Future use of new imaging technologies in developing countries

Report of a WHO Scientific Group

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# CONTENTS

1. General introduction ................................................................................. 7  
   1.1 The differences between ultrasound and computed tomography .............. 8  
   1.2 Magnetic resonance ............................................................................ 9  
   1.3 Current world status of facilities for ultrasound and computed tomography ................................................................................. 10  
   1.4 Levels of care and the use of ultrasound and computed tomography. ................................................................................. 13  

2. Ultrasound ............................................................................................... 14  
   2.1 Introduction ....................................................................................... 14  
   2.2 Safety of diagnostic ultrasound ............................................................ 15  
   2.3 Minimum specifications for the general purpose ultrasound scanner....... 16  
   2.4 Specifications for the special purpose ultrasound scanner ....................... 18  
   2.5 Operator training ............................................................................... 18  

3. Computed tomography ............................................................................ 19  
   3.1 Introduction ....................................................................................... 19  
   3.2 Planning radiotherapy treatment ........................................................... 20  
   3.3 The radiation dose from the use of computed tomography ....................... 21  
   3.4 Specifications for a computed tomography scanner .................................. 21  

4. Clinical indications ............................................................................... 27  
   4.1 Introduction ....................................................................................... 27  
   4.2 Obstetrics and gynaecology ................................................................. 28  
   4.3 Liver ................................................................................................ 32  
   4.4 Gall-bladder ..................................................................................... 32  
   4.5 Pancreas ........................................................................................... 33  
   4.6 Spleen ................................................................................................ 34  
   4.7 Kidney ............................................................................................... 34  
   4.8 Adrenal .............................................................................................. 36  
   4.9 Urinary bladder and prostate ............................................................... 36  
   4.10 Scrotum ............................................................................................. 37  
   4.11 Pelvis ............................................................................................... 37  
   4.12 Retroperitoneum .............................................................................. 37  
   4.13 Intra-abdominal abscesses ................................................................. 37  
   4.14 Cerebral: skull and brain .................................................................... 39  
   4.15 Face, head, neck, and soft tissues ....................................................... 40  
   4.16 Thorax ............................................................................................. 42  
   4.17 Heart and great vessels ..................................................................... 43  
   4.18 Spine ............................................................................................... 44  
   4.19 Interventional procedures ................................................................... 45  
   4.20 Cancer staging ................................................................................ 47  

5. Summary of recommendations ................................................................ 49  

Acknowledgements .................................................................................. 50  

References ............................................................................................... 50  

3
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Geneva, 24 September – 1 October 1984

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THE FUTURE USE OF NEW IMAGING TECHNOLOGIES IN DEVELOPING COUNTRIES

Report of a WHO Scientific Group

A WHO Scientific Group on the Future Use of New Imaging Technologies in Developing Countries met in Geneva from 24 September to 1 October 1984 to consider the use of ultrasound and computed tomography as well as the specifications for the equipment required.

1. GENERAL INTRODUCTION

In many countries, radiological services are either nonexistent or inadequate; in view of this, WHO has introduced a specially designed Basic Radiological System.\(^1\) Where there are larger hospitals, the basic radiological services should be complemented with the proposed General Purpose Radiological System and the Specialized Radiological System (3), both of which will normally be operated by radiologists. In the last few years the techniques of ultrasound and computed tomography have become more widely available and experience in their clinical use is increasing. There are advantages and disadvantages associated with the use of both techniques when compared with conventional radiology and they should be considered as being additional to, rather than as substitutes for, the basic and specialized radiological systems. The primary need in diagnostic imaging in any health care system is conventional radiology; only when conventional radiology is already available should the use of ultrasound or computed tomography be contemplated. For the majority of patients radiographic diagnosis of their injuries or chest infections will be adequate; only a few will ever need additional examinations by ultrasound or computed tomography.

Nevertheless, there is an increasing demand for both of these techniques, making it essential that the costs, medical indications,

\(^1\) Technical specifications for the X-ray apparatus to be used in a basic radiological system. Geneva, 1981 (unpublished WHO document, RAD. 81.2).
and the types of equipment needed should be carefully examined. In addition, the necessary clinical support must be considered and made available, and, in the case of computed tomography, the ongoing running expenses should be anticipated. Neither technique is worth considering unless the appropriate specialist physicians are well trained and the resources and manpower are available to provide the necessary treatment and care. These requirements apply particularly to ultrasound. Both techniques have limitations to their use and these must be considered with particular reference to the health problems of the country concerned.

1.1 The differences between ultrasound and computed tomography

Ultrasound uses high-frequency, non-ionizing sound waves to produce images on a screen. A small anatomical field is covered and the equipment can be used almost anywhere, at the bedside or in any suitable room. No structural protection is required and there is no currently known risk to the operator or the patient. At the present time, certain special-purpose ultrasound units are larger and less mobile, but are not essentially different. Ultrasound diagnosis is normally carried out and interpreted by a physician, although specially trained technicians can also operate the apparatus under supervision.

Computed tomography uses X-radiation, which is ionizing, to produce images on a screen. The equipment is large and heavy, and full radiation protection is needed in the examination room, and for the operator; the patient must not be unnecessarily irradiated. Although such units can be mobile in large vehicles, this is not, at present, a practical solution for developing countries. A large air-conditioned space is needed for a computed tomography scanner and, however ill the patients may be, they will always have to be taken to the scanner.

Ultrasound is the method of choice for imaging during obstetric examinations, having almost replaced radiography (13). Most of the other examinations made using ultrasound are of the abdomen, which can be viewed easily and rapidly in any plane with real-time imaging that allows a systematic search to be made for pathological signs. Soft tissues, such as the thyroid, can be imaged using ultrasound and it can be of use in paediatric cerebral diagnosis. With special attachments, the eyes, the heart, and major vessels can be investigated. It has only a limited use in the examination of the lungs.
(being used particularly for pleural effusions) and has no use in the examination of bones or the adult head.

Computed tomography can be used to examine the whole body but is restricted to axial slices with some exceptions in the head, and has no real-time capability. It is particularly useful for the examination of the brain, skull, and spine and, unlike ultrasound, the images produced are not impaired by gas in the bowel. Although it is helpful to have the examination monitored by a physician, satisfactory images may often be obtained by a technician. On average it takes longer to obtain satisfactory images using computed tomography than with ultrasound. For many investigations using computed tomography, intravenous contrast enhancement is required and this is associated with a risk of adverse patient reaction; no such contrast enhancement is needed when using ultrasound.

These and other differences, advantages, and limitations are discussed in more detail in sections 2 and 3.

The science of electronics is advancing rapidly and there may be some concern that equipment will become rapidly outdated. In fact, both techniques are now well developed and the units available at present will probably remain satisfactory for general purpose diagnosis; any advances that occur are likely to be in highly specialized areas. Nevertheless, the investment needed for equipment for computed tomography is considerable, and the cost of a more specialized ultrasound system may be more than twice that of a basic radiological system, and equivalent to the cost of a general purpose radiological unit. The Scientific Group cannot provide universal guidelines since local circumstances vary, but in this report an attempt is made to explain the needs, provide the specifications for equipment that is suitable for different requirements, and indicate those clinical problems for which each method of imaging will be useful or unhelpful.

As with all diagnostic investigations, there must be a close collaboration between the referring physician and the imager and both must have a clear understanding of the benefits and limitations of the procedures. Prior consultation is always desirable in order to obtain the most useful result.

1.2 Magnetic resonance

If the purchase of a computed tomography scanner is being considered, it is important to assess any new developments that
might make the scanner obsolete within its useful lifetime. Magnetic resonance (or nuclear magnetic resonance), which involves radiofrequencies and magnetic fields, produces images without using ionizing radiation. With proper patient selection, the images are, in general, very similar to those produced by computed tomography, and there is no known risk to the patient or operator. The use of magnetic resonance is, at present, considerably more costly than computed tomography and the technique is less comprehensive in evaluating all parts of the body. However, good images can be obtained of the brain, chest, abdomen, and soft tissues. Although it can be used for some skeletal investigations, it is not helpful in cases of trauma. The effects of magnetic resonance on diagnosis and therapy, hospital costs, and all aspects of health care have not yet been assessed. It is not known whether, in time, it will completely replace, or only complement, the use of computed tomography. It seems unlikely that any firm appraisal of magnetic resonance will be made during the present decade.

1.3 Current world status of facilities for ultrasound and computed tomography

Because of the rapid and continuous development of facilities for both techniques no reliable, up-to-date statistics are available. The few examples outlined in this section are presented to demonstrate the current disparity in the population coverage of these techniques and to emphasize the need for the development of appropriate policies to guide the acquisition of such equipment.

1.3.1 Computed tomography

In industrialized countries the number of computed tomography scanners per million population varies greatly and is changing continuously. For example, Japan with approximately 25 scanners per million people,1 seems to be the country with the highest coverage, followed by the United States of America and some western European countries.

In the United States of America in 1980, the Office for Technology Assessment found large differences in the number of computed tomography scanners in the various states (from 1.6 scanners per 10^6 population in Puerto Rico to 16.7 scanners per 10^6

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1 Sakuma, S. Personal communication, 1984.
population in the District of Columbia). In 1980, the national average was 6.7 scanners per 10^6 population.\(^1\)

Pietzch & Hintz (14) demonstrated a similar pattern in the Federal Republic of Germany; in April 1979 the number of scanners was 0.92 per 10^6 population in Saarland and 8.89 per 10^6 population in Hamburg.

Bruguerà (4) has described a similar distribution in 8 Latin American countries, with Venezuela having 0.07 scanners per 10^6 population and Argentina 1.25 scanners per 10^6 population.

The developing countries can be divided into 3 categories:

1. countries that have acquired scanners in recent years (e.g., Algeria, Argentina, Brazil, China, Egypt, India, Indonesia);
2. countries that are at present considering or will soon consider acquiring computed tomography scanners;
3. countries that will need more time to develop their health infrastructure before they can justify the acquisition of a scanner.

The recommendations presented in this report will be of particular value to those countries in categories 2 and 3, and will help them to avoid the major errors that often occur when a new medical technique is introduced. The high costs of acquiring and operating computed tomography scanners have already been considered in countries with high per capita health expenditure [United States of America (1, 7–10); Federal Republic of Germany (5, 15)] and must be one of the major factors to be seriously explored when the technique is introduced into a developing country.

The high cost of computed tomography includes both the initial investment (cost of the machine, premises where the machine is installed, and auxiliary equipment such as air-conditioner, stabilizers, etc.), and the running costs (power used for air-conditioning and machine, contrast media, image recording and storage, salaries of personnel, X-ray tubes, spare parts, etc.).

Evens (8, 9) in the United States of America gives typical charges (US$) for computed tomography examinations as shown below:

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\(^1\) Policy implications of the computed tomography (CT) scanner; an update. Background paper. Washington, Office of Technology Assessment, 1981.
In the Federal Republic of Germany, Deckner (5) found the
global cost of the use of computed tomography to be DM 524 per
A number of authors emphasize that the use of computed
tomography has economic and health benefits that can be measured
in terms of, for example, fewer days in hospital; fewer complications
and recurrences; reduced number of diagnostic procedures; and, in
particular, fewer invasive studies such as pneumoencephalography,
cerebral arteriography, and exploratory surgery (1, 2, 5–12, 15, 16).
However, it will be more difficult to demonstrate such savings in
most of the developing countries.

1.3.2 Ultrasound

Information on the number of ultrasound scanners at present in
use is even more scarce than for computed tomography. For 8 Latin
American countries, Bruguera (4) in 1982, indicated that the range
is from 0.33 machines per 10⁶ population in Peru to 17.9 in
Argentina. It is interesting to note that there is a great discrepancy
between the population coverage with the two techniques.
Venezuela, which has only 0.07 computed tomography scanners per
10⁶ population, has 17.7 ultrasound machines per 10⁶ population,
while Uruguay, with 1 computed tomography scanner per 10⁶
population, has 4 ultrasound machines for the same number of
people.

In British Columbia (Canada) 49 ultrasound units serve 2.6
million people and are used for 95,000 examinations per year.
The costs of using ultrasound differ from those of computed
tomography. The capital investment for the most advanced
ultrasound machine is approximately 10% of the amount needed for
a computed tomography scanner and no specially constructed
premises are required. Running costs are also much less since there
is no requirement for air-conditioning, contrast media, or expensive
spare parts such as X-ray tubes—the only items needed being
personnel, the image-recording material, and the lubricant for the
skin.

There are few published reports dealing with the economics of the
ultrasound technique and this suggests that, unlike computed
tomography, it does not pose an economic problem, provided that
generalized self-referral or abused referral do not result in the
overuse of the apparatus.

12
The availability of ultrasound machines in developing countries can be categorized in a similar way as for computed tomography scanners; there are many more countries in categories 1 or 2 than there are for computed tomography.

The diagnostic problems for which ultrasound is particularly suited are much closer to the needs of developing countries (obstetrics and many parasitic diseases). Therefore the acquisition of this equipment should have a higher priority in such countries and all efforts to promote its use and the necessary specialized training for physicians should be encouraged.

1.4 Levels of care and the use of ultrasound and computed tomography

A major aim of the present report is to outline the appropriate levels of care for each of the two techniques.

Existing radiological services may be available at three different levels:

(1) Basic Radiological System—serving a small rural (or suburban) hospital or health centre;

(2) General Purpose Radiological System—serving a secondary care hospital with 100–500 beds and a number of medical specialties (surgery, medicine, obstetrics, gynaecology, paediatrics, etc.);

(3) Specialized Radiological System—serving tertiary care (usually the top-level referral hospital, often a university hospital) (3)\(^1\).

Within these three levels the distribution of computed tomography and ultrasound will have to follow a very different pattern.

It is conceivable that adequately designed ultrasound machines, as specified within this report and known as general-purpose ultrasound machines, could have a place at all of the above levels. However, for some time many developing countries may be obliged to restrict the use of ultrasound to levels 2 and 3, depending on the ancillary equipment and manpower and the maintenance resources available.

The high cost of computed tomography—even when designed according to the recommendations of this report, and moderately

\(^1\) Technical specifications for the X-ray apparatus to be used in a basic radiological system. Geneva, 1981 (unpublished WHO document, RAD. 81.2).
priced—will restrict the acquisition of this equipment by developing countries. Wherever countries are, or will soon be, able to use this technique, there is no doubt that its use will be restricted to level 3, since an appropriate referral system and the adequate selection of patients will be essential in ensuring the adequate use of computed tomography equipment.

Countries that already have a fully developed radiological service and sufficient resources to ensure that the acquisition of computed tomography will not use up resources allocated to other aspects of health care, may be able to consider, with due caution, the purchase of such scanners for level 2 of the radiological service on the understanding that the conditions required for such installations (see section 3.4.5) are fully met.

Such a policy will not only avoid the misuse of limited resources, but will also allow the effective use of this powerful diagnostic technique for the benefit of the individual patient, without prejudicing the health care of the population in general.

2. ULTRASOUND

2.1 Introduction

There has been a rapid expansion in the use of diagnostic ultrasound techniques in the developed countries and the value of these techniques, particularly in abdominal diagnosis and obstetrics (see section 4.2), is now well established (17, 18, 20, 24, 25, 27, 31–36). However, it is also true that in many of the most heavily populated parts of the world there may be no or few ultrasound facilities available.

It is probable that the major use of ultrasound will be in obstetric and abdominal investigations and it must be the first choice for imaging pregnant women even where X-ray machines are available.

Ultrasound irradiations fall into two categories: pulsed fields (pulse-echo method) and continuous wave (the blood-flow method, which is based on the Doppler principle). In most hospitals the pulse-echo imaging system will be adequate for normal use, but in centres where specialized investigations and therapies are available, specialized ultrasonic equipment may be needed, for example, in cardiology, blood-flow analysis, and intraluminal examinations.
Specialized equipment of this type is already available, but may have to be adapted to operate under difficult climatic conditions.

Small hospitals and health centres will need a general-purpose ultrasound scanner with a high imaging quality but without Doppler or other specialized facilities. This apparatus should be inexpensive, portable, small, rugged, and with simple controls (see section 2.3). Equipment with a curved linear transducer is recommended for use in abdominal and obstetric examinations and will provide a wide field of view together with the facility to work through a narrow access window (e.g., an intercostal space).

2.2 Safety of diagnostic ultrasound

As far as is known, the medical use of ultrasound irradiation is safe. However, absolute safety is difficult to prove and therefore should not be assumed. Even very low levels of risk may be important when many people are involved (29).

The indiscriminate use of ultrasound, particularly in obstetrics, is still a subject of extensive research. However, the information currently available does not suggest that ultrasound should be withheld on the grounds of safety, wherever there is any clinical need for its use (23, 30).

A considerable amount of laboratory and epidemiological research has been carried out on the subject of the safety of ultrasound and the findings are summarized in two World Health Organization publications (37, 38). The conclusions of the latter (38), which have been endorsed in the USA by the National Council on Radiological Protection and Measurement, include the following statements:

"...there is at present no clearly established evidence to indicate that the ultrasound exposures involved [in diagnostic medicine] constitute a hazard to the patient."

"With regard to medical exposures, both therapeutic and diagnostic, it is important to recognize that a patient will normally be exposed, even to a level where it may be considered that some element of risk may be involved, in the expectation of some benefit to him. In this situation, as in that of medical exposures to ionizing radiation, informed judgement as to the balance of risk and benefit will need to be made by the physician responsible for the care of the patient" (ref. 38, pp. 221–223).
2.3 Minimum specifications for the general-purpose ultrasound scanner

(1) Transducer
   Standard unit: 3.5 MHz centre frequency.
   Optional unit: 5.0 MHz centre frequency.
   Fixed in-slice focusing on both units desirable but not essential.
   Sector angle 40° (sector scanner) or better.
   Array length: 5–8 cm (linear array scanner).

(2) Controls
   To be simple and clearly arranged.
   Gain control is required.
   Time gain compensation to be by choice of preset and variable conditions.

(3) Frame rate
   5–10 Hz (sector scanner), 15–30 Hz (linear array scanner).

(4) Frame freeze and display
   $512 \times 512 \times 4$ bits (to provide 16 “grey” levels).

(5) Omnidirectional calipers
   One pair to be provided, with facility for quantitative read-out and recording.

(6) Patient identification
   Facilities to be provided for manually entering and recording data—patient identification, date, etc.—on the image screen.

(7) Permanent recording
   Provision must be made for the economical preparation of good-quality permanent image records.

(8) Construction
   The unit should be portable (not more than 8 kg), drip-proof, and dust-proof. Proper and continuous operation should be possible under the following conditions:
   Temperature: $0 \, ^\circ\text{C}$ to $+40 \, ^\circ\text{C}$.
   Humidity: up to 95%.
   Prolonged storage should be possible under the following conditions:
   Temperature: $-30 \, ^\circ\text{C}$ to $+50 \, ^\circ\text{C}$.
   Humidity: up to 100%.
The unit should be rugged and capable of withstanding the vibration likely to occur during rough, cross-country transport. Special care should be taken to avoid failure of the transducer, its cable, and its connector under the above conditions. The mechanical design of the transducer should include:

(a) Maximum protection against damage by dropping;
(b) Tolerance of the use of a variety of coupling media, particularly local vegetable oils.

(9) Electrical and mechanical safety

The equipment should conform to the standards set out by the International Electrotechnical Commission (Medical Electrical Equipment). Where interventional use is intended, particular care must be taken to ensure that the relevant standards of equipment earthing (grounding) and leakage of current are met.

(10) Power supply

The equipment must be capable of working from any of the following types of supply:

Direct current: standard batteries, preferably rechargeable.

Alternating current:
- 50 and 60 Hz
- 100, 110, 117, 125 and 200, 220, 240 V.
- Line voltage variation ± 15%.

Surge protection to be provided.

(11) Servicing and quality control

Although modern equipment should be reliable and stable in performance, both failures and degradation should be anticipated; the following quality control procedures are highly recommended:

(a) At regular intervals (at least every 3 months and preferably every week) the resolution and sensitivity performance of the unit should be checked using a suitable phantom. Corrections should be made if there is any appreciable change in performance over a period of time.

(b) Arrangements should be made (with the manufacturer or otherwise) for a centralized repair and maintenance service to be provided, to cover a number of units in a country or region.

(c) Provision must be made for a supply of spare parts to be rapidly available. These parts must include spares for the transducer, the display monitors, and the principal electronic assemblies.

(12) **Space**

Ultrasound examinations may be made at the bedside, but it is preferable to set aside a room that will provide both privacy (if necessary by curtains) and a suitable horizontal support for the patient. It is helpful if the room illumination can be reduced. A toilet should be provided close to this room. In busy departments the provision of several changing cubicles will increase the number of patient examinations that can be carried out. No added structural protection is required.

**2.4 Specifications for the special-purpose ultrasound scanner**

In addition to the specifications of the general-purpose ultrasound scanner, the special-purpose machines for use in major centres will include the following: combined sector and linear array; Doppler and M-mode for cardiac and vascular studies; and special probes for interventional and intraluminal use.

Similar specifications as regards humidity, dust protection, and mains power supply will be required for the special purpose machines.

**2.5 Operator training**

The usefulness of any ultrasound machine largely depends on the skill and experience of the operator. The following operator requirements represent the minimum, and should be exceeded wherever possible. However, these requirements are not intended to replace any national, federal, or state regulations that may be in force.

A general practitioner should perform a minimum of 200 obstetric and abdominal examinations with a general-purpose machine before he or she can be considered to be able to interpret the studies with any reliability. This requirement will probably
involve at least one month of full-time training by a competent expert.

Many general books are available (19, 20, 22, 26, 28) and these and the study of stored images can be helpful but cannot replace practical experience. It is important that a physician from a small hospital is trained on the same type of ultrasound machine that is available at his or her place of work. To become an expert sonographer at least 6 months of full-time training in a recognized centre is required and additional experience will also be necessary.

Wherever possible, ultrasound examinations should be carried out by trained physicians. However, it is recognized that where highly qualified radiographers or experienced nurses are available, they can, with one year of additional full-time training in ultrasound, be useful as sonographers/ultrasound technicians but should always work under the supervision of an experienced sonologist.

The difficulties in making an accurate diagnosis from ultrasound images are such that the purchase of ultrasound equipment without making provision for the training of an operator is contrary to good health care practice and is unlikely to be cost-effective.

3. COMPUTED TOMOGRAPHY

3.1 Introduction

The use of computed tomography has been a most important advance in the field of imaging techniques and there have been many developments since 1970. For cerebral investigations in particular, which must be carried out with precision, it has replaced techniques that were more difficult and often both painful and dangerous for the patient (e.g., pneumoencephalography). Examination of the rest of the body is equally simple and effective. However, no technique is the best under all conditions and for some abdominal examinations ultrasound is considered to be a more satisfactory non-ionizing alternative to computed tomography. Computed tomography should not be used for obstetric examinations, but it is more effective than ultrasound for chest and spine examinations (the various alternatives and benefits, or disadvantages, are discussed in sections 4.16 and 4.18).

The use of computed tomography means that the appropriate therapy can be chosen more effectively. However, the impact of this
technique on the health care system should be assessed by evaluating how often its use significantly improves patient care. In two university-affiliated hospitals in the United States of America, the use of computed tomography has significantly affected the diagnosis of 36–51% of patients (46, 53, 58) and has resulted in a switch to more appropriate therapy in 15% of the patients examined. The use of computed tomography has also been shown to replace up to 90% of more invasive imaging examinations (45). One study showed that 40% of planned surgical procedures were inappropriate and could be avoided. In the United Kingdom similar studies have shown that there has been a change in patient management in approximately 30% of patients following examination by computed tomography (50, 51).

Unlike ultrasound, computed tomography is a highly complex technique requiring a substantial computer capacity which is not only expensive to supply but needs continuous air-conditioning. To this running cost must be added the costs of well-trained personnel, continuous maintenance, and the frequent repair and replacement of parts. The decision by any hospital to purchase a computed tomography scanner can only be made after taking into account not only the capital expense involved but also the recurrent annual expenditure as well. The benefits must be balanced against the considerable costs involved. In general, most computed tomography scanners will be used to carry out more examinations of the cranium than of the rest of the body. Therefore, adequate neurosurgical support is essential, but good specialist services in other departments are also necessary.

3.2 Planning radiotherapy treatment

The use of computed tomography is an excellent way of planning for radiotherapy treatment because the tumour, normal anatomy, and body contour can be accurately delineated in the cross-sectional planes. This technique has been found to improve the accuracy of treatment plans in approximately one-third of patients when compared with conventional planning (39, 40, 43, 49). However, a recent study by Husband & Jones (personal communication, 1984) has shown that the use of computed tomography for direct radiotherapy planning in the palliative treatment of recurrent carcinoma of the rectum had no influence on patient survival. This suggests that computed tomography-directed planning should only
be applied to those patients undergoing curative radiotherapy (39, 40, 43, 49), but even the value of this in terms of tumour control has yet to be proved (48, 58).

3.3 The radiation dose from the use of computed tomography

The radiation doses associated with the use of computed tomography scanners have been reported by several authors (42, 54, 55). Generally, peak single-slice doses are in the order of 0.01–0.05 Gy (1–5 rad).

The maximum dose obtained from a complete procedure will be somewhat higher than the peak single-slice dose because of the contribution from adjacent slices. If high-resolution techniques are chosen together with overlapping slices, the procedure radiation dose can be as much as 0.25 Gy (25 rad) or higher.

The dose will be distributed more evenly if the examination is performed using a modern system that rotates through 360° compared to a plain film examination. The integral dose from a computed tomography examination is likely to be of the same order of magnitude as is delivered during some high-dose special procedures (e.g., barium studies). Particular caution should be taken when certain radiosensitive organs are included in the scan field (such as eye, thyroid, breast, ovary, and testes).

3.4 Specifications for a computed tomography scanner

The Group made suggestions concerning the technical requirements for computed tomography scanners destined for use throughout the developing world. These data have not been previously published. Some studies to evaluate the performance of computed tomography scanners have been included (41, 42, 44, 52, 56, 57). For computed tomography equipment that is to be used in developing countries the single most important requirement is reliability under the prevailing climatic conditions.

3.4.1 Specifications for a general-purpose computed tomography scanner

(1) Scan time: a range of scan times should be provided, the shortest being 6 s or less.

(2) *Slice thickness:* a range of different slice thicknesses should be provided, the thinnest being *5 mm or less.*

(3) *Reconstruction times:* times up to 40 s are acceptable for standard conditions; however, the use of shorter times will increase the number of patients examined.

(4) *Spatial resolution:* in the order of 5–6 LP/cm (line pairs per cm) at the 50% point of the modular transfer function (MTF) curve, when used in the head mode.

(5) *Tube life:* minimum 25 000 scans per tube.

(6) *Gantry:* a tilting gantry is necessary with angles ranging from +20° to −20°. Aperture size of at least 50 cm in diameter.

(7) *Field of view:* fields of view of 48 cm (or larger) and of 25 cm are the minimum requirements. Additional intermediate fields of view should be offered on an optional basis.

(8) *Upgrading:* it must be possible to adapt the system to changing demands and/or progress in computed tomography imaging, as necessary.

(9) *Documentation:* hard copies produced by a single/multi-format camera should be the regular form of documentation. Magnetic tapes or floppy discs are not considered to be essential for this type of unit.

(10) *Software:* the operation of the machine should be easy to learn and no special computer knowledge should be required. The user should be guided with a simple dialogue (text in clear), interacting with simple YES or NO answers or menu-technique. Certain operations should be implemented as push-button functions. Essential features of the software should include: density measurements in absolute units (Hounsfield units); region of interest; distance/area determination; zoom/magnification.

A desirable feature of the software (optional) would be automated quality control using a specially designed phantom.

(11) *Patient protocols:* there should be the capacity for a number of patient protocols including different scanning times, slice thickness, and other parameters and including differential
algorithms for reconstruction for studying brain, abdomen (two protocols), and extremities.

3.4.2 Advanced computed tomography scanners

Advanced scanners offer shorter scanning times, better spatial and contrast resolution, and a wider range of software programs. They are particularly well suited for investigations of the pituitary gland, orbits, middle ear, and spine, as well as all examinations that can be performed on the general purpose scanner.

Specifications for such advanced systems are as follows:

(1) Scan time: a range of scanning times—the shortest being 1.5 s or less.

(2) Slice thickness: a range of slice thicknesses—the thinnest being 1.5 mm or less.

(3) Reconstruction time: should not exceed 20 s when using minimum matrix size (256 × 256 bits or larger), and a slice thickness of 8–10 mm (standard scan). May be longer in special programs.

(4) Options:
   (a) Dynamic scanning is preferable in advanced computed tomography systems.
   (b) Stand-alone consoles are not considered essential for patient care, but are useful for teaching and research purposes.
   (c) Cardiac gating is not generally required, unless the local situation (large cardiac centre) calls for special computed tomography studies of the heart.
   (d) Dual kV-energy seems, at the present time, to be mainly of interest to research centres examining bone density.
   (e) Histograms and other post-processing programs seem to be of limited value in daily clinical practice.
   (f) Scanogram, topogram, scanview, etc., are highly recommended for advanced systems. They are mandatory if examinations of the spine are to be performed regularly.
   (g) Treatment planning systems ("on line" or "off line") are valuable if the scanner is commonly used for radiation therapy. "Off line" capacity may be sufficient for many radiotherapy requirements.
(h) Documentation using film hard copy or a system of similar quality is mandatory. While magnetic tape is generally accepted as an economic way of storing data, it may deteriorate under certain climatic conditions (hot and humid) unless kept in an air-conditioned and humidity-controlled room. Thus, floppy discs may be preferable.

3.4.3 Further requirements for computed tomography equipment

(1) Safety: the system must conform to internationally accepted standards of radiation and electrical safety for patients and personnel, as required by the present International Commission on Radiological Protection recommendations and International Electrotechnical Commission standards, and future updates.

(2) New versus used machines: the following considerations must be taken into account if the purchase of a used computed tomography machine is contemplated:

—all used equipment should meet at least the specifications of a general-purpose scanner;
—replacement parts may not be available;
—service may not be guaranteed;
—quality may not be satisfactory;
—down time may be longer than for a new system;
—upgrading may not be possible.

Reconditioned, remanufactured computed tomography units could be considered if the above limitations are acceptable, but they are not usually a good investment.

(3) Service: it should be clearly understood that any piece of computed tomography equipment will require regular service including both preventive maintenance and on-call repair services. Considerable recurrent expenditure is to be anticipated for preventive maintenance, repair, and spare parts (e.g., in a busy department X-ray tubes need to be replaced almost every six months).

(a) Spare parts: the availability of service and spare parts should be negotiated before buying a computed tomography unit.

(b) Service engineers: in-house training of local service engineers is highly recommended.
(c) Quality control: should be in accordance with the WHO publication *Quality assurance in diagnostic radiology*, published in 1982. Automated quality control using a specially designed phantom capable of measuring parameters specified in that publication would be desirable.

(4) **Environmental requirements**

(a) *Room size.* An area of approximately 70–100 m² is required for the scanning room (air-conditioned), operator's console (air-conditioned), computer room (air-conditioned), and a room for the heavy equipment (generator, voltage and frequency stabilizer, etc.)

A waiting area of adequate size for hospital patients as well as outpatients must be provided. A preparation room might be useful in certain clinical settings. A toilet should be available nearby.

(b) *Power supply.* The supplier should indicate the exact requirements (see also section 3.4.7).

(5) **Mobile units:** Mobile units are not at present recommended for use in developing countries.

3.4.4 **Requirements in the radiology department**

Because of the complex nature of computed tomography imaging and the need to integrate all imaging procedures, the best results will be achieved if the scanning is supervised by a radiologist. The scanner will usually be installed in a department with the following facilities:

—approximately 50 000 radiological examinations yearly;
—conventional radiography including conventional tomography;
—angiography;
—myelography;
—ultrasonography should be available, preferably in the radiological department;
—radiologist and radiographers with special training (see section 3.4.6).

3.4.5 **Requirements in the hospital**

Before acquiring a computed tomography scanner, any hospital should provide the following:
—about 500 beds;
—general surgery;
—neurosurgical service;
—active emergency service, including traumatology.

In addition it might also provide:

—specialized surgery (thoracic, vascular, orthopaedics, urology, etc.);
—neurology;
—comprehensive cancer therapy (preferably including radiotherapy).

Large specialized hospitals, e.g., cancer hospitals that do not cover different aspects of medical treatment, may qualify for scanners because of special needs.

3.4.6 Training and education

(1) Radiologist. He or she should have completed training as a qualified radiologist, with at least six months’ full-time training in computed tomography, preferably at a training centre in a similar geographical area.

The radiologist should provide continuing education to the hospital medical staff concerning:

—indications/rational approach for computed tomography investigations;
—economics of scanning;
—hazards of scanning investigations.

(2) Radiographer. A qualified radiographer who has received on-the-job training should be available.

(3) Physicists. If there are physicists already in the hospital it would be preferable if they were responsible for supervising certain tasks in the computed tomography unit, such as quality control and dose measurements.

(4) Service engineer. The service engineer must receive on-the-job training by the manufacturer.

(5) Training by manufacturer. Arrangements should be made with the manufacturer of the equipment to train both a physician and radiographer/technician at a centre where similar equipment is installed. This arrangement should be part of the purchase contract.
3.4.7 Essential pre-installation requirements

If the following conditions cannot be met then the feasibility of installing a computed tomography unit should be reconsidered.

(a) There should be a stable electrical supply with the correct type of cables forming the connection with the electrical sub-station to avoid a voltage drop. The supplier should indicate the cables necessary.

(b) Voltage stabilizers should be provided to compensate for any variation.

(c) Surge depressors should be provided to take care of momentary surges in power.

(d) There should be an uninterrupted power supply (by generator) to the air-conditioner.

(e) A line-frequency stabilizer should be provided.

(f) A continuous water supply should be available if the X-ray tube is of the “water-cooled” variety.

(g) Air-conditioning should be provided in the scanner room, machine room, computer room, and record room. The desirable environmental temperature is 18–24°C. Changes in temperature should not exceed 2°C per hour. The air-conditioning system should be fitted with filters capable of removing particles as small as 5 μ.

(h) A relative humidity of between 40 and 60% is essential at the temperatures given above and should be provided by the air-conditioning system or by separate de-humidifiers.

(i) Air-conditioning systems should be duplicated, so that the machine is not damaged if one system fails.

(j) All systems should operate for 24 hours each day, throughout the year.

(k) Prior arrangements need to be made with the currency exchange control and customs authorities to ensure that essential spare parts will be allowed to enter the country without unnecessary delay.

4. CLINICAL INDICATIONS

4.1 Introduction

The pattern of clinical use of ultrasound and computed tomography has now become firmly established. There are of course
many areas in which the two techniques overlap to give the same information with approximately similar accuracy. When ultrasound is available and there are no disadvantages associated with its use it will be the method of choice in most cases because non-ionizing radiation is involved and the costs are low.\(^1\) However, there will be occasions, in individual patients, when the use of computed tomography will provide more accurate information permitting the selection of more appropriate therapy. The imaging technique selected will depend on the opinion of the referring physician and his or her colleague responsible for the imaging process.

A brief summary of clinical indications for both techniques is outlined in Table 1, but this is, of necessity, incomplete and in many areas subject to change as experience increases and the equipment is improved. Nor has it been possible to cover every eventuality, particularly since experience in developing countries is still limited. Local skills, economic considerations, and the pattern of local disease will have a very significant influence on the clinical decisions to be made.

4.2 Obstetrics and gynaecology

Ultrasound should be the first choice for the imaging of pregnant women and the major use of ultrasound in most parts of the world will be for obstetric examinations. It must be emphasized, however, that the use of imaging techniques is not a substitute for comprehensive anamnestic and clinical investigations of pregnant women, such as the measurement of uterine height (93). Ultrasound provides a direct, easy, and (so far as is known) safe way of imaging the fetus, for both serial observation and measurement. It is used for a wide variety of clinical investigations and there is substantial evidence in the literature to demonstrate its advantages (75, 77, 84).

\(^1\) The simplicity, the relatively low cost, and the apparent lack of hazards of ultrasound investigations have led to their overuse in the examination of pregnant women in industrialized countries. This overuse has had important consequences not only because of the escalating costs that have resulted from unnecessary diagnostic investigations, but also because it may lead to therapeutic measures that are not always justified.

N.B. Dr J. Wittenberg, member of the Scientific Group, expressed disagreement with the content of this footnote. Professor C.R. Hill, who represented the World Federation of Ultrasound in Medicine and Biology, and the International Organization for Medical Physics, also disagreed with the footnote.
<table>
<thead>
<tr>
<th>Ultrasound</th>
<th>Computed tomography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small anatomical field</td>
<td>Large anatomical field</td>
</tr>
<tr>
<td>Dynamic images</td>
<td>Static images (except with special program)</td>
</tr>
<tr>
<td>Parenchymal analysis</td>
<td>Contour, vascular, and parenchymal analysis, often enhanced by contrast media</td>
</tr>
<tr>
<td>Measures tissue echogenicity</td>
<td>Measures tissue density</td>
</tr>
<tr>
<td>Mobile – done at bedside</td>
<td>Patient must go to scanner</td>
</tr>
<tr>
<td>Usually short duration</td>
<td>Usually lengthy</td>
</tr>
<tr>
<td>Non-ionizing radiation</td>
<td>Ionizing radiation</td>
</tr>
<tr>
<td>Operator dependent</td>
<td>Operator independent</td>
</tr>
<tr>
<td>Variable image plane</td>
<td>Limited image planes (additional planes provided by reformating)</td>
</tr>
<tr>
<td>Bone or gas causes total obstruction</td>
<td>Bone well visualized; gas no problem</td>
</tr>
<tr>
<td>Main indications</td>
<td>Intravenous or organ specific contrast medium needed for the majority of examinations</td>
</tr>
<tr>
<td>Obstetrics (and fetal therapy)</td>
<td>Brain studies</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Total body</td>
</tr>
<tr>
<td>Neonates (brain, heart, abdomen, hips)</td>
<td>Not obstetrics</td>
</tr>
<tr>
<td>Cardiac (special unit)</td>
<td>Special programs</td>
</tr>
<tr>
<td>Examination of soft tissues such as thyroid, but limited use in lung and head</td>
<td>(1) Dynamic scanning</td>
</tr>
<tr>
<td>Some thoracic collections</td>
<td>(2) Gated cardiac computed tomography</td>
</tr>
<tr>
<td>Special attachments needed for vascular, ophthalmological, and breast examinations</td>
<td></td>
</tr>
</tbody>
</table>

A recent randomized study demonstrated that, when carried out by experienced personnel, the use of ultrasound does not reduce hospital resources but does produce a decrease in the perinatal death rate and morbidity (68). However, there are conflicting results from other trials which failed to find any improvement in perinatal morbidity and mortality (60, 62). Recent publications from developing countries support the view that the use of ultrasound is valuable in obstetrics (59, 72, 77, 81). There is, however, a need for randomized controlled trials to determine the efficacy of routine ultrasound screening in pregnancy, and these trials may, at the same time, remove any doubts about the safety of ultrasound.

Ultrasound should be performed only for specific medical indications (83), which include the following:

(1) Estimation and verification of gestational age (65, 77, 85, 86, 88):
(a) confirmation of uncertain clinical dates;
(b) scheduling of elective Caesarian section or induction of labour;
(c) decisions concerning other means of elective termination of pregnancy.

(2) Evaluation of fetal growth (63, 64, 71, 87, 89)—in order to assess the impact of any complicating condition on the development of the fetus (see also 61):

(a) placental insufficiency;
(b) pre-eclampsia;
(c) chronic hypertension;
(d) chronic renal disease;
(e) diabetes mellitus;
(f) fetal malnutrition (intrauterine growth retardation; macrosomia).

(3) Vaginal bleeding of uncertain etiology in pregnancy (73, 74). Ultrasound can often be used to determine the source of the bleeding and the status of the fetus.

(4) Multiple gestation (78, 86) (more than one fetal heartbeat, discrepancy in fundal height for dates, prior use of fertility drugs).

(5) Suspected fetal death (77).

(6) Suspected uterine abnormality (77) (myomata, bicornuate or didelphic uterus).

(7) Localization of intrauterine contraceptive device (facilitates removal, reduces complications) (66).

(8) Discrepancy between uterine size and clinical dates (77, 79) (oligohydramnios, polyhydramnios, multiple gestation, intrauterine growth retardation, other anomalies).

(9) Pelvic mass (67, 82, 93). Ultrasound can be used to detect the location and the nature of the mass and assist in the diagnosis.

(10) Suspected hydatidiform mole (77, 87). Ultrasound can be used to diagnose and differentiate this neoplasm from a dead fetus when other clinical signs are present such as hypertension, proteinuria, or ovarian cysts, and when there is no fetal heartbeat after 12 weeks.

In specialized obstetrical departments there will be a need for ultrasound equipment with extra attachments which can be used by trained personnel to assist in the following interventions:
(1) Amniocentesis \((80, 90)\) and chorionic villi sampling. Ultrasound can be used in guiding the needle to avoid the placenta and the fetus, thus increasing the chance of obtaining amniotic fluid and decreasing the chance of fetal loss.

(2) Cervical cerclage placement \((81)\). Ultrasound can be used to assist in the timing and proper placement of the cerclage in patients with an incompetent cervix.

(3) Diagnosis of ectopic pregnancy \((77)\). Ultrasound can be useful as a diagnostic aid when pregnancy occurs after tuboplasty or prior ectopic gestation.

(4) Fetoscopy \((77)\).

(5) Intrauterine transfusion \((77)\).

(6) Shunt placement in utero \((77)\).

(7) Biophysical evaluation of the fetus after 28 weeks’ gestation \((91, 92)\) (amniotic fluid, fetal tone, body movements, breathing movements, heart-rate pattern). Ultrasound can be used to guide the instruments used for these investigations and therefore increases the safety of these procedures \((62–65)\).

(8) Observation of pre- and intrapartum events \((77)\) (version, extraction of second twin, manual removal of placenta).

(9) Fetal and uterine blood-flow measurements \((70, 80, 92)\).

(10) Abruptio placenta \((77)\). Confirmation of diagnosis and observation of the extent assists in clinical management.

(11) Estimation of fetal weight \((76)\). Information provided by ultrasound guides management decisions on timing and method of delivery.

(12) Gestational age and elevated level of abnormal serum alpha-fetoprotein \((79)\). The use of ultrasound can provide an accurate assessment of gestational age for the alpha-fetoprotein standard and can indicate several conditions, e.g., twins, anencephaly, that may cause elevated alpha-fetoprotein values.

(13) Serial observation of:

(a) fetus \((79)\);

(b) placenta \((91)\);

(c) fetal growth in multiple gestation \((86)\).

(14) Fetal abnormality \((79)\). Where there is a history of previous congenital anomaly, ultrasound may be used to detect any recurrence of that anomaly. Reassurance that there is no recurrence may be psychologically important to the patient.
Specialized gynaecological uses of ultrasound will include:

1. *In vitro* fertilization and embryo transfer (69).
2. Ovarian follicle development surveillance (69, 77).

### 4.3 Liver

Ultrasound and computed tomography are both excellent techniques for the recognition of abnormal masses in the liver and they are more accurate than either conventional radiology or radionuclide scanning (107, 116). Both techniques can be reliably used to detect metastases or primary hepatic tumours (94–97, 100, 101, 118, 119), but computed tomography is the technique of choice for the preoperative staging of hepatocellular carcinoma because the borders and extension of the tumour can be more accurately defined (109, 112). However, because cysts and abscesses invariably contain fluid, ultrasound can be satisfactorily used for the initial examination, permitting percutaneous aspiration both for diagnosis and therapy, where necessary (103, 106, 110, 113, 115, 117).

Neither technique is very useful for the recognition of early cirrhosis (102, 111). Ultrasound can be used to demonstrate functional and anatomical changes in the portal system (114), and the use of computed tomography can reveal diffuse or focal fatty and haemosiderotic infiltration as well as the later stages of cirrhosis (104, 105, 108).

Both techniques (98, 99, 120) are useful in cases of trauma of the liver during the processes of diagnosis, treatment-planning, and follow-up.

### 4.4 Gall-bladder

If a trained physician and a high-resolution ultrasound scanner are available, then the use of ultrasound can replace oral and intravenous cholecystography (130, 136, 137, 142) for the diagnosis of gall-bladder calculi (127, 128, 133), thickening of the gall-bladder wall (129, 132, 141), and acute cholecystitis (123, 135–137, 142).

However, the detection of stones in the bile duct using ultrasound is not as accurate as in the gall-bladder (128, 131, 138). Such stones may be detected using computed tomography which is also more accurate in the preoperative staging of gall-bladder carcinoma (121, 134, 139, 140).
4.4.1 Jaundice

In about 30% of jaundiced patients it is not possible to distinguish between obstructive and non-obstructive jaundice by means of clinical or laboratory tests. In many parts of the world one of the common causes of jaundice, particularly in children, is the presence of a roundworm (*Ascaris lumbricoides*) in the biliary tract (125, 126). The use of ultrasound (121, 122, 124, 144) (or computed tomography) can provide useful information by revealing the state of the intrahepatic biliary ducts in jaundiced patients (143).

\[
\text{Accuracy rate for ultrasound}
\]

<table>
<thead>
<tr>
<th>Feature</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilated or non-dilated</td>
<td>90%</td>
</tr>
<tr>
<td>Level of obstruction</td>
<td>70%</td>
</tr>
<tr>
<td>Etiology (including calculi)</td>
<td>30%–50%</td>
</tr>
</tbody>
</table>

In some cases the use of computed tomography will provide additional information on the etiology and level of the obstruction. If the results of these non-invasive procedures remain inconclusive then the use of percutaneous transhepatic cholangiography and endoscopic retrograde cholangiopancreatography should be considered (see also section 4.5).

4.5 Pancreas

Provided that very careful and detailed scanning techniques are used the anatomy of the pancreas can be demonstrated using ultrasound in more than 90% of patients, the tail of the pancreas being the most difficult part of the organ to visualize. In obese patients, those with thick abdominal muscles, or when the stomach and bowel are distended with gas, the use of computed tomography will be more reliable.

In mild pancreatitis ultrasound is the imaging method of choice for the initial examination and can detect focal parenchymal changes, which may, if necessary, be sequentially evaluated (146, 147, 149). In more complicated pancreatitis where there is necrosis or abscess formation, the use of computed tomography provides the surgeon with more information regarding any spread of infection into the retroperitoneum or other areas (145, 148, 151, 157).

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Calcification in chronic pancreatitis can be accurately demonstrated using computed tomography; ductal visualization is better with ultrasound (154, 159, 160). However, for the preoperative evaluation of the pancreatic duct, endoscopic retrograde cholangio-pancreatography remains the method of choice (156).

Pancreatic cysts and pseudocysts can usually be assessed by the use of ultrasound (or computed tomography) (153, 159, 161), but in emaciated patients and in children the lack of intervening fatty tissue makes ultrasound the preferred technique.

Pancreatic carcinoma can be accurately recognized in approximately 75% of patients using either technique (150, 152, 155). Surgically curable endocrine tumours are usually small and multiple and may be easily missed during ultrasound scanning and occasionally during contrast-enhanced computed tomography scanning (158). These tumours are highly vascular and selective angiography is currently the method of choice for their detection. The use of ultrasound during an operation offers promise for the future.

4.6 Spleen

Both ultrasound and computed tomography scanning can be used to detect focal abnormalities in the spleen, such as cysts, abscesses, and tumours (163, 167–172). However, when splenomegaly is present the findings are non-specific.

In cases of spleen trauma, ultrasound can be used to detect quickly and easily subcapsular or parenchymal haematomas and associated haemoperitoneum (162, 164, 166, 173). However, in patients with multiple injuries the use of computed tomography may be preferable because it can detect bony injuries and further soft tissue damage (165).

4.7 Kidney

The use of ultrasound plays a major role in imaging the kidney (181, 186, 192, 196, 199, 207), but for some renal diseases computed tomography may provide important additional information. In the majority of patients the findings from both techniques may need to be correlated with an intravenous urogram. The use of ultrasonography compares favourably with the use of intravenous urography and cystoscopy for the detection of abnormalities of the
urinary tract caused by *Schistosoma haematobium* infection of the kidney and bladder (174, 182a).

4.7.1 **Hydronephrosis**

This condition can be detected using ultrasound at a very early stage and the renal tissue can be assessed (177, 183, 187, 188, 203). The cause of hydronephrosis may be recognized in some patients, e.g., calculus, diseased lymph nodes, or pelvic tumour. The diagnosis of hydronephrosis is independent of renal function (e.g., when there is anuria ultrasound can be used to replace i.v. urography). The use of computed tomography can provide the same information, sometimes with better anatomical detail.

4.7.2 **Calculi**

Calculi of any composition can be detected using ultrasound provided that they are larger than 5 mm in diameter (178, 182, 196). The presence of ureteric stones is not so easy to verify unless they are located in a dilated upper ureter or close to the bladder. By using computed tomography it is possible to detect smaller stones.

4.7.3 **Chronic pyelonephritis**

Neither technique is employed routinely to diagnose chronic pyelonephritis, but both methods can be used to detect non-specific pathological changes in the renal parenchyma (189, 201).

4.7.4 **Renal masses**

Both techniques can be used to demonstrate renal masses and in many cases will distinguish between cysts and tumours (180, 198). The computed tomography technique can show tumour invasion of perinephric fat and muscle and is therefore useful for staging renal carcinoma (see section 4.2.0) (175, 191, 193, 202, 208).

When the mass is of indeterminate nature, computed tomography is a more useful technique than ultrasound because additional information can be obtained from densitometry (e.g., angiomylipoma) (175, 190, 202, 204). Urothelial (e.g., transitional cell) tumours smaller than 5–7 mm in diameter cannot be reliably detected with either technique and intravenous urography is essential (180, 186, 192, 194, 199, 207).
4.7.5 Renal trauma

About 75–85% of cases of renal trauma are relatively minor and can be adequately evaluated by a combination of clinical examination, laboratory studies, ultrasonography, and excretory urography. The use of computed tomography will more accurately distinguish minor from major trauma by defining the extent of parenchymal injury and perirenal haemorrhage (184, 197, 200).

Sequelae following renal trauma (parenchymal fractures, haematomas, hydronephrosis, etc.) can be well visualized using both techniques and may be followed sequentially (195, 205, 206). However, contrast-enhanced computed tomography (or an intravenous urogram) will provide an additional assessment of function.

4.7.6 Renal transplant

The use of ultrasound is of considerable assistance in follow-up examinations of the transplanted kidney (176, 179, 185).

4.8 Adrenal

For the diagnosis of primary or metastatic adrenal tumours (209, 210, 212, 213), computed tomography is the more accurate of the two techniques although a carefully executed ultrasound examination is a useful alternative (211, 214, 215) provided that the imager is aware that a normal or hyperplastic adrenal may not be visualized.

4.9 Urinary bladder and prostate

The use of ultrasound can readily demonstrate residual urine in the bladder. While either technique can be used to demonstrate all types of bladder stone. Ureteroceles, bladder diverticula, and tumours may also be recognized (216, 218). The use of intravesical ultrasound scanning provides the most information. Prostatic size can be estimated and advanced cancer may be diagnosed using ultrasound. If intraluminal probes are available transrectal scanning reveals prostatic size and permits the evaluation of the prostatic parenchyma and capsule.

Computed tomography has a limited role to play in assessing the size of the prostate and is generally reserved for staging advanced malignant disease (217, 219).
4.10 Scrotum

Ultrasonic scanning of the scrotum is especially useful to differentiate between testicular and extra-testicular pathology and to detect small testicular cancers (220, 221). Computed tomography has no role to play in the scanning of the scrotum.

4.11 Pelvis

Suspected or palpable masses in the pelvis are best investigated using ultrasound scanning. Computed tomography may be a useful additional technique if the results of ultrasound and conventional studies are inconclusive (see section 4.20.1) (227).

Computed tomography scanning of the pelvis can identify injuries to bony and ligamentous structures, the joints, and soft tissues. The axial demonstration of acetabular fractures facilitates the planning of surgical treatment (222–226).

4.12 Retroperitoneum

The presence of tumours, abscesses, and haematomas can be demonstrated using either computed tomography or ultrasound scanning (although intestinal gas may interfere with ultrasound in some patients) (177, 228–233, 235, 236). If lymphadenopathy is suspected but not detected, lymphography is indicated (see section 4.20.1). For retroperitoneal haemorrhage the use of contrast-enhanced computed tomography scanning to obtain density measurements (234, 237) improves the specificity of the scanning.

4.13 Intra-abdominal abscesses

The use of both techniques can reveal perihepatic (including subdiaphragmatic), perisplenic, and pericolic abscesses with equal accuracy. However, elsewhere in the abdomen and pelvis computed tomography scanning is preferable because unlike ultrasound the accuracy of the technique is not impaired by gas or fluid in the bowel (241, 246).

By using computed tomography more than 90% of abscesses may be detected (244, 246, 247). It can also be used to define the exact position of an abscess, permitting its safe percutaneous drainage (241–243). However, if computed tomography is not available then ultrasound is an excellent substitute (see section 4.19).
Abnormal collections of abdominal fluid can also be recognized successfully using either technique (239), and aspirated for cytological and bacteriological information (245). Collections of blood may be more accurately identified using computed tomography scanning (240).

4.13.1 Abdominal cavity

The technique of computed tomography is accurate and cost-effective when used for the initial examination of patients with abdominal masses (238). When these masses are palpable, the use of ultrasound may be equally accurate (252). However, when the masses are less than 5 cm in diameter computed tomography should be used (251).

4.13.2 Gastrointestinal tract

Contrast fluoroscopy and/or endoscopy remain the best techniques for detecting abnormalities in the gastrointestinal tract. The use of ultrasound is not recommended although tumours can be recognized and biopsied using this technique when appropriate (248). The most common use of computed tomography in the gastrointestinal tract is for the staging of previously diagnosed malignancy and for the detection of recurrence, particularly in patients with carcinoma of the rectum (240, 245, 250–253).

Neither technique has a role to play in cases of gastrointestinal inflammatory disease except for the detection of complicating intra-abdominal abscesses (238, 239, 249).

4.14 Cerebral: skull and brain

4.14.1 Intracranial tumour

There is no doubt that computed tomography scanning is the technique of choice for the investigation of intracranial tumours (255). In a cooperative study by five university centres, sponsored by the National Cancer Institute in the USA, the usefulness of computed tomography compared with conventional skull radiography, radionuclide brain scanning, and neuroangiography was assessed (255). A total of 2928 patients were investigated, 1071 of whom were found to have intracranial tumours. The study
showed that the use of contrast-enhanced computed tomography can reveal up to 98% of all intracranial neoplasms and can specifically identify approximately 90%. However, without contrast enhancement the usefulness of computed tomography is limited. For primary tumours, angiography has an accuracy similar to that of contrast enhanced computed tomography, but there are obvious disadvantages associated with the use of this technique since it is hazardous and requires expert neuroradiological skills (255). Radionuclide scanning is a much less accurate technique and should seldom be required (258, 262). The conventional skull radiograph is also of little use (269). In general, neurologists and neurosurgeons rely heavily on the information provided by computed tomography scanning and there has been a marked reduction in the use of arteriography, pneumoencephalography, and radionuclide brain scanning (7, 267).

The introduction of computed tomography scanning has been shown to be cost-effective, reducing the total cost for the diagnosis of intracranial tumours by 25% (6).

Computed tomography is also the best technique for use in patients with suspected metastases in the brain (269). A specific identification of metastases can be made in a high proportion of patients.

The main drawback of the computed tomography technique is that benign granulomas may be indistinguishable from metastases, and in countries where granulomatous disease is prevalent caution must be exercised when interpreting the scans (257, 263, 268, 271).

4.14.2 Cerebral trauma

Computed tomography is generally accepted as being the method of choice for investigating non-penetrating injuries of the head.

No other method is as safe, quick, or accurate (260, 266, 270). The use of computed tomography scanning usually means that the need to use other radiological examinations such as conventional skull radiography and cerebral arteriography is significantly reduced (254, 272).

4.14.3 Cerebrovascular diseases

Computed tomography scanning can be used to demonstrate acute and chronic intracranial haemorrhage and other fluid
collections, as well as the sequelae of obliterate cerebrovascular disease. The indications for its use depend upon the clinical findings and the therapeutic implications. However, in a study by Larson et al. (264), the additional use of computed tomography resulted in little obvious improvement in the care of patients with cerebrovascular disease, but it did increase the cost of their care.

4.14.4 Cerebral inflammation and infection

The use of cranial computed tomography also plays an important role in the evaluation of focal intracranial inflammatory disease including abscesses, parasitic infections, and granulomas (259, 268). It is useful in monitoring therapy and sequelae.

4.14.5 Cerebral atrophy

Computed tomography is the method of choice for the evaluation of cerebral atrophy and determination of the size of the ventricular system.

4.14.6 Headache

If patients present with headache as the sole neurological symptom, the use of computed tomography can contribute little to the diagnosis. A careful clinical history and physical and neurological examinations have been found to be adequate in detecting intracranial mass lesions or systemic diseases associated with headache (256, 265).

4.14.7 Paediatric brain

Ultrasound scanning is extremely useful in the diagnosis and management of hydrocephalus and intracranial haemorrhage in young children as long as the cranial sutures remain sufficiently wide (261). Hydrocephalus and intraventricular haemorrhage can be diagnosed in utero using ultrasound scanning.

4.15 Face, head, neck, and soft tissues

4.15.1 Face and neck

Ultrasound can be used to examine the neonatal skull, the thyroid, parathyroid, salivary glands, and lymph nodes, but
otherwise it is of limited use in the head and neck region (281). The use of computed tomography provides excellent detail for evaluating lesions of the base of the skull and of the paranasal sinuses, pharynx, and larynx (273, 278, 289).

(1) Face. Computed tomography has proved to be very valuable in the diagnosis of maxillo-facial fractures (274, 275, 279, 283, 290); it is rarely used for the primary diagnosis of head and neck tumours.

(2) Orbit. Tumours and other masses arising in the orbit can be directly visualized using computed tomography scanning, which is also useful in cases of orbital trauma (277, 288).

(3) Eyes. Special ultrasound equipment is extremely useful in the diagnosis and monitoring of intraocular lesions including tumours, foreign bodies, and detachment of the retina.

(4) Thyroid gland. Ultrasound scanning can be used to differentiate between solid and cystic masses, but does not provide a definitive diagnosis. Computed tomography is seldom used to investigate the thyroid gland.

(5) Parathyroid. Neither technique can be used to visualize a normal parathyroid gland; if the gland can be detected using these techniques then it is probably abnormal; while often successful, false positives and negatives may occur (285, 286).

(6) Salivary glands. Ultrasound scanning can be used to demonstrate the salivary glands (for needling where appropriate). Computed tomography is useful for the staging of parotid tumours, especially those involving the deep-seated lobe of the gland.

4.15.2 Soft tissues

(1) Breast. Mammography remains the method of choice for the detection of breast cancer, although it does involve the use of ionizing radiation. Ultrasound, with special equipment and training, can be used to demonstrate cysts; however, this is not yet a routine examination for other lesions (284). The use of ultrasound may be helpful after negative mammography in the young, dense breast.

(2) Soft tissues. In patients with diagnosed tumours, computed tomography can be used to determine the size and extent of the tumour and its relationship to adjacent structures, e.g., nerves and vessels, and can thus be used to assess the operability of the tumour (50). However, neither technique can be used to distinguish a neoplasia from a benign lesion such as an inflammation or a
haematoma. Computed tomography can be used to demonstrate tumours that arise from fatty tissues (280).

(3) Peripheral musculoskeletal system. There are special indications for the use of computed tomography in the peripheral musculoskeletal system, particularly in the knee joint (276, 282, 287). However, the technique has virtually no place in the primary diagnosis of fractures and tumours in these areas (for tumour staging see section 4.20).

4.16 Thorax

Ultrasound scanning has little part to play in the imaging of the lungs; it can be useful in locating (and needling) pleural fluid and can help to locate caudal mediastinal fluid collections and cysts.

The use of computed tomography scanning of the thorax can provide much useful information and may occasionally demonstrate pathological signs that have not been recognized on conventional chest radiographs. Nevertheless, the first and most important method of imaging the chest remains conventional radiography.

4.16.1 Lung cancer

Computed tomography scanning is of limited use as the primary method of detecting lung cancer, and its use is controversial in differentiating the etiology of solitary pulmonary lesions. It has an important use in showing direct extension of the lesion to the mediastinum and spread to the chest wall (292, 294–296). Its use in staging lung cancer is not yet clear. The detection of mediastinal lymphadenopathy based on nodal size alone, as shown by computed tomography, is not accurate enough to verify the presence or absence of metastasis (see section 4.20.1).

4.16.2 Pulmonary metastases

Computed tomography is the most sensitive technique at present available for diagnosing pulmonary metastases, being significantly more accurate than conventional films and whole-lung tomography (298). Its main drawback is that benign granulomas may be indistinguishable from metastases; this limitation may lessen its usefulness in many developing countries.
4.16.3 *Mediastinal mass*

There is general agreement that computed tomography is the method of choice for evaluating patients with mediastinal abnormalities that have been detected by conventional chest radiography. Contrast-enhanced computed tomography can differentiate vascular from avascular causes of mediastinal widening and provide a specific and conclusive diagnosis, e.g., lipoma or cyst, in many patients (291, 293, 297). Lymphadenopathy remains a problem because computed tomography cannot be used to differentiate between benign hyperplasia and malignancy.

4.16.4 *Pulmonary inflammation*

Computed tomography is not very useful for evaluating acute or chronic inflammatory lesions of the lung. It may be helpful when an abscess or necrosis develops, particularly when a hepatic abscess spreads through the diaphragm.

4.16.5 *Pleura*

Computed tomography can be used to detect small pleural effusions. Ultrasound can also be useful for the localization and aspiration of these effusions. Although the use of computed tomography can demonstrate the extent and spread of mesothelioma and other pleural malignancies, it has little effect on the management or outcome of these conditions. Both techniques can be effectively used for the drainage of empyemas (299).

4.16.6 *Diaphragm*

Ultrasound scanning can be used to assess diaphragmatic movement. Both techniques are accurate in the diagnosis of subphrenic abscess.

4.17 *Heart and great vessels*

Ultrasound echocardiography is of the greatest value in demonstrating valvular lesions, bacterial valvular diseases, myocardial disease, myocardial tumours, and septal pathology.

In pericardial disease, the use of ultrasound will accurately demonstrate pericardial effusion, pericardial thickening, or tumours.
The use of computed tomography can provide further information (309), including the nature of the fluid and the extent of pericardial constriction.

Computed tomography can directly demonstrate the myocardium and individual cardiac chambers, but this method is of secondary importance compared with ultrasound, scintigraphy, and angiocardiography (305).

Dissecting aneurysm of the aorta, trauma to the aorta or major vessels, and aortic graft status can be assessed by computed tomography at least as accurately as by aortography (303, 304, 307, 310).

The carotid arteries can be accurately assessed using Doppler ultrasound, thus providing an evaluation of blood flow (velocity, volume, turbulence) (300–302).

The abdominal aorta and branches, the inferior vena cava with major branches, and the portal system can be readily observed using either computed tomography or ultrasound. Ultrasound has the advantages over computed tomography of flexibility in the selection of scan-planes, providing a dynamic image, and contrast media are not needed. The use of abdominal Doppler ultrasonography gives poor results except in the portal vein and vena cava (301, 311), where indications for its use are few.

Abdominal aortic aneurysms can be readily diagnosed and measured using either method (306), although haemorrhages surrounding the aorta and the renal arteries are better defined using computed tomography (308). Angiography may be necessary before surgery.

4.18 Spine

4.18.1 Trauma

Computed tomography is not suitable for use in the search for spinal fractures or other injuries even if digital imaging and reformating are available. However, when spinal injury has been previously demonstrated by conventional radiography or its suspected location established by clinical examination, then computed tomography can be used to confirm the diagnosis and to plan conservative or surgical treatment (313–316). Displaced bone fragments, damaged discs, fresh blood, or foreign bodies can also be located using this technique.
4.18.2 Intervertebral disc damage

The use of computed tomography provides a non-invasive method of evaluating herniated discs and lumbar stenosis (319). There may be some difficulty in the post-surgical patient in whom fibrosis has replaced epidural fat. Computed tomography can be combined with contrast myelography, but water-soluble agents must be used.

4.18.3 Spinal infection

The use of computed tomography has proved valuable in recognizing early spinal infection and demonstrating the extent of any paravertebral or intrathecal abscess.

4.18.4 Infant spine

Ultrasound can be used to examine congenital anomalies of the infant spine, particularly those involving the neural tube (312, 317, 318).

4.18.5 Tumours

Both primary and secondary tumours of the spine are usually first detected by conventional radiology or radionuclide scanning. The use of computed tomography combined with myelography can provide additional useful information.

4.19 Interventional procedures

The ability to place needles and catheters precisely and percutaneously in predetermined parts of the body using imaging techniques has numerous diagnostic and therapeutic applications (241, 331). For example, the techniques of tumour biopsy and amniocentesis both provide diagnostic information, while abscess drainage and nephrostomy are therapeutically significant procedures. However, the physician who performs such an intervention must be competent and at ease with the particular imaging method to be used, and also trained to carry out the particular intervention; the latter will require more skill than merely imaging the area. Whenever biopsy is performed there must be a competent cytologist available.
The simplest imaging technique that gives the safest and most accurate result should be employed, e.g., fluoroscopy for a lung mass. However, computed tomography and ultrasound scanning are most commonly employed for the abdomen, with ultrasound being used whenever possible. A guided puncture has many advantages and the equipment should always be available during a diagnostic procedure, so that whenever any lesion or tumour is identified a morphological, cytological, histological, or bacteriological diagnosis may be made immediately.

Many lesions can be identified using dynamic (real-time) ultrasound scanning, making it the method of choice for many investigations. It is convenient, usually rapid, and the needle can be monitored as it is inserted in any direction. The procedure is independent of organ function, no ionizing radiation is used, and the equipment is mobile. In addition, the technique is not expensive.

To perform interventional ultrasound imaging with either a general or special purpose ultrasound apparatus, a relatively cheap attachment is necessary. Alternatively, a much more expensive puncture transducer can be used.

Computed tomography can also be used to guide percutaneous biopsy and is particularly useful for deep-seated small tumours in the abdomen, retroperitoneum, and pelvis.

The complication rate of percutaneous intervention is very low (320–324, 325, 326, 329–336), provided fine needles (0.5 mm, gauge 22–23) are used for the biopsy of solid lesions (337). Larger needles (less than 1.2 mm) are used for fluid filled masses (328).

The insertion of a catheter into an abscess can be guided by either computed tomography or ultrasound scanning; the advantage of using computed tomography is the assurance that the surrounding intestine will not be punctured. The use of contrast-enhanced computed tomography scanning makes it easier to avoid the complications of haemorrhage from vessels or a vascular lesion, particularly when larger gauge needles are used to obtain histological samples (327, 328). The larger needles provide greater tissue specificity at the expense of a slightly increased risk. Unfortunately for some tumours, such as lymphoma, this risk must be accepted because only a large bore needle will provide a sufficient core of tissue to permit accurate histological diagnosis. If a choice is possible, small, thin needles should be used because there seems to be much less associated risk of tumour seeding.
4.20 Cancer staging

Knowledge of the exact spread of any cancer (cancer stage) is of the utmost importance when deciding on the appropriate treatment for a patient with malignant disease. For the staging of tumours computed tomography, where clinically indicated, can be used to detect metastases in lymph nodes, brain, liver, chest, and bone during a single examination. Therefore, this technique has had a major impact on the accuracy of non-interventional staging of cancer. However, if computed tomography is not available, then the use of ultrasound can also be helpful at certain sites.

4.20.1 Staging at different sites

(1) **Head and neck.** In the head and neck the use of computed tomography provides an elegant display of anatomy and is thus a highly effective method of tumour staging. For example, paranasal sinus tumours that have extended posteriorly or superiorly, can be clearly shown (345, 353). However, the neck can be a difficult region to evaluate with this technique because of the relative lack of fat between adjacent soft tissues.

(2) **Larynx.** Computed tomography can be used to demonstrate the extent of carcinoma of the larynx more accurately than clinical examination or conventional tomography (338, 349, 354).

(3) **Chest.** Computed tomography can be used to demonstrate the extent of intrathoracic malignancy and to distinguish operable from inoperable tumours, thus avoiding unnecessary thoracotomies. Unfortunately when tumours metastasise to the mediastinal lymph nodes, the accuracy of this technique when used to separate benign and malignant lymphadenopathy is unsatisfactory; mediastinoscopy or surgical biopsy will be necessary (292, 350, 351, 356).

(4) **Gastrointestinal tract.** Computed tomography is useful for assessing the extra-luminal spread of tumours of the alimentary tract and for providing valuable information for the planning of surgery or other management (248, 250, 253).

(5) **Kidney.** When used for the staging of renal cell carcinoma computed tomography is so accurate that angiography is reserved for selected cases only (208).

(6) **Pelvis and bladder.** Primary pelvic cancers are often difficult to stage accurately by conventional methods and it is not simple using computed tomography. In bladder cancer, computed tomography is more reliable than clinical staging for invasive
tumours, but is of little value for assessing superficial malignant disease; however, intravesical ultrasound scanning is extremely helpful. In a series of 75 patients studied in the United Kingdom, the use of computed tomography gave additional useful information compared with clinical staging in 57% of cases (219, 340, 343, 344, 346, 348, 352).

(7) Gynaecological cancers. For cases of gynaecological cancer the use of computed tomography is more accurate in advanced than early disease (347, 355, 358). In cases of carcinoma of the ovary the technique of staging laparotomy remains essential. Computed tomography does have a role to play in advanced disease and can provide a baseline prior to the use of chemotherapy (357).

(8) Bone. In patients with malignant bone tumours the use of computed tomography has shown that the soft tissue component is frequently larger than implied from conventional films (341). For the detection of skeletal metastases scintigraphy is the method of choice, to be complemented where indicated by conventional radiography and computed tomography.

(9) Non-osseus metastases. Lymphadenopathy can be detected by ultrasound or computed tomography scanning in the abdomen and (with reservations as noted already) in the mediastinum. If the scanning of the abdomen with either technique reveals normal-sized lymph nodes, lymphography is indicated because otherwise any metastatic spread without enlargement that occurs will not be recognized (229).

(10) Cerebral metastases. These can best be detected by the use of computed tomography.

(11) Liver metastases. These can be detected by either ultrasound or computed tomography scanning.

(12) Adrenal metastases. For the detection of adrenal metastasis, computed tomography is more accurate than ultrasound but benign adenomas can occur in up to 8% of individuals, and it is not possible to differentiate these from malignant adenomas.

(13) Lymphoma: Hodgkin's disease. In Hodgkin's disease computed tomography can be used to demonstrate the extent of lymph node involvement both above and below the diaphragm. In those patients where the use of computed tomography scanning does not reveal any abnormalities then lymphography should also be performed (339). Since diffuse splenic involvement cannot be detected using imaging techniques, staging laparotomy remains an essential investigative technique. In non-Hodgkin's lymphoma both
computed tomography and ultrasound can be used to demonstrate lymph nodes in the abdomen, and extra-nodal involvement (342); if conventional chest radiographs are normal, computed tomography will be needed for accurate thoracic lymphoma staging.

4.20.2 Cancer follow-up

The use of computed tomography is an important way of following up tumours at various sites so that changes in size and occasionally in composition can be documented and related to treatment. Ultrasound is also useful for the follow-up of liver and lymph node metastases (see section 4.3).

5. SUMMARY OF RECOMMENDATIONS

In this report an attempt has been made to delineate the conditions under which these two new imaging technologies will be of use in developing countries, and to provide specifications so that appropriate equipment can be made available to the many different hospitals and centres throughout the world.

Emphasis has been placed on the need for careful planning, which must include realistic consideration of the inevitable expense involved. In particular, the purchase of computed tomography equipment will have a significant effect on the total health budget of many countries; this financial burden does not disappear when the equipment has been installed. Planning must also include education, because even the purchase of ultrasound machines, which are relatively inexpensive, will be an investment wasted if the physicians who will operate them have not been properly trained in their clinical use. In addition, the maintenance costs of this equipment are not negligible, and providing properly trained service engineers is as important as providing the operating staff. The Scientific Group has attempted to review all aspects of the specifications and choice of equipment, as well as the type of buildings and other requirements, the education, and the maintenance that are essential.

The preceding section of this report outlines the major clinical indications for the use of ultrasound and computed tomography, and also specifies the particular areas where the most benefit can be gained from the use of these two techniques. The Scientific Group has no doubt of the very real advantages to be gained from the use
of these two very important technical advances in developing countries, if they are made available after proper planning and education. The wider use of ultrasound and computed tomography scanning will also open up a broad field of research into improved patient management and care of the individual.

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REFERENCES

General introduction


**Ultrasound**

Computed tomography


Clinical indications

Obstetrics and gynaecology


*Liver*


**Gall-bladder**


**Pancreas**


57


*Spleen*


*Kidney*


**Adrenal**


**Urinary bladder and prostate**


**Scrotum**


**Pelvis**


**Retroperitoneum**


**Intra-abdominal abscesses and gastrointestinal tract**


246. KNOCHEL, J.O. ET AL. Diagnosis of abdominal abscesses with computed tomography, ultrasound, and $^{111}$In leukocyte scans. Radiology, 137: 425–432 (1980).


Skull and brain


*Face, neck, and soft tissues*


Thorax

Heart and great vessels


Spine


Interventional procedures


Cancer staging


66


<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Pages</th>
<th>Price</th>
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<tbody>
<tr>
<td>701</td>
<td>The leishmaniases Report of a WHO Expert Committee</td>
<td>140</td>
<td>11.00</td>
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<tr>
<td>702</td>
<td>Lymphatic filariasis Fourth report of the WHO Expert Committee on</td>
<td>112</td>
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<td>Filaria related diseases</td>
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<td>703</td>
<td>Road traffic accidents in developing countries Report of a WHO</td>
<td>36</td>
<td>5.00</td>
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<td></td>
<td>Meeting</td>
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<tr>
<td>704</td>
<td>WHO Expert Committee on Specifications for Pharmaceutical Preparations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Twenty-ninth report</td>
<td>54</td>
<td>6.00</td>
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<tr>
<td>705</td>
<td>The role of food safety in health and development Report of a Joint</td>
<td>79</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>FAO/WHO Expert Committee on Food Safety</td>
<td></td>
<td></td>
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<tr>
<td>706</td>
<td>The uses of epidemiology in the study of the elderly Report of a</td>
<td>84</td>
<td>8.00</td>
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<td></td>
<td>WHO Scientific Group on the Epidemiology of Aging</td>
<td></td>
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<tr>
<td>707</td>
<td>Recommended health-based occupational exposure limits for</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>respiratory irritants Report of a WHO Study Group</td>
<td>154</td>
<td>14.00</td>
</tr>
<tr>
<td>708</td>
<td>Education and training of nurse teachers and managers with special</td>
<td>54</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>regard to primary health care Report of a WHO Expert Committee</td>
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<tr>
<td>709</td>
<td>Rabies Seventh report</td>
<td>104</td>
<td>9.00</td>
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<tr>
<td>710</td>
<td>Evaluation of certain food additives and contaminants Twenty-eighth</td>
<td>44</td>
<td>5.00</td>
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<tr>
<td></td>
<td>report of the Joint FAO/WHO Expert Committee on Food Additives</td>
<td></td>
<td></td>
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<tr>
<td>711</td>
<td>Advances in malaria chemotherapy Report of a WHO Scientific Group</td>
<td>218</td>
<td>20.00</td>
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<td></td>
<td>(218 pages)</td>
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<tr>
<td>712</td>
<td>Malaria control as part of primary health care Report of a WHO</td>
<td>73</td>
<td>8.00</td>
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<td>Study Group</td>
<td></td>
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<tr>
<td>713</td>
<td>Prevention methods and programmes for oral diseases Report of a</td>
<td>46</td>
<td>5.00</td>
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<td>WHO Expert Committee</td>
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<td>714</td>
<td>Identification and control of work-related diseases Report of a</td>
<td>71</td>
<td>7.00</td>
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<td></td>
<td>WHO Expert Committee</td>
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<tr>
<td>715</td>
<td>Blood pressure studies in children Report of a WHO Study Group</td>
<td>36</td>
<td>5.00</td>
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<tr>
<td>716</td>
<td>Epidemiology of leprosy in relation to control Report of a WHO</td>
<td>60</td>
<td>6.00</td>
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<td>Study Group</td>
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<td></td>
</tr>
<tr>
<td>717</td>
<td>Health manpower requirements for the achievement of health for all</td>
<td>92</td>
<td>8.00</td>
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<tr>
<td></td>
<td>by the year 2000 through primary health care Report of a WHO Expert</td>
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<td>Committee</td>
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<tr>
<td>718</td>
<td>Environmental pollution control in relation to development Report</td>
<td>63</td>
<td>6.00</td>
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<td>of a WHO Expert Committee</td>
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