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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 advice 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 practitioners, 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 **Single Photon Emission Computed Tomography (SPECT)** or **Positron Emission Tomography (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 fontanelles are still open and thereby allowing a sound beam to be directed into the brain.

Important requirements

As ultrasonography has proven to be a very efficient tool for diagnostic imaging and both equipment and infrastructure are regarded to be rather inexpensive, the technique has spread very quickly worldwide. Unfortunately, pure medical considerations are not always behind the purchase and installation of such equipment.

The use of X-ray based imaging techniques is generally well regulated by national and international laws. For ultrasonography, however, few countries have imposed any kind of regulations or certification. Although ultrasonography has proven to be an excellent diagnostic tool in many instances and absolutely safe for the patients, it must be operated by highly skilled and specially trained medical personnel. In wrong hands (e.g., insufficiently trained persons), however, such examinations may do more harm than good to a patient by generating incorrect diagnostic information. Therefore, national authorities should take the necessary steps to regulate the use of ultrasonography as most other specialized medical procedures or techniques.

Magnetic resonance imaging (MRI)

General considerations

Although (still) more expensive and in most cases, more time consuming than other imaging modalities, the number of MRI installations worldwide has increased rapidly during the last decade. Firstly, MRI imaging was regarded to be an “add-on” to other diagnostic modalities. Today, however, its diagnostic superiority to other modalities in several fields has made it substitute many other diagnostic procedures. That is specially the case for examination of the central nervous system including the spinal cord. The excellent way of demonstrating anatomy has also made it very useful when examining anatomical abnormalities such as congenital heart malformations.

Basic principles

Due to the complexity of MRI it is far beyond the scope of this presentation to give any profound information about the physical and mathematical theories of MRI. Thus, readers wishing to look deeper into this subject, are kindly requested to consult specialized literature.

The main parts of an MRI equipment are a very strong *magnet* normally in the range of 0.2 - 2.0 Tesla, a *radio transmitter and -receiver*, and a *computer*. The magnet is so large that the patient or the part of the patient to be examined can be placed into it. In that sense it may look very similar to a CT scanner although the principles for imaging are fundamentally different.

Important is, that MRI represents a completely new technique for diagnostic imaging, completely different from anything else in use, and at least today regarded to be safe for the patients. In many situations it offers excellent diagnostic information, and in some cases it gives more diagnostic information than obtainable by other modalities. However, the human and financial resources required both for purchasing and for running an MRI installation makes is inappropriate for most small and mid-size hospitals.

Diagnostic imaging and pregnancy

A large number of publications have been issued on this topic. Among those, the International Basic Safety Standards for Protection Against Ionizing Radiation and for Safety of Radiation Sources, published by the International Atomic Energy Agency and jointly sponsored by the International Labour Organisation, Food and Agriculture Organization of the United Nations, Nuclear Energy Agency of the Organization of Economical Co-operation and Development, and the World Health Organization in 1996, is probably the most comprehensive publication on radiation protection. Taking various publications and opinions into account, however, and realizing that correctly performed diagnostic imaging procedures give an absorbed radiation dose to the embryo/foetus well below the internationally agreed limit of 100 mGy, it seems reasonable and correct to state that *medically justified* diagnostic imaging procedure may be performed also in pregnant women without fearing any harm to patient or foetus.

For diagnostic modalities other than those based on ionizing radiation (ultrasonography and magnetic resonance imaging) no scientifically based evidence for possible harmful effects exist.

Specific clinical problems and diagnostic imaging

General considerations

The following sections intend to give some advice on the practical use of diagnostic imaging facilities in order to solve diagnostic problems in small hospitals and clinics with very limited resources in regard to equipment and medical staff. For the purpose of this document it is assumed that the hospitals addressed will have merely one or two, relatively basic, stationary X-ray machines, perhaps a mobile X-ray unit, and a general purpose ultrasound machine. It is also assumed that no radiologist is available - at least not on a permanent basis. However, the medical interpretation of examinations is not within the scope of this booklet. Much literature already exists on this subject, and specific publications targeting the needs in hospitals and clinics with limited resources are being prepared separately by the WHO.

It should be made clear that any diagnostic efforts are justified only when followed by appropriate therapeutic measurements. Where possibilities for treatment are limited, the diagnostic efforts might be limited accordingly. Instead, all efforts should aim at having the patient transferred to another hospital where treatment is available.

It is of great importance to realize that general "recipes" and recommendations are valid only for the "average patient". For the individual patient, however, techniques and procedures need to be "tailored" according to specific clinical problems, clinical findings and clinical considerations.

Diagnostic imaging: why and when?

In general, patients seek medical help, or are brought to hospital due to specific health problems, be it acute requiring urgent assistance and treatment, or be it for symptoms and concerns remaining and/or increasing over some time. The diagnostic procedure, e.g., the evaluation process needed before treatment can be given (or not given), consists of three major parts: 1) the patient history; 2) the clinical examination by medically competent person(s); 3) additional diagnostic measurements such as laboratory tests and diagnostic imaging. In a majority of cases a combination of patient history and a clinical examination is enough to decide whether medical treatment is needed, and - when yes - which treatment should be given. For some patients, however, additional examinations are needed

either to ascertain a clinically suspected diagnosis, or to obtain more information about the actual problems before proper treatment can be given. For example, a fracture of a bone is mostly diagnosed clinically. However, an X-ray will often be needed either to decide how to treat it, or to ascertain whether the treatment given was successful. Another example could be a patient with acute abdominal pain. Various reasons for this could be postulated clinically, but in most cases no firm diagnosis can be made without either ultrasound or X-ray examinations -or both. Otherwise, a possibly unnecessary and potentially dangerous abdominal operation might be the only way to establish a diagnosis, and eventually to help the patient.

Accidents and trauma

Patients suffering from trauma, be it due to accidents or violence, can roughly and for practical reasons, be grouped as follows:

- Trauma to the head
- Trauma to the chest
- Trauma of abdomen
- Multitrauma of head, chest, abdomen, and skeleton
- Trauma of skeleton and/or soft tissue including spine

In nearly all cases, diagnostic imaging will be of secondary importance for these patients. Vital emergency treatment such as ensuring respiration and heart function and controlling eventual bleedings certainly should be given highest priority. Further diagnostic and therapeutic measurements will normally be initiated when the clinical situation is under control and stabilized.

Head injuries

When such injuries are suspected or clinically observed, emergency X-ray examinations are often requested. In general, however, *conventional* skull radiographs are of very limited value if any. Dangerous and eventually life threatening intra-cranial injuries are normally not shown on such images, and they are therefore in most cases not needed or medically indicated. Radiological detection or exclusion of one or more skull fractures do not say very much about eventual damage to the brain or other intra-cranial structures. Suspecting and/or observing facial injuries, however, would in many cases justify X-ray examinations. Additionally, it is regarded mandatory that all unconscious head injured patients should have their cervical spine examined radiologically, and an absolute minimum would be a lateral view eventually performed with a mobile X-ray unit. In the

unlikely event of having a CT machine available, however, the situation would be totally different, and in most patients with serious injuries to the head and eventually also to the cervical spine, such examinations would be of extremely high diagnostic value.

Chest injuries

Patients having experienced some type of chest trauma will often need to be examined radiologically, and primarily to evaluate possible lesions to the lungs and mediastinal structures. Normally, a plain chest radiograph is all that is needed to prove or exclude a pneumothorax, atelectasis, pleural fluid collection, or other serious changes. Whenever possible, the patient should be examined in the X-ray department using stationary equipment. Both diagnostic quality of images, and radiation safety are much more difficult to ensure when using mobile units, and relatively few patients would be in such a clinical condition that they could not be transported safely to the appropriate location for imaging.

A chest X-ray to prove or exclude a suspected, simple rib fracture, is in most cases not indicated, or necessary. In the absence of more serious injuries or symptoms, a rib fracture is normally diagnosed easily clinically. When suspecting lesions to the pleural sack, however, high quality radiographs may be needed to see whether a pneumothorax or other lesions might be present.

The justification for any radiological examination, and in this context for chest examinations should depend fully on the clinical conditions of the patient and the medical need for such examinations. "Control radiographs" because hospital routines say so, or "it has always been done" should be strongly discouraged.

Abdominal injuries

Trauma to the abdomen often requires extensive and difficult diagnostic considerations. Especially in the absence of external or maybe penetrating abdominal injuries, it can be nearly impossible to diagnose intra-abdominal injuries with adequate certainty. Physicians or other well trained medical professionals may be able to verify or exclude the *likeliness* of such injuries, but more exact diagnostic information can hardly be obtained without additional diagnostic measurements and procedures.

Patients with abdominal trauma suspected to have internal lesions, should as soon as possible have their abdomen examined ultrasonographically (given that equipment is available, and that *well trained operators* are at hand). Such

examination can be done in the emergency department/theatre very soon after the arrival of the patient. If necessary, it can also be performed simultaneously with other, maybe life saving treatment being given. It does not need any preparation of the patient although gas in the bowel often makes examinations difficult. Performed by adequately trained personnel, however, most types of serious intra-abdominal lesions such as intra-peritoneal bleeding, or severe injuries to liver, spleen or kidneys can be verified or excluded within minutes, and does not influence on the patient's general condition.

Where ultrasonography is not available, conventional abdominal X-ray examinations should be considered as they can offer valuable information on possible intra-abdominal lesions. However, such examinations performed in an emergency situation, often with mobile X-ray equipment, may not be of sufficiently high quality to give the necessary and definite diagnostic information, and more sophisticated radiological examinations, including contrast medium, are often not possible in small hospitals and clinics. Similarly, abdominal CT examinations, which in most cases would offer sufficient diagnostic information to initiate necessary and adequate treatment, are generally not available in these institutions. In such situations, surgical measurements such as an exploratory laparotomy, may be required.

Injuries to the skeleton

Although most injuries to the skeleton are diagnosed clinically, it is often difficult to give adequate treatment without information obtained by diagnostic imaging. In such cases, basic radiological examinations are the method of choice, and a basic, general purpose X-ray machine such as the WHIS-RAD System is highly adequate and in many cases superior to more sophisticated equipment for such examinations, given that it is operated properly by well trained staff. Apart from the radiation safety aspects, which may easily be compromised or difficult to maintain, mobile X-ray units are often not able to produce images of sufficiently high diagnostic quality even when operated by highly skilled personnel. This is especially the case when suspecting injuries and fractures to the lumbar spine where lateral projections are of greatest importance, and to the pelvis and the hips.

In general, a minimum of two projections normally positioned at a 90 degree angle to each other, are needed. Special and additional projections may be required according to type and location of the injury/fracture. Thus, the clinical situation and conditions should be extensively discussed between the clinician and the X-ray operator in order to "tailor" the examination properly.

Ultrasonography may be of some use when evaluating soft tissue injuries and eventual injuries affecting joints. For the skeleton, however, ultrasonography is practically unusable (*see page 8*).

Diagnostic imaging of patients with non-acute clinical symptoms

Symptoms from head, neck and facial structures with or without central nervous affection

In this context it is important to realize that less than 0.5% of acute headaches are due to serious intracranial disease. Consequently, patients with headache but no additional neurological symptoms would normally not need diagnostic imaging of any kind.

Similar to patients with head injuries, conventional radiographs are of little if any use. Exceptions may be occasional findings of bone lesions such as sclerotic or lytic metastases. Also, intracranial calcifications may indicate the presence of cerebral disease, but any such diagnosis requires a profound knowledge of normal anatomy and normal variants in order to distinguish normal conditions from pathologic ones.

In general, patients suspected to have an intracranial disease or intracranial pathologic changes possibly treatable, but requiring more sophisticated diagnostic procedures, should be transferred to a hospital where CT, cerebral angiography and possibly also MRI examinations could be performed, and where necessary treatment can be given.

Symptoms, be it pain or swelling of tissue, or both, located to the vizeral part of the cranium, including the face, are mostly due to infections and/or malignant disease. In patients where sinusitis is clinically diagnosed, but not responding adequately to treatment, a standard series of radiographs of the sinues (AP, Walters, and lateral) might be ordered and justified. Frontal and maxillary sinuses are well demonstrated by performing a standard AP and a Walters projection, the latter specifically to expose the maxillary sinuses sufficiently well. In case of densities in one or both of the maxillary sinues, and it is of clinical importance to know whether fluid is present, an additional Walters projection with the patient's head tilted some 10 - 20 degrees to the right or left, would normally solve that problem easily (water-air line stays horizontal!).

Foreign bodies swallowed and stuck in the neck can easily be located by conventional radiography using one lateral projection of the region. However, a "normal" image does not exclude the presence of a foreign body since many such "articles", including most fish bones, are not sufficiently radiopaque to be detected. When technically possible, additional lateral and AP projections taken during the swallowing of diluted contrast media (barium suspension or water-soluble contrast medium) might be of some help. However, such procedures normally require a possibility for fluoroscopy and the presence of a radiologist.

Foreign bodies eventually located in an eye, can be demonstrated radiographically when they are metallic, or otherwise radiopaque. However, the best and most easy way to locate orbital foreign bodies, would be by ultrasonography.

Symptoms of upper airway obstruction and dysphagia may on relatively rare occasions indicate the presence of a retropharyngeal process, mostly an abscess. In such cases, conventional X-ray examination such as a lateral radiograph of the neck structures, may often strengthen the suspicion, or even confirm the diagnosis, but more sophisticated and reliable diagnostic information can hardly be expected from conventional radiography alone. Again, CT would be the method of choice if available. Also, a very well trained ultrasound operator might be able to supply some more diagnostic information, but that would highly depend on her or his skills.

Inflammatory processes and especially abscesses originating from the teeth, are mostly diagnosed clinically, and diagnostic imaging is normally not indicated or needed. However, when a firm clinical diagnosis cannot be made, the presence of an eventual abscess within the bony structures can be fairly well demonstrated with conventional radiography without any need for specially dedicated dental imaging equipment.

Enlargement of the thyroid and especially nodules suspected to be part of the thyroid gland may sometimes be clinically suspected to be caused by a malignant process. An ultrasound examination carried out by a well-trained operator and using appropriate equipment (mostly a 7 MHz transducer) would be recommended as the method of choice. Scintigraphic examinations (nuclear medicine) might often give better diagnostic information, but are normally not available in small hospitals and clinics.

Pain and other clinical symptoms located in the chest

General considerations

Pain located in the chest may be caused by a multitude of diseases. Again, a proper clinical evaluation of the patient (history, inspection, and clinical examinations including the use of a stethoscope) normally gives sufficient information to initiate proper treatment, or to decide whether treatment is needed.

Diagnostic imaging should be considered only to verify or reject a clinically based diagnostic hypothesis. In cases where diagnostic imaging is needed and clinically justified, it would be advisable to start with a simple PA-radiograph with the patient in the up-right position. If the clinical conditions do not allow the patient to stand up, an AP-radiograph of the chest with the patient on a stretcher or on the examination table will do. Major pathologic processes such as pulmonary consolidations due to pneumonia (or tuberculosis), clinically significant atelectasis, tumours, heart failure with pulmonary congestion, abscesses, parasitic and fungal affections, and pleural fluid are mostly demonstrated sufficiently well for initial diagnostic purposes on a single PA (or AP) chest radiograph. However, the image quality needs to be sufficiently good, and both for the sake of radiation protection and for the quality of images to be taken, it is important that the examinations are performed in the X-ray department using stationary equipment, and not with mobile equipment. Most patients can relatively easily be transported (or walk) to the X-ray department to have the examinations performed. The use of mobile units should be restricted to those patients who cannot be moved due to their medical conditions.

Ultrasonography may be of some value when evaluating and locating pleural fluid and an eventual pathologic process located close to or affecting the chest wall. Also, cardiac and pericardial disease may be visualized by ultrasonography ("Echocardiography"), but such examinations require specially trained operators and often more sophisticated equipment than generally found in small hospitals and clinics. In general, however, ultrasonography is of no particular value for chest examination (*see page 8*).

Specific symptom complexes

Cardiac symptoms

Patients presenting with a more or less typical picture of ischaemic heart disease or a cardiac infarction, do not need any diagnostic imaging in the initial stage. Even in the presence of symptoms indicating heart failure and pulmonary congestion, the clinical evaluation followed by appropriate treatment should normally be given the highest priority. A chest radiograph might be indicated when complicating conditions, such as pneumonia emerge, or when the patients' condition does not improve in spite of adequate treatment. Also, it might be of some value to have a chest radiograph taken to evaluate the course of treatment, or eventually before dismissing the patient from hospital after having treated such complications.

When pericardial effusion or intracardiac pathologic changes such as valvular stenosis or insufficiencies are suspected, ultrasonography (*"Echocardiography"*) may be considered. However, such examinations require operators with special training, and are rarely available in small hospitals and clinics.

Pulmonary symptoms (dyspnoe, cough, and pain with or without fever)

For practical purposes, patients with pulmonary symptoms may be divided into three major categories: 1) patients with cardio-pulmonary disease; 2) patients with pulmonary infectious disease; and 3) patients with non-infectious pulmonary/airway disease such as pulmonary fibrosis, silicosis, or similar. Although many patients will present with clinical symptoms originating from various types of diseases, diagnostic imaging procedures to be applied in small hospitals and clinics will be more or less the same although clinical approach and treatment may differ significantly.

When decided that diagnostic imaging is needed, plain PA and lateral chest radiographs with the patient in the upright position, should be ordered, and will normally give sufficient diagnostic information to decide upon treatment. When the clinical conditions are such that the patient is unable to stand upright, a normal AP radiograph of the chest with the patient lying on her / his back on the examination table, will normally be enough (mobile X-ray equipment to be avoided whenever possible!). In such cases, additional valuable diagnostic information, especially on the presence of, and quantity of pleural fluid can be obtained by placing the patient on her / his side, and making an examination with a horizontal X-ray beam (*"lateral decubitus"* position).

Symptoms located in the abdomen

General considerations

Except for abdominal problems caused by injuries (*page 13*), these patients may be divided into two main categories: 1) those presenting with acute abdominal symptoms, and 2) those with abdominal symptoms developing or persistent for some time. A majority of patients in both categories can often be diagnosed adequately by clinical means, eventually supported by simple laboratory tests. In some patients, however, a proper diagnosis becomes difficult without the aid of diagnostic imaging, and too many patients world wide have to undergo potentially dangerous abdominal surgery only to establish a diagnosis (exploratory laparotomy) because no diagnostic imaging facility is in place. Although many patients with abdominal symptoms should ideally be examined with CT, this is a procedure which is very rarely available in small hospitals and clinics. Assuming that basic X-ray examinations can be performed, and ideally facilities for ultrasound examinations are also available, the latter technique would in most cases be the method of choice, be it for acute or more prolonged symptoms. Conventional radiological examinations may be performed where ultrasound is not available or inconclusive.

None of the methods should, however, be applied without a clinical justification, and any clinically based suspicion needs to be communicated extremely well to the operator of the imaging facilities. Thus, an abdominal ultrasound examination performed without clinically based suspicion of a specific pathologic process, will too often - even in well experienced hands - not detect pathological changes although they may be present. The operator needs to know what to look for. Otherwise, the result of such examinations may often be incorrect or questionable. This also applies to abdominal X-ray examinations although sometimes to a lesser extent. However, any well trained X-ray technician or radiographer who is fully informed about what the clinician suspects or expects to find, will normally be able to tailor the examination for that specific purpose, thereby supplying X-rays with more relevant diagnostic information than might otherwise be the case.

Acute abdominal symptoms (“acute abdomen”)

Although a multitude of diseases may be behind this alarming condition, gastrointestinal perforation, gastrointestinal obstruction, and pancreatic and biliary tract disease are some of the most common ones, and a well trained clinician will in most cases be able to diagnose, or at least suspect, the reason for the symptoms.

In many of these patients, however, diagnostic imaging will be needed to confirm or reject the clinically suspected diagnosis in order to plan a surgical intervention properly, or to avoid unnecessary and potentially dangerous operations.

Gastrointestinal perforation

Patients with symptoms indicating a perforated gastrointestinal ulcer, where no firm diagnosis can be made clinically, should be examined radiologically as soon as possible. In addition to a plain AP projection with the patient lying down, a "lateral decubitus" with the patient lying on her or his *left* side is recommended. It may also be wise to leave the patient in that position for a couple of minutes before the X-ray is taken. Thereby, the possibility of detecting "free air" in the peritoneal cavity (*pneumoperitoneum*) and confirming an intestinal perforation, may increase substantially. Eventual additional projections and images may be taken, but are often not needed. However, a chest X-ray, with the patient in the up-right position, should always be taken. Such an image may even better reveal "free air" in the peritoneal cavity than a "lateral decubitus" image. Additionally, it may also indicate the presence of other upper abdominal or lower pulmonary pathologic changes, for example a subphrenic abscess.

If a firm diagnosis still cannot be made, an abdominal ultrasound examination should be considered - where available. Otherwise, ultrasonography is of no particular use in such patients. Similarly, patients with symptoms indicating some sort of -

Gastrointestinal obstruction

- should also be referred to X-ray examinations as the method of choice. Preferably, at least one abdominal AP image should be made with the patient standing up-right in addition to the supine abdominal AP(s), left *and* right lateral decubitus, and chest X-ray. Thus, the presence or absence of a mechanic or paralytic ileus can in most cases be confirmed. Also, the level of obstruction (jejunum, ileum, colon) can often be indicated with a relatively good certainty.

Depending upon the clinical conditions of the patients and the urgency for an eventual surgical intervention, it might be considered to give the patient some diluted, water-soluble contrast medium (NO BARIUM SUSPENSION!) to drink, and thereafter to follow its course through the intestines for a few hours. Such a procedure will often give a relatively exact diagnosis of the level of obstruction. In addition, some, mostly undocumented, clinical observations, may give rise to the assumption that in some cases, mechanical, intestinal obstructions can dissolve during such a procedure thereby avoiding a potentially dangerous surgical

intervention. Such prolonged examinations, however, should only be considered when the clinician in charge of the patient orders or recommends this.

An intestinal obstruction caused by a (mainly) large bowel volvulus, or, in small children, a (mostly) ileocolic intussusception (invagination), may also be diagnosed on conventional abdominal radiographs. For the latter, radiologically performed reposition may be indicated and often successful. However, such a procedure should only be considered and performed by a fully qualified radiologist, and a description of such procedures are beyond the scope of this document.

Ultrasonography is generally of little use in patients with intestinal obstruction, except for the relatively rare situation where the obstruction is caused by malignancy with eventual spread to the liver. Nevertheless, a well trained ultrasonography operator may be able to diagnose both obstruction level and type of obstruction, but such investigations are difficult because of the large amount of gas normally present in the bowel (*see page 8*).

Symptoms originating from pancreas

Except for confirming the clinical suspicion of a peritoneal irritation, which, depending on the severity and the time passed since the symptoms started, may already have developed a paralytic ileus, conventional radiography and ultrasonography are not of much use. The diagnosis of pancreatitis will normally have to be based on clinical findings supported by laboratory tests. It is, however, recommended to have ultrasound examinations performed when available, mainly to look for total or partial obstructions of the biliary tract, which could be of major importance for immediate therapeutic considerations. In larger hospitals where CT is available, such examinations should be performed as soon as possible in order to sort out already developed complications within the pancreas itself, and to look for extrapancreatic reasons for the disease, for example a tumour or pathological changes in the biliary tract. Depending upon such findings, the treatment considered may differ significantly.

Symptoms related to the biliary tract

Patients with acute abdominal pain originating from biliary tract disease may be difficult to evaluate clinically, especially in the absence of jaundice. However, the medical history combined with clinical and laboratory examinations may point towards the biliary tract, and diagnostic imaging may be required for further evaluation. If this is the case, the method of choice would be ultrasonography, where available. Concrements within the gall bladder, or eventually in the biliary ducts, widening of the biliary ducts indicating some degree of obstruction, and inflammatory changes, will in most cases be detected during such examinations.

However, where ultrasonography is not available, conventional abdominal radiographs including chest X-ray should be considered, although diagnostic information to be expected is generally limited to the detection of possibly *radiopaque (calcified)* structures indicating chole(cysto)lithiasis. Cholecystography with contrast medium given orally, could be considered, or advisable only when a fully trained radiologist is present. It should, however, be considered only in clinically sub-acute or chronic stages of biliary tract disease, and only when clinical and laboratory findings indicate absence of biliary tract obstruction. Cholangiography (intravenously injected contrast medium) is generally considered to be a dangerous examination due to the frequent and serious adverse reaction to contrast medium. Such examinations would have little if any place in the evaluation of an acute situation, and should only be considered in larger hospitals where all necessary radiological and anaesthesiological services are in place.

Acute abdominal symptoms in pregnancy

When diagnostic imaging is needed in such patients, be it early or late in the pregnancy, the method of choice would be ultrasonography. Although correctly performed X-ray examinations by no means should be regarded as contra-indicated, the diagnostic information to be expected would normally be of minor importance, and would therefore rarely be medically justified. However, when medical history and clinical examination indicate acute pathology not directly related to the pregnancy, however, the considerations mentioned in the above paragraphs would apply, given that necessary and correct radiation protection measurements can be ensured.

Acute symptoms originating from the upper urinary tract

Acute problems in this sense are mostly caused by an urinary tract obstruction, and a nephrolithiasis is obviously the most common reason for this. Both due to the heavy pain accompanying such a condition, and the possibility of inducing renal damage when not treated in time, early diagnosis and treatment are necessary. Although a concrement or most other pathologic processes in a ureter are very difficult to detect by ultrasonography, a dilatation of the renal pelvis as easily detected with this modality, strongly suggests an obstruction of the ureter. Where ultrasonography is not in place, or more diagnostic information is needed, a plain, conventional AP abdominal radiograph may be considered. Radiopaque "shadows", mostly with calcifications detected where the ureters are expected to be, would strongly confirm the ultrasound findings, or be a relevant although not a firm indicator of ureterolithiasis. In such patients, intravenous pyelography (IVP) should be considered, given that relevant and well trained radiological staff is available,

and that a radiologist or another qualified physician is present and responsible for the injection of the contrast medium. When IVP is possible and considered in such patients, the procedure can be reduced from a whole sequence of images as is the standard for IVP, to a few (2 - 3) images, for example one image before contrast medium is injected (*obligatory*), and another image 15 - 20 minutes thereafter.

Non-acute abdominal symptoms

Patients with slowly developing, and often long-standing abdominal symptoms represent a diagnostic challenge for the physician, and a well experienced clinician is certainly needed to judge whether the symptoms are so alarming that further investigations and eventual treatment are needed. If so, some sort of diagnostic imaging may be necessary, but again, such examinations are only relevant to verify or reject specific clinical suspicions. Too often, the information given to the imaging department is too vague, or too superficial to plan and conduct an imaging procedure of the abdomen, and the slogan: "you find what you are looking for" is especially valid for abdominal ultrasound examinations.

Epigastric and upper abdominal symptoms

As epigastric and upper abdominal symptoms are most commonly related to the biliary tract, the stomach and duodenum, or the pancreas, diagnostic imaging procedures should primarily be aimed at those organs. Depending upon what is possible and available in that specific hospital, it would be reasonable to order ultrasonography, of the liver, biliary tract, and pancreas, as a first diagnostic step. The operator will often also look at the spleen and the kidneys, but a specific, clinical suspicion in this direction must be communicated. The sensitivity of such examinations depends heavily upon the skills of the operator, and a frequently valid rule would be to consider examination results and especially those indicating "normal" with some scepticism, and to look at them in view of the clinical findings and eventual suspicions.

Although plain abdominal radiographs of such patients may reveal various pathological changes, for example, calcifications indicating parasitic disease, they are often of very little value, and may not be indicated. Further radiographic examinations would mostly include contrast media (barium suspension), but such examinations will normally have to be performed by a qualified radiologist using fluoroscopic technique. Consequently, these examinations will be mentioned only briefly in this document.

Where ultrasound examinations cannot be performed, or are inconclusive, cholecystography (peroral fat-soluble contrast medium) may be considered. Such an examination should, however, be done by a radiologist, and even so, the sensitivity is broadly questioned whereas the specificity is diagnostically acceptable. In other words, a cholecystogramme indicating gall bladder stones should be regarded as a clear answer, whereas a “normal” one does not say very much, and certainly does not exclude the presence of gall bladder disease.

The next radiological procedure to be considered, might be an intravenous cholangiogramme. This type of examination, however, is hampered with a relatively high occurrence of severe adverse reactions to the contrast medium, and should therefore be considered only in hospitals with well-trained radiological and anaesthesiological staff present.

Barium swallows using either single-contrast or double-contrast technique for examining the stomach and the duodenum, should be reserved for hospitals with qualified radiologists and possibilities for fluoroscopy equipped with an image intensifier.

Symptoms located in the lower abdomen

Besides possible gynaecological problems, which are dealt with in a separate chapter (*page 25*), a majority of “organic” symptoms in this area may originate from the bowel. Both infectious and non-infectious inflammatory changes, including parasitic diseases in the small and/or the large bowel are most commonly responsible for the clinical problems. Thus, most cases are diagnosed clinically and taken care of without using any kind of diagnostic imaging techniques. Radiological bowel examination (barium enema) is rather specialized, and is often not available in small hospitals and clinics.

In general, ultrasonography is of limited use, as bowel gas will make examinations difficult. In most cases, also conventional, plain abdominal radiographs will add little information to what can be found clinically and from laboratory tests. Pathologic calcifications indicating some sort of parasitic disease may be detected. Also, severe inflammatory bowel disease with dilatation of bowel loops can be observed. Furthermore, high-quality radiographs may reveal the presence of pathologic soft tissue masses (tumours) and displaced organs, but even in the hands of a well-trained radiologist, the amount of information to be “extracted” from such images is limited.

Barium studies such as a small bowel “pass through”, or barium enema using either single or double contrast technique for the large bowel, are good diagnostic tools when performed correctly. However, both equipment (fluoroscopy with image

intensifier) and well trained operators are required. Otherwise, such examinations are not to be recommended.

If symptoms are suspected to originate from the kidneys or the urinary tract, the imaging method of choice would be ultrasonography. Additionally, and where ultrasound examinations are not feasible or inconclusive, radiological contrast examinations (intravenous pyelography, IVP) should be considered. Performing an IVP, however, requires highly skilled operators, and the necessary intravenous injection of a contrast medium should be performed by a radiologist/physician or at least under the responsibility of a fully qualified physician who must be present in the department during the examination. Additionally, national laws and regulations for such procedures have to be followed.

An IVP will normally be carried out according to standard routines of the department, and it shall always start with a plain, abdominal radiograph before any contrast medium is injected. Eventual modifications, however, may often be needed according to clinical problems of a specific patient, but such modifications should be done only in close collaboration with the clinician in charge of the patient.

Symptoms related to the female genital tract

Conventional radiography will be of very little value for gynaecological problems, and is rarely indicated. Thus, and for all practical purposes in small hospitals and clinics, the only imaging technique of value is ultrasonography, which can give the diagnostic information needed when performed and interpreted by a well-trained operator. Specialized radiological examinations like hysterosalpingography (HSG) should not at all be considered when no radiologist familiar with such procedures is available to perform and interpret. Patients with complex clinical symptoms and eventual malignant disease, should wherever possible be transferred to hospitals with facilities for CT examinations before planning eventual surgical intervention or radiotherapy.

Musculoskeletal symptoms including vertebral column

General considerations

Except for traumatic lesions and fractures, which in most cases should be referred to diagnostic imaging (*page 14*), it is a general observation worldwide that patients with other types of musculoskeletal complaints, and especially low back pain, are too often referred to diagnostic imaging. In general, however, the physician in charge of a patient is normally the best person to decide whether such examinations

are medically justified. In doubt, it is highly recommended that she or he consult and discuss the problems with the radiologist or the technician in charge of the imaging procedures that are being considered.

The imaging method of choice for the skeleton is conventional radiography. Ultrasonography may be valuable for examining soft tissue and joints, but bony structures cannot be visualized with normal ultrasound equipment, and nuclear medicine examinations, CT and MRI, which can be excellent methods for musculoskeletal problems, are normally not available in hospitals and clinics targeted by this document.

Vertebral column/spine

Except for acute symptoms often related to trauma, radiography should be considered only when clinical symptoms are regarded to be serious and are persisting. Both neck pain, and even more so low back pain, are most often caused by muscular tension and similar problems. A narrowing of one or more intervertebral spaces in the cervical and the lumbosacral region may support a clinical diagnosis of nerve root affection. However, no firm diagnosis can be established upon such findings, and in general, the clinical relevance of degenerative changes which are well demonstrated with radiography, are often to be questioned as the correlation between even major degenerative skeletal changes and the clinical symptoms may be relatively poor.

With persisting clinical problems, however, radiological examinations may be considered, especially to exclude more serious changes such as eventual malignant disease, or inflammatory processes. And if performed, it is important to obtain images of good diagnostic quality including all necessary projections, and such examinations should not be carried out with mobile X-ray equipment. Apart from problems related to radiation safety, such equipment will normally produce images of inferior quality. This is especially the case for lateral projections of the lumbar spine and the lumbosacral junction.

When ordering X-ray examinations of the spine, it is crucial to communicate the clinically proven or suspected findings to the radiologist or technician in charge of the examinations, and the various parts of the spine must be targeted separately. A "whole column" or "thoracolumbal column" in one exposure in order to save film, would, even in children, be insufficient, and should not be carried out. When X-ray examinations are medically justified, sufficiently good image quality needs to be achieved. Otherwise, the radiation exposure to the patient as well as the use of resources should be regarded as a questionable practice.

Extremities including pelvis and hips

Traumatic lesions have been dealt with in an earlier chapter (*page 14*). Clinical symptoms, mostly pain, related to the extremities and joints should be referred to diagnostic imaging as soon as possible when clinical data suggest the possibility of malignancy or an inflammatory process. In such cases, high quality radiography will normally give sufficient diagnostic information to decide on treatment to be given. It is, however, necessary to stress that inflammatory processes such as osteomyelitis are normally not seen until 10 - 14 days after onset. On such occasions, a "negative" X-ray does not exclude the presence of any type of bone infection, and the examination should be repeated after some days if the clinical symptoms persist or even get worse.

The reasons for symptoms such as pain, swelling, or reduced motion of joints, can often be sufficiently diagnosed clinically, and in the absence of inflammatory symptoms, radiography is rarely needed. However, when inflammatory symptoms are present, X-ray examinations may give valuable diagnostic information in addition to what can be obtained clinically. One should, however, note that acute inflammatory processes in joints, can only be assumed indirectly in its early stages by using radiography, e.g., by the presence of hydrops. In later stages they may be recognized when bony structures are already affected or eventually damaged. The presence of increased articular fluid, including haemarthros and pyoarthros, may be difficult to diagnose clinically, especially in the shoulder and hip joints. In such cases, a well trained ultrasonography operator will often be able to give the necessary information to confirm or reject the diagnosis. It is, however, not possible to say anything for certain about the type of fluid found in a joint, and a puncture is often needed to obtain more information.

Degenerative changes affecting joints and surrounding bony structures are well demonstrated by X-ray. Similar to the spine, however, the clinical importance of such radiological changes are not always relevant and explanatory for the clinical symptoms experienced by the patient, and should therefore be judged cautiously. Radiologically demonstrated soft tissue calcifications is another entity which may or may not explain the clinical symptoms. Although soft tissue calcifications consistent with a calcified tendinitis in the shoulder or hip region mostly prove the presence of such non-infectious inflammations, their absence cannot not be regarded as a prove for the non-existence of such processes. Other radiopaque or calcified structures suspected within or in the surroundings of a joint as easily demonstrated radiologically, should also be interpreted cautiously, as "normal variants" are frequent, and a well trained radiologist is normally needed to judge the clinical significance of such findings.

Radiological changes indicating bony metastases are relatively easily detected. However, such changes demonstrated "by chance" in patients without relevant clinical symptoms or medical history should always be regarded with some scepticism and strongly indicate the need for more diagnostic work. Radiological changes suspected to represent a malignant, primary bone tumour, however, need immediate further evaluation. At the early stages, a final diagnosis may be extremely difficult to establish even for a fully qualified and well experienced radiologist, and sincere considerations should be given to whether the patient should be transferred as soon as possible to a major medical institution with facilities for CT, nuclear medicine, and eventually MRI examinations.

As a general rule, clinical symptoms related to most soft tissue changes cannot be further evaluated by conventional radiography. Although eventual radio-opacities and calcifications are easily demonstrated, more specific diagnostic information cannot be obtained. Ultrasonography may be of some value, especially in evaluating whether a soft tissue "swelling" is some sort of a fluid collection or cyst. More than this, however, is difficult to demonstrate with general ultrasound equipment. When using special, high frequency transducers, however, a well trained operator may be able to demonstrate more details, and even some diseases affecting the skin may be made visible. One such example is filariasis, but equipment and training needed for such subtle examinations are rarely available in small hospitals and clinics.

Concluding remarks

This document has been written in the belief that diagnostic imaging is crucial for any type of hospitals and clinics, independent of location, size, and type of resources available. In settings where resources are sparse, it is very important that they are used efficiently, and that patients in most need can have access to the necessary diagnostic tools in a most efficient and medically justified way. The most important message, however, is that no diagnostic imaging procedure should be a "stand alone". In addition to a solid knowledge about what is relevant and what might not be, an open-minded communication between clinician and radiologist or radiological technician is the most basic requirement for medical success in this context. Also, the clinical examination of the patients should always be given first and highest priority. Any diagnostic imaging procedure regardless of type and degree of sophistication, may be positive for the patient only when seen in a clinical perspective.

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