.

Photoplethysmography is based on the intensity of penetration of a light beam through tissues, which depends on blood content and varies correspondingly during the arterial pulse cycle or venostasis. Recording of pulse curves makes it possible to screen arterial abnormalities by graphical analysis, or to measure local arterial pressure in the toes by cuff compression. However, the existence of abnormal pulse waves gives no indication of the site of the arterial lesion. Photoplethysmography is simple and the device is not expensive (US \$2000 plus the cost of a recorder).

Exercise oscillography makes use of the pressure drop distal to an arterial stenosis after muscular work which is characterized by diminished arterial oscillations. Signals are recorded by means of a simple built-in system. The equipment is inexpensive, but resting oscillography is of very little value.

Skin temperature changes may be measured by means of a thermocouple in contact with the skin, which generates an electrical voltage proportional to temperature. Measurements are taken before and after heating the body; a large difference in skin temperature before and after heating indicates pronounced sympathetic vasoconstriction. This condition may be corrected by sympathectomy if the procedure is clinically warranted. The heating test is well standardized and easily reproducible, but takes 1.5 hours to perform. The requisite type of thermometer costs between US \$500 and US \$1000.

Infrared thermography employs an infrared camera to portray body surface temperatures, based on the infrared radiation of the body itself. In the context of cardiographic diagnosis, the expense of the equipment (US \$50 000–100 000) is not justified by the amount of additional information it produces.

Contrast angiography of the vascular tree is essential if surgical treatment is considered. The original single-plane technique is gradually being replaced by the more accurate double-plane approach. Digital subtraction angiography and densitometry are

interesting recent improvements. The price of simple angiography equipment, which is generally adequate, is of the order of US \$200 000.

The following should be available in all centres that regularly treat patients with vascular disease: Doppler arterial flow equipment, thermographic equipment, treadmill, and facilities for angiography. Plethysmography is a valuable adjunct to these techniques.

3.13.2 *Venous diseases*

Varicose veins are a very common and troublesome complaint but do not constitute a life-threatening disease; thus their investigation generally requires only a careful clinical examination.

Deep venous thrombosis is the most important disease of the veins, for which phlebography is a valuable diagnostic tool but indicated only in some patients. Noninvasive procedures, such as measurement of venous emptying after short-term venostasis by plethysmography, or testing the patency of deep veins by the Doppler technique, are commonly accepted procedures. Diagnosis by detection of radioisotope-labelled fibrinogen accumulated in the thrombus is quite reliable but has been criticized recently because of the risk of transmission of viral diseases (hepatitis, AIDS, etc.) in blood products.

When deep vein thrombosis is complicated by pulmonary embolism, the latter can often be diagnosed on the basis of the clinical history, chest X-ray, and isotopic techniques utilizing macro-aggregates. Pulmonary and venous angiography may also be required.

3.14 Ambulatory and home blood pressure monitoring

In *self-measured* ambulatory and home blood pressure monitoring, the patient or a family member learns to take the patient's blood pressure accurately and does so regularly. This helps to characterize the variations in blood pressure during everyday activities and avoids the stress encountered by some patients in the medical setting; it also helps to identify the circumstances that may adversely affect blood pressure. Patients are encouraged to become involved in the management of their conditions, and their compliance with treatment regimens improves. Some physicians also

teach some of their patients how to titrate their medication to obtain adequate control with minimum side-effects.

The necessary instrumentation (sphygmomanometer and attached stethoscope) is sturdy and inexpensive (about US \$50), but requires twice-yearly calibration. Electronic apparatus for blood pressure measurement is more expensive (US \$80–300) and, although it may be preferable in some patients, it is probably generally less satisfactory and less reliable than the mechanical equipment.

With *automated* measurement, the blood pressure apparatus is worn by the patient for a specified period of time, and frequent blood pressure readings, with automatic sphygmomanometer inflation/deflation and signal recording, are generally taken at regular intervals determined either by the apparatus or by the patient. There is no observer bias in the recording of the figures, which can later be printed out. At present the instrument is troublesome and awkward to wear during everyday activity, it is generally available only for limited periods of time and it is relatively expensive (US \$6000–10 000). This apparatus is useful in research. Some physicians have found it useful in the diagnosis and management of hypertension, but it is not widely used and is not generally considered necessary for patient care.

3.15 Laboratory studies

Appropriate laboratory technology is essential for the diagnosis and management of disease, and it also provides information useful in the prevention of disease. Laboratories should be available to fulfil clinical needs, but only essential studies should be ordered. The highly sophisticated laboratory technology of the developed countries is lacking in developing countries. However, the inappropriate and excessive use of laboratory studies is common in most settings.

Just as an effective referral system must exist for patients, effective referral systems should exist for certain types of laboratory specimens. This is already the case in some settings and should be made generally available.

In developing countries available resources are meagre, and the development of laboratory facilities to fulfil health care needs at various levels requires most careful planning. The minimal requirements at each level of health care should be ascertained; these

may vary with time and with local need (determined partly by the prevalence of specific diseases) and resources.

The infrastructure available at each health care level must be used in establishing proposed laboratory facilities. Successful laboratories require knowledgeable, professional leadership, trained technical personnel, appropriate and well maintained equipment, reagents and other disposables. For certain equipment familiarity with service and maintenance needs and the availability of spare parts pose special problems.

All laboratory results must be reliable. Accordingly, all laboratories must have adequate quality control. Their methodology and equipment calibration must be standardized with appropriate reference laboratories.

The recommendations for the minimal requirements at each level of care are listed below.

First level: routine urine analysis, white blood cell count, haemoglobin or erythrocyte volume fraction (haematocrit), erythrocyte sedimentation rate, and a simple test for identification of group A beta haemolytic streptococcal pharyngitis when that is available. These tests require a microscope, glassware, reagents and a centrifuge.

Second level (in addition to tests available at the first level): levels of blood sugar; blood urea or preferably serum creatinine levels; serum levels of sodium, potassium and cholesterol, and the enzymes aspartate aminotransferase (ASAT or SGOT), lactate dehydrogenase (LDH) and creatine kinase (CPK); microbial laboratory for culture of throat swabs, blood and urine specimens; estimation of antistreptolysin O titres; liver function tests; serum amylase; prothrombin time; Australia-antigen tests, and detection of antibodies to the human immunodeficiency virus (HIV). High density lipoprotein cholesterol measurements would also be useful. As a minimum, the required equipment consists of a spectrophotometer, centrifuges, flame photometer or ion-selective analyser, oven, sterilizer, incubator, refrigerator, bacteriological cabinet, haemoglobinometer, and water bath.

Third level: laboratory facilities should fulfil the advanced needs of a major general hospital. A detailed list of requirements cannot be given because it will vary as a function of available resources and of local needs and priorities.

4. SPECIAL ISSUES

4.1 Issues of special importance to paediatric cardiology

Almost 1% of newborn infants have congenital heart disease, which represents a substantial fraction of the paediatric cardiac caseload; roughly one-third of such patients need surgical intervention. Rheumatic fever and rheumatic heart disease, now rare in many areas, are still very common in many developing countries and constitute a major problem. Other problems encountered in both developed and developing countries include infections and inflammatory conditions of the heart muscle and its surfaces (myocarditis, pericarditis, endocarditis, pancarditis—often due to such systemic infections as tuberculosis, diphtheria, and viral disease), cardiomyopathies, mitral valve prolapse, and hypertension (including that due to vascular disease). The recognition of some heart murmurs as functional and of no clinical significance is also an important paediatric cardiological responsibility.

Prevention and early recognition of disease are important elements in avoiding some problems of paediatric cardiology; accordingly, the relevant diagnostic technologies must be available. Some serious conditions can be prevented, such as rheumatic fever and rheumatic heart disease (by the prompt treatment of streptococcal infection, and prophylactic therapy thereafter), bacterial endocarditis (by prophylaxis for those at risk because of certain forms of heart disease), and congenital heart disease caused by the rubella virus (through pre-pregnancy rubella immunization). For other forms of paediatric heart disease, prompt surgical intervention can effect complete correction.

For a successful paediatric health care system certain conditions must be met.

- (1) In many settings, strenuous efforts must be made among health workers involved in first-level health care to increase awareness of paediatric cardiovascular disease.
- (2) Physicians involved in second-level health care must be able to identify patients who require referral to the third level for further investigation and treatment. Thorough knowledge of the diseases and their natural history is needed to avoid unnecessary referrals and to decide whether surgery should be performed on an emergency or an elective basis.

- (3) A third-level centre should offer all facilities for detailed evaluation and treatment of paediatric cardiac cases. It should handle a sufficiently large number of patients to make optimal use of its resources and for the staff to acquire and maintain the necessary expertise. Financial resources must be adequate for this.

For patients with rheumatic fever or rheumatic heart disease, the diagnosis and management can generally be undertaken at the second level of care. However, if severe valvular disease develops and produces significant functional impairment, the patient may have to be referred to the third level for treatment.

A number of other paediatric cardiovascular problems can be properly diagnosed and managed at the second level. Moreover, in health care systems where paediatricians and extensively trained family physicians provide the first level of care, some of these problems may be appropriately handled at that level; in such systems, it is not uncommon for paediatric cardiology problems to be referred routinely and directly to third-level facilities.

4.2 Issues of special importance to developing countries

New diagnostic technology, with greater accuracy and versatility, is constantly being developed, but the price for this is generally one of increasingly expensive equipment. This presents difficulties for potential users the world over but especially in the developing countries, where the need for careful management and conservation of scarce resources is paramount. Among the particular problems for such countries are the following.

- New equipment may be acquired on the basis of its prestige value even though the actual information it yields may be limited.
- Expertise in the use of the new technology and in the interpretation of the results produced may not be readily available.
- Actual performance may differ from what is expected.
- There may be infrastructural difficulties, such as unreliable electric power supplies, poor control over environmental extremes of temperature and humidity, lack of maintenance and repair services, and inadequacy of medical technological support.
- Difficulties may arise in obtaining spare parts because of geographical location, poor communications, small volume of

demand and the tendency of manufacturers to phase out the production of spare parts for older equipment.

Given the need to optimize the acquisition and utilization of equipment for cardiovascular diagnosis, the following guidelines would seem to be appropriate.

- (1) For each country or major area to be served, the prevailing pattern of cardiovascular disease and health service infrastructure should be considered in determining the appropriateness of the equipment and services to be provided at the three levels of health care.
- (2) Adequate training and retraining programmes on the use and maintenance of equipment must be available for both health service personnel and equipment service personnel.
- (3) The concept that complementary clusters of fully functional equipment are necessary for the optimal functioning of a health service facility must be recognized.
- (4) Dialogue between the manufacturers and the users should be fostered by the World Health Organization, focusing on local needs and constraints (e.g., hot, humid conditions, and dust). The present policy of replacing equipment at regular intervals of a few years should be replaced by one of regular maintenance and maximal utilization of existing equipment.
- (5) Acquisition of equipment by a health care system must be conditional upon the availability of funds for its purchase, regular operation and maintenance. Where recurring costs cannot be met the equipment is better not acquired, even if offered as a gift.
- (6) Strengthening of the technological infrastructure is necessary in all developing countries. Some of the larger countries should aim at self-reliance by producing their own supplies and spare parts, ultimately becoming a source of technology specially suited to their needs.
- (7) When equipment is imported, developing countries should ascertain that manufacturers will guarantee availability of spare parts and technological support for a specified period. Health care workers in those countries should have access to spare parts and supplies without administrative delays for importation formalities.

4.3 Diagnostic technologies and traditional medicine

Traditional medicine is practised in many societies, but in general has not been fully evaluated. Such systems rely largely upon such methods as history, observation and physical examination by the practitioner, but other diagnostic technologies may be needed in the future.

4.4 Population studies

Population studies have varied goals—screening programmes to identify individuals who warrant further evaluation and possible therapy for the treatment or prevention of disease, and epidemiological studies for data acquisition. They may focus on a specific disease, a number of diseases, an organ system, or health in general.

A disease or condition that is to be the subject of a screening programme must be important in terms of its prevalence or severity and its prognostic significance, and must be susceptible to intervention that is practicable, effective, affordable, and available if needed. The relevant screening method must be deemed appropriate after consideration of the factors listed in Section 2.

For epidemiological studies involving health status assessment or health care planning, there are analogous issues. The data sought must be important and likely to be the basis for action. (Epidemiological studies to test research hypotheses are outside the scope of this report.)

A wide range of diagnostic technologies may be appropriate for population studies, depending upon the questions to be resolved. For some, the simplest techniques may be adequate—systematic questioning or questionnaires, and such basic equipment as the blood pressure cuff and stethoscope, apparatus for determining height and weight and possibly for skin-fold measurement. For others, more complex tests may be necessary. The standard electrocardiogram may be appropriate as may blood chemistry, particularly for total cholesterol; triglycerides and HDL-cholesterol may be utilized for calculating LDL-cholesterol. Echocardiography may be appropriate in some circumstances, while in others ambulatory electrocardiographic and blood pressure measurements may be suitable. Even retinal photography has been used for assessment of one part of the microcirculation.

Adequate reliability, accuracy, ruggedness, and utility under the circumstances of use in varied settings are of particular importance.

Standardization in the method of measurement and in the interpretation of results is essential.

5. AVAILABILITY OF DIAGNOSTIC TECHNOLOGY AT VARIOUS LEVELS OF HEALTH CARE

For the purpose of this report, three degrees of development and resource availability of the health care system are considered. Development and resource availability are seen as varying together—advanced health care systems having relatively abundant resource availability, those of intermediate development having intermediate levels of resource availability, and the least advanced health care systems also being those in which resource availability is the most limited—but it is recognized that these two factors do not necessarily go hand-in-hand.

Three levels of facilities are assumed within each of these three types of health care system, although it is acknowledged that the distinctions are rarely so clear or easily defined.

A first-level facility involves the initial contact of a patient with the health care system, whatever that may be—a health care worker, a nurse or a physician—and includes the first level of referral.

A second-level facility receives patients referred from a first-level facility and itself commonly refers patients to third-level facilities when more sophisticated studies or therapies are needed.

A third-level facility is one where the most advanced diagnostic and therapeutic techniques are practised. It may serve in teaching and research capacities, but these needs are not considered in the present report.

In certain circumstances, second- and third-level facilities may also provide first-level services.

Table 1 summarizes the recommendations on availability of the different techniques at each level of health care. It is emphasized that the table is intended to be illustrative rather than definitive. The numerous other factors discussed in Section 2 enter importantly into the consideration of appropriateness of a technology at any level of health care and for health care systems with any degree of development and resource availability. This table can serve as a guide, but decisions on the appropriateness of a technology in any specific setting should be based upon careful consideration of the concepts discussed throughout the report.

6. CONCLUSIONS AND RECOMMENDATIONS

- (1) Advances in diagnostic technology have yielded major benefits in the treatment and even prevention of cardiovascular diseases. However, the use of technology is an adjunct to, and not a substitute for, the physician's responsibilities for taking a careful history, making a thorough physical examination, and developing a close relationship with the patient. Training should emphasize these responsibilities and should include not simply the use of technology but also the appropriateness of its application.
- (2) Many of the problems of diagnostic technology and its utilization are common to most parts of the world. There is usually inadequate appreciation of cost-effectiveness—the concept, its components, and its importance. There is inappropriate use of technology, e.g., in circumstances when it is redundant, when the results are not likely to be the basis for action, or when the results could be obtained more efficiently by other means. There is a proliferation of equipment with inadequately validated efficacy. In the selection of technology and equipment, non-medical factors such as institutional and individual prestige, personal goals, and external pressures sometimes play a powerful role. The features, advantages and utility of a technology are often exaggerated by its advocates within both the medical profession and industry. Projections of benefits are often over-optimistic, while inadequate consideration is given to the limitations, burdens, costs and other consequences of the technology. Greater, and more objective, consideration must be given to the appropriateness of technology and equipment before selections are made.
- (3) The distribution of diagnostic technology in many regions is less than optimum for its efficient utilization for health care. In some cases there is excessive concentration at a few centres at the expense of the rest of the health care system, in others the opposite is true. Health care planning must consider all levels of care within a region.
- (4) An effective referral system is beneficial to the individual patient and allows more efficient utilization of health care resources.
- (5) Some of the factors to be taken into account in choosing appropriate diagnostic technologies are of particular importance to developing countries; these include infrastructural

constraints, extremes of climate, poor communications, limited availability of spare parts and service (particularly for older equipment), small markets and limited interest from vendors. These points are dealt with in more detail in Section 4.2.

- (6) In developed countries there is an overproliferation of high technology, even though resources for health care are limited almost universally. Increasing concern about cost containment underscores the importance of the appropriate selection and use of technology.
- (7) Selection of diagnostic tests should be based upon and limited to the clinical needs of individual patients.
- (8) The varied factors that go into the appropriateness of a diagnostic technology, summarized in Section 2, are enduring principles. The discussion of individual technologies in Section 3 and the summary table in Section 5 may serve as guides, but decisions on the appropriateness of a technology in any specific setting should be based upon careful consideration of the concepts throughout the report, bearing in mind any changes in the technologies that may have taken place since the preparation of the report.

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