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Diagnostic Imaging:

What is it?

When and how to use it where resources are limited?

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Preface

Diagnostic imaging has developed rapidly to play a central role in medicine today. However, many countries in the developing world cannot afford to purchase expensive high technology imaging equipment. There is an urgent need to use imaging resources that are available in the most cost effective way possible. This requires training of health care professionals. The World Health Organization plays an important role in providing training and education in diagnostic imaging in developing countries.

This book reviews important clinical problems in which diagnostic imaging can assist and how to use limited imaging resources effectively in daily clinical practice.

I hope that you find this book helpful in your practice.

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Introductory remarks

This document is developed in the hope that it may offer some practical advise on *when, why and why not* to refer patients with some of the most commonly seen diseases and clinical problems to diagnostic imaging.

It is intended to be used mainly by clinicians working in small hospitals and clinics with limited resources, and (mostly) without any possibility to consult with a radiologist or other medical staff specially trained in diagnostic imaging. However, it may also be found useful by physicians, mainly general practioners, working outside hospitals when considering to refer patients to diagnostic imaging departments.

It is not giving specific information on how to *perform* or *interpret* diagnostic imaging examinations. Much literature is available on this subject. However, special manuals focusing on the needs in medical institutions with no radiologists and/or fully qualified radiological technicians are presently being developed by the WHO Team of Diagnostic Imaging and Laboratory Technology (DIL). The work is carried out under the umbrella of the WHO Global Steering Group for Education and Training in Diagnostic Imaging, which was established in November 1999 following a WHO meeting held in Geneva earlier that year with representatives of major international and regional societies in diagnostic imaging.

The document is distributed free of charge and can be obtained by contacting the following address:

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Diagnostic Imaging -
Techniques and Routines

Historical remarks

Diagnostic imaging as known today, originates back to November 1895 as the German professor Wilhelm Konrad Röntgen discovered the high energetic "rays", which, after having penetrated solid material, still induced a chemical process on a photographic plate. On 28 December the same year he published his discovery in a speech at the University of Würzburg, Germany, under the title *"Über eine neue Art von Strahlen"*.

Although modern equipment looks very different from what was used a hundred years ago, the basic physics and principles behind **X-ray** examinations have not changed.

As new and completely different imaging modalities like ultrasonography (US) *(see page 8)* and magnetic resonance (MRI) *(see page 9)* are coming into use, the need for X-ray based examinations declines where such techniques are available. Ultrasound examinations especially have reduced the need for X-ray examinations substantially. On the average, however, more than two thirds of all diagnostic imaging procedures performed worldwide, are still based on the principles introduced by Professor Röntgen more than one hundred years ago, and can be performed by using a most basic X-ray equipment such as the World Health Imaging System for Radiography (WHIS-RAD).

Diagnostic imaging based on ionizing radiation

Conventional X-ray examinations

The basic principles behind X-ray imaging techniques are very much the same as those known for ordinary photography. In both instances the light (*visible*, *low-energy* for photography; *invisible* and *high-energy* for X-ray examinations) induce changes in a photographic film or electric detector. Also, both types of "light" "travel" along straight lines. A fundamental difference to "normal" light, however, is the high energy state of "X-ray-light", which allows it to penetrate solid material, such as the human body.

The amount of X-ray penetrating a material - in our case the human body - depends upon how that specific material is built up. More specifically, it depends upon the type of atoms contained in the material. In general, light atoms, i.e. atoms with low atomic numbers, allow more of the X-rays to pass through than heavier atoms, i.e. with higher atomic numbers.

In a broad sense the human body consists of three types of "material": *soft tissue* containing mainly light atoms, *bone* containing heavy atoms (minerals), and *air* (or some sort of gas) built up by very light atoms. Accordingly, a film exposed to X-rays that have penetrated a human body, will have white or very bright areas (little exposure), grey areas (more exposure), or nearly black areas (heavy exposure) depending upon the amount of X-rays having penetrated various parts of the body. For example, bones letting a small amount of X-rays passing through, will appear very bright or white on the film, and gas/air bubble letting a large amount of X-rays through, will appear nearly black on the film.

As most soft tissues, be it muscles, blood vessels, liver, kidneys, or others, are built up nearly by the same type of atoms (mainly hydrogen, oxygen, nitrogen, and carbon), it is often impossible to distinguish between them on an X-ray film without using more complicated procedures (contrast agent for conventional X-rays, or computed tomography (CT)). In such cases, however, the method of choice for diagnostic imaging would often be ultrasonography, which offers excellent possibilities to distinguish between various types of soft tissues.

Computed tomography (CT)

CT images are generated according to the same principles as conventional X-ray images. The main difference is that the X-rays after penetrating the body induce electrical signals in electrical detectors in stead of creating a chemical process on a photographic film, and that the sensitivity of the system is much higher than that of conventional X-ray systems. Thus, various types of soft tissues may be more easily distinguished from each other. Furthermore, the final "product" i.e. the CT images, are built up digitally, and therefore it is possible to manipulate the way such images are displayed (contrast, brightness etc.). It is also possible to transfer them electronically to other monitors within the hospital or to remote destinations ("Teleradiology").

Nuclear medicine («Scintigraphy»)

In contrast to other imaging modalities this technique, which has been used for decades, has proven to be better for obtaining physiologic and pathophysiologic information than for pure *imaging* purposes. Similar to X-ray examinations, scintigraphy is based on ionizing radiation. In contrast to X-ray detecting the amount of radiation passing through the patient, however, a scintigram is "constructed" by radiation emitted by radioactive material injected, swallowed, inhaled, or by other means given to the patient. Substances used for diagnostic purposes - the radiopharmaceuticals - contain unstable radioactive isotopes with a "half-live" of a few minutes up to some hours. Generally, the radioactive atoms are incorporated in large molecules, the so-called *carriers* or *tracers,* which are specifically intended to be attracted by certain organs or processes. Examples are molecules containing a radioactive iodine isotope for examination of the thyroid.

Various types of "detectors" may be used for "constructing" images and other diagnostic information. The most frequently used detector is a so-called gamma-camera, but much more sophisticated equipment and techniques such as **S**ingle **P**hoton **E**mission **C**omputed **T**omography (SPECT) or **P**ositron **E**mission **T**omography (PET) may be considered for large and specialized hospitals and clinics.

Other modalities for diagnostic imaging

Ultrasonography

Technical considerations

Ultrasound means sound waves with frequencies higher than 20.000 Hz and thereby not recognized by the human ear. One of the most important non-medical application for US is in maritime navigation and fishing, the so-called sonar, for locating underwater objects or fish swarms.

In diagnostic imaging, sound waves with frequencies from two up to twenty MHz are frequently used. For most diagnostic purposes, however, the frequency range is between 3.5 and 7 MHz. Each examination "probe", or "transducer" attached to an US equipment has its specific frequency. Thus, different "probes" are used for different organs or tissue structures. An abdominal examination is mostly performed with a 3.5 MHz probe whereas more superficially located structures, such as the thyroid may be better examined with higher frequencies (5 or 7 MHz). Both emitting and receiving devices are located within the transducer.

Roughly, the main principle behind US examinations is that sound waves transmitted into the body, are partly or totally reflected (following general physical laws for reflection) to the surface (i.e. the receiver) when passing from one type of tissue into another, and the time passed between sending out the sound and receiving the reflected portion, is basically used by the computer attached for "constructing" the image as the distance from the surface to a certain structure correlates exactly with the time passed from emitting the soundwave until receiving the reflected portion of it.

Ultrasonography in contrast to conventional X-ray examinations distinguishes well between various types of soft tissue, and is therefore predominantly used for abdominal examinations, including obstetrics. As the sound beams used in clinical settings do not sufficiently penetrate bony structures or air/gas, ultrasonography cannot be used for pulmonary examinations or for examinations of the skeleton and the brain, which is surrounded by bones. For the brain, however, there is one exception, and that is in new-borns/infants where the fontanels are still open and thereby allowing a sound beam to be directed into the brain.