

EUROPEAN COMMISSION

EUROPEAN GUIDELINES ON QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES IN PAEDIATRICS



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EUROPEAN GUIDELINES ON QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES IN PAEDIATRICS

These guidelines result from a European wide cooperation between the various professionals and authorities involved in diagnostic radiology (see Chapter 4).

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EUROPEAN GUIDELINES ON QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES IN PAEDIATRICS

PREAMBLE

Quality and safety have become hallmarks for efficient and successful medical intervention. A comprehensive quality and safety culture has been progressively developed throughout the European Union with regard to the medical use of ionising radiation, and has been integrated into the various branches of diagnosis and treatment.

The Commission of the European Communities contributes to this evolution by the establishment of legal requirements for the radiation protection of persons undergoing medical examination or treatment,¹ of safety requirements for medical devices² and by participating in research for the implementation and updating of these requirements.

The establishment of the Quality Criteria for Diagnostic Radiographic Images is one of the milestones of these European initiatives. It started in 1984 when also the first Directive on Radiation Protection of the Patient was adopted by the Member States of the European Union. Following the development of Quality Criteria for adult radiology³ it was **recognised that Quality Criteria needed to be specifically adapted to paediatric radiology.**

This is supported by the fact that, because of their longer life expectancy, the risk of late manifestations of detrimental radiation effects is greater in children than in adults. Radiation exposure in the first ten years of life is estimated, for certain detrimental effects, to have an attributable lifetime risk three to four times greater than after exposures between the ages of 30 and 40 years, and five to seven times greater when compared to exposures after the age of 50 years.⁴

This impressively higher individual somatic radiation risk in the younger age groups has been only inadequately considered in radiation protection so far. It is therefore essential to develop appropriate radiation protection measures also in the field of diagnostic radiology for paediatric patients.

¹ Council Directive 84/466 EURATOM, Official Journal L 265/1, 5.10.1994.

² Council Directive 93/42 EEC, Official Journal L 169/1, 12.7.1993.

³ Report EUR 16260, 1996.

⁴ UNSCEAR Report "Sources, Effects and Risks of Ionizing Radiation", p. 433, 1988.

The Quality Criteria for paediatric radiology have been elaborated in a common effort by a European Group of paediatric radiologists, (the Lake Starnberg Group), together with radiographers, physicists, radiation protection experts, health authorities and professional national and international organisations.

The aim of the Quality Criteria is to characterize a level of acceptability of normal basic radiographs which could address any clinical indication. They have first been set up for conventional radiography, concentrating on examinations of high frequency or with relatively high doses to the patient.

The following frequent paediatric radiographic examinations were selected as a first step: chest, skull, pelvis, full and segmental spine, abdomen and urinary tract. The age groups and X-ray examinations using fixed X-ray installations were limited to 10 month old infants for chest AP/PA, skull AP/PA, spine, lateral view, abdomen, AP supine position; and 4 month old babies for pelvis AP. The corresponding criteria for mobile X-ray equipment were for 10 month old infants, and premature babies with weight approximately 1 kg undergoing a chest AP examination in supine position. In a second and third step the age groups of 5 and 10 year old children were added.

The applicability of the Quality Criteria has been checked in European wide Trials involving about 160 paediatric X-ray departments in 14 Member States and other European countries, and roughly 1600 radiographic films and dose measurements.

The results have been discussed at Workshops, by working parties and dedicated study groups, as well as by independent experts all over the world. The conclusions have been integrated in the present Guidelines and provided elements for the improvement of the lists of Quality Criteria.

The **European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics** contain four chapters:

The first chapter concerns the updated lists of the Quality Criteria for conventional paediatric examinations of chest, skull, pelvis, full and segmental spine, abdomen and urinary tract for different projections and, where necessary, specific criteria for newborns. This first chapter defines Diagnostic Requirements for a normal, basic radiograph, specifying anatomical Image Criteria; indicates Criteria for the Radiation Dose to the Patient, as far as available, and gives an Example for Good Radiographic Technique by which the Diagnostic Requirements and the dose criteria can be achieved.

The second chapter summarises the analysis of the findings of the European wide Trials and explains the updating of the Quality Criteria as listed in Chapter 1.

The third chapter outlines a procedure for implementing and auditing the Quality Criteria; a model of the scoring tables, and adapted questionnaires that have been developed during the evaluation of the Trials, are reproduced and can become tools for self-learning and performance checking.

The fourth chapter presents all those to whom the European Commission's services wish to express their sincere thanks for co-operation and creative criticism, which encouraged the EC's Radiation Protection Actions to concentrate on the development of this Quality Criteria concept.

These efforts will continue in the near future in the framework of the coming research programmes and in the updating of the EURATOM Directive.¹ The ongoing revision of this Directive proposes the establishment of quality assurance measures including criteria that can be employed and checked in a comparable way so that the radiation dose to the patient can be linked to the required image quality and to the performance of the radiographic procedure. The indication of reference dose values is also recommended.

Therefore it is with great satisfaction that the services of the European Commission present these "European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics". The Guidelines do not pretend to give strict instructions for the day-to-day radiological practice but attempt to introduce basic criteria that have been proved to lead to the necessary quality of the diagnostic information with reasonable dose values applied to the patient. This is a first step in the optimisation of medical exposures, whereby a lower quality standard should ideally be associated to lower dose. Compliance with these Guidelines will help to protect the patient and staff against unnecessary radiation exposure and will prevent any degradation of the equipment or faulty use of the imaging procedure from resulting in unsatisfactory images.

It is the hope of the European Commission's services that the Guidelines will stimulate the professionals involved in diagnostic radiology to look for the improvements in the criteria and their extension to other types of examination or new techniques.

The Guidelines will be available in nine official languages of the European Union.

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QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES IN PAEDIATRICS

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INTRODUCTION

The two basic principles of radiation protection of the patient as recommended by ICRP are justification of practice and optimisation of protection, including the consideration of dose reference levels (1,2,3). These principles are largely translated into a legal framework by the EURATOM Directive (4).

Justification is the first step in radiation protection, particularly in paediatric patients. It is accepted that no diagnostic exposure is justifiable without a valid clinical indication, no matter how good the imaging performance may be. Every examination must result in a net benefit for the patient. This only applies when it can be anticipated that the examination will influence the efficacy of the decision of the physician with respect to the following:

- diagnosis
- patient management and therapy
- final outcome for the patient

Justification also implies that the necessary result cannot be achieved with other methods which would be associated with lower risks for the patient.⁵

As a corollary, justification requires that the selected imaging procedure is acceptably reliable, i.e. its results are reproducible and have sufficient sensitivity, specificity, accuracy, and predictive value with respect to the particular clinical question.

Justification also necessitates that a person, trained and experienced in radiological techniques and in radiation protection (as recognised by the competent authority), normally a radiologist, takes the overall clinical responsibility for an examination. This person should work in close contact with the referring physician in order to establish the most appropriate procedure for the patient management and therapy. The responsible person can - as appropriate - delegate responsibility to perform the examination to a qualified technician, who must be suitably trained and experienced.

Guidance on referral criteria for adult and paediatric patients can be found in WHO reports 689 (5), and 757 (6), respectively, and guidelines for making the best use of a department of radiology are available from the Royal College of Radiologists, London, (7a) and from the German Federal Medical Board (7b).

In respect of diagnostic examinations ICRP does not recommend the application of dose limits to patient irradiation but draws attention to the use of dose reference levels as an aid to optimisation of protection in medical exposure. Once a diagnostic examination has been clinically justified, the subsequent imaging process must be optimised. The optimal use of ionising radiation involves the interplay of three important aspects of the imaging process:

- the diagnostic quality of the radiographic image
- the radiation dose to the patient
- the choice of radiographic technique.

This document provides guidelines on all three of these aspects. As it is not practicable to assess the full range of radiodiagnostic procedures, examinations have been chosen which are either common or give significant patient dose, or both. The examinations are: chest, skull, pelvis, full and segmental spine, abdomen and urinary tract on fixed X-ray installations and chest employing mobile equipment. No attempt has been made to define the procedure for complete examinations. These are often a matter of personal preference of the radiologist and will be determined by local conditions and particular clinical situations. Instead, quality criteria have been drawn up for representative radiographs from the routine examinations listed above. Compliance with the criteria for these radiographs is a first but important step in ensuring satisfactory overall performance.

Similar documents have been prepared for conventional radiodiagnostic procedures in the adult (8) and for computed tomography (9). The need for a comparable effort for fluoroscopy employing image intensification is recognised.

⁵ H. Fendel et al. "Efficacy of Diagnostic Use of X-Rays in Paediatrics", 2nd Report for the Federal Ministry of Environment, Protection of Nature and Reactor Safety, Bonn, 1987, in German.

OBJECTIVES

The objectives of the Guidelines presented in this document are to achieve:

- adequate image quality, comparable throughout Europe;
- accurate radiological interpretation of the image; and
- reasonably low radiation dose per radiograph.

The Guidelines are primarily directed at the technical and clinical staff involved in taking the radiographs and in reporting on them. The Quality Criteria may provide the standard for quality assurance programmes and also serve as a basis for self-education and training in good imaging practice. They will also be of interest to those responsible for the design of X-ray imaging equipment and for the maintenance of its functional performance. They will be helpful to those who have responsibility for equipment specification and purchase.

The Guidelines represent an achievable standard of good practice which can be used as a basis for further development by the radiological community.

The **Image Criteria** for paediatric patients presented for a particular type of radiograph are those deemed necessary to produce an image of standard quality. No attempt has been made to define acceptability for particular clinical indications. The listed image criteria allow an immediate evaluation of the image quality of the respective radiograph. They are appropriate for the most frequent requirements of radiographic imaging of paediatric patients. Where necessary, specific clinical questions and situations are taken into account.

The anatomical features and body proportions vary due to the developmental process in infancy, childhood and adolescence. They are different in the respective age groups and are distinct from those of a mature patient. The Guidelines presuppose knowledge of the changing radiographic anatomy of the developing child. The term "consistent with age" indicates that the respective image criteria essentially depend on the age of the patient.

The smaller body size, the age dependent body composition, the lack of co-operation and many functional differences (e.g. higher heart rate, faster respiration, inability to stop breathing on command, increased intestinal gas etc.) prevent the production of radiographic images in paediatric patients to which standard adult image criteria can be applied. This, however, does not imply that all quality criteria are inappropriate; they must be adapted to paediatric imaging.

Correct positioning of paediatric patients may be much more difficult than in co-operative adult patients. Effective immobilisation often necessitates the use of auxiliary devices. Sufficient skill and experience of the imaging staff and ample time for the particular investigation are the imperative prerequisites to fulfil this quality criterion in infants and younger children. No diagnostic radiation exposure should be allowed unless there is a high probability that the exact positioning will be maintained. Incorrect positioning is the most frequent cause of inadequate image quality in paediatric radiographs. Image criteria for the assessment of adequate positioning (symmetry and absence of tilting etc.) are much more important in paediatric imaging than in adults.

The reasons for diagnostic imaging in paediatrics are often essentially different from those in adult medicine. They vary in the different paediatric age groups. Image quality must be adapted to the particular clinical problem.

In paediatric diagnostic imaging, image quality must be a constant preoccupation; nevertheless, more often than in adults, a lower level of image quality may be acceptable for certain clinical indications. An inferior image quality, however, cannot be justified unless this has been intentionally designed and must then be associated with a lower radiation dose. The fact that the X-ray was taken from a non-cooperative paediatric patient (anxious, crying, heavily resisting) is not an excuse for producing an inferior quality film which is often associated with an excessive dose.





Important Image Details

In contrast to the European Guidelines on Quality Criteria for Diagnostic Radiographic Images for adult patients (8), minimum dimensions of important image details as a means to recognise specific normal or abnormal anatomical details are not indicated in these Guidelines, since in paediatric radiology such image details essentially depend on the particular clinical situation. The fulfilment of the appropriate Image Criteria and the adherence to the example of good radiographic technique will ensure that important pathological image details will not be missed.

The Criteria for Radiation Dose to the Patient included in these Guidelines are expressed in terms of a reference value for the entrance surface dose for a “standardized” paediatric patient. However, reference dose values are available only for the most frequently performed types of radiographs for which sufficient data were acquired in a series of European Trials on infants, 5 year old and 10 year old patients. An overview of the derivation of the reference dose values from the Trial data is given in Chapter 2: Summary of the Evaluations of the European Trials of the Quality Criteria, Part 2: Patient Dose. For reasons indicated there, the reference dose values given under the Criteria for Radiation Dose to the Patient are those for the standard 5 year old patient. The purpose of these reference doses and methods for checking compliance with them are discussed in Appendix I to this Chapter.

The Examples of Good Radiographic Technique included in these Guidelines have evolved from the results of a European Trials of the Quality Criteria. Compliance with the image and patient dose criteria, where available, was possible when the recommended techniques were used.

To encourage widespread use, the image criteria have been expressed in a manner requiring personal visual assessment rather than objective physical measurements, which need sophisticated equipment unavailable to most departments. However, the assessment of compliance with the criteria for radiation dose to the patient for a specific radiograph unavoidably involves some form of dose measurement. This requires representative sampling of the patient population. A number of dose measurements methods are described in Appendix I.



GENERAL PRINCIPLES ASSOCIATED WITH GOOD IMAGING PERFORMANCE

The following general principles are common to all radiographic X-ray examinations. All those who either carry out X-ray examinations or report on the results should be aware of them.

Specific aspects of these principles are discussed in greater detail in a number of publications by national and international organisations, some of which are listed in reference (1) to (17) (see page 15).

1. Image Annotation

The patient identification, the date of examination, positional markers and the name of the facility must be present and legible on the film. These annotations should not obscure the diagnostically relevant regions of the radiograph. An identification of the radiographers on the film would also be desirable.

2. Quality Control of X-ray Imaging Equipment

Quality control programmes form an essential part of dose-effective radiological practice. Such programmes should be instigated in every medical X-ray facility and should cover a selection of the most important physical and technical parameters associated with the types of X-ray examination being carried out. Limiting values for these technical parameters and tolerances on the accuracy of their measurement will be required for meaningful application of the Examples of Good Radiographic Technique presented in these Guidelines. BIR Report 18 (12) provides further useful information on this subject.

3. Low Attenuation Materials

Recent developments in materials for cassettes, grids, tabletops and front plates of film-changers using carbon fibre and some new plastics enable significant reduction in patient doses. This reduction is most significant in the radiographic-voltage range recommended in paediatric patients and may reach 40%. Use of these materials should be encouraged.

4. Patient Positioning and Immobilisation

Patient positioning must be exact whether or not the patient co-operates. In infants, toddlers and younger children immobilisation devices, properly applied, must ensure that;

- the patient does not move
- the beam can be centred correctly
- the film is obtained in the proper projection
- accurate collimation limits the field size exclusively to the required area
- shielding of the remainder of the body is possible.

Immobilisation devices must be easy to use, and their application atraumatic to the patient. Their usefulness should be explained to the accompanying parent(s).

Radiological staff members should only hold a patient under exceptional circumstances. Where physical restraint by parents or another accompanying person is unavoidable, they must know exactly what is required of them. They must be provided with protection from scattered radiation and be absolutely outside the primary beam of radiation applied to the patient. Pregnant women must not be allowed to assist.

Even in quite young children the time allocation for an examination must include the time to explain the procedure not only to the parents but also to the child. It is essential that

both cooperate, and time taken to explain to a child what will happen is time well spent in achieving an optimised examination fulfilling the necessary quality criteria.

5. Field Size and X-ray Beam Limitation

Inappropriate field size is the most important fault in paediatric radiographic technique. A field which is too small will immediately degrade the respective image criteria. A field which is too large will not only impair image contrast and resolution by increasing the amount of scattered radiation but also — most importantly — result in unnecessary irradiation of the body outside the area of interest.

Consequently, the anatomical areas specified by the respective image criteria define the minimal and the maximal field sizes. Although some degree of latitude is necessary to ensure that the entire field of interest is included, this cannot be accepted as an excuse or repeatedly using too large a field size in paediatric patients.

Correct beam limitation requires proper knowledge of the external anatomical landmarks by the technician. These differ with the age of the patient according to the varying proportions of the developing body. In addition, the size of the field of interest depends much more on the nature of the underlying disease in infants and younger children than in adults (e.g. the lung fields may be extremely large in congestive heart failure and emphysematous pulmonary diseases; the position of the diaphragm may be very high in intestinal meteorism, chronic obstruction or digestive diseases). Therefore, a basic knowledge of paediatric pathology is required for radiographers and other technical assistants to ensure proper beam limitation in these age groups.

The acceptable minimal field size is set by the listed recognisable anatomical landmarks or specific examinations. Beyond the neonatal period, the tolerance for maximal field size should be less than 2 cm greater than the minimal. In the neonatal period, the tolerance level should be reduced to 1.0 cm at each edge.

In paediatric patients, evidence of the field limits should be apparent by clear rims of unexposed film. This is of particular importance; beam-limiting devices automatically adjusting the field to the full size of the cassette are inappropriate for paediatric patients. Discrepancies between the radiation beam and the light beam must be avoided by regular assessment. Even minimal deviations may have a large effect in relation to the usually small field of interest.

6. Protective Shielding

In all examinations of paediatric patients, the Example for Good Radiographic Technique includes standard equipment of lead-rubber shielding of the body in the immediate proximity of the diagnostic field; special shielding has to be added for certain examinations to protect against external scattered and extra-focal radiation. For exposures of 60 - 80 kV, maximum gonadal dose reduction of about 30 to 40% can be obtained by shielding with 0.25 mm lead equivalent rubber immediately at the field edge. However, this is only true when the protection is placed correctly at the field edge. Lead-rubber covering further away is less effective, and at a distance of more than 4 cm is completely ineffective. This may have a psychological effect but provides no radiation protection at all.

The gonads in "hot examinations", i.e. when they lie within or close (nearer than 5 cm) to the primary beam, should be protected whenever this is possible without impairing necessary diagnostic information. It is best to make one's own lead contact shields for girls and lead capsules for boys. They must be available in varied sizes. The testes must be protected by securing them within the scrotum to avoid upward movement caused by the cremasteric reflex. By properly adjusted capsules, the absorbed dose in the testes can be reduced by up to 95%. In girls, shadow masks within the diaphragm of the collimator are as efficient as direct shields. They can be more exactly positioned and do not slip as easily as contact shields. When shielding of the female gonads is effective, the reduction of the absorbed dose in the ovaries can be about 50%.



There is no reason to include the male gonads in the scrotum within the primary radiation field for radiographs of the abdomen. The same applies, usually, for films of the pelvis and micturating cystourethrographies. The tests should be protected with a lead capsule, but kept outside the field. In abdominal examinations gonad protection for girls is not possible. In practice, the great majority of pelvic films show that female gonad protection is completely ineffective. The position of all sorts of lead material is often ludicrous. There are justifiable reasons for omitting gonad protection for pelvic films in girls, e.g. trauma, incontinence, abdominal pain, etc.

The eyes should be shielded for X-ray examinations involving high absorbed doses in the eyes, e.g. for conventional tomography of the petrous bone, when patient co-operation permits. The absorbed dose in the eyes can be reduced by 50% - 70%. In any radiography of the skull the use of PA-projection rather than the AP-projection can reduce the absorbed dose in the eyes by 95%. PA-projection, therefore, should be preferred as soon as patient age and co-operation permit prone or erect positioning.

As developing breast tissue is particularly sensitive to radiation, exposure must be limited. The most effective method is by using the PA-projection, rather than the AP. While this is well accepted for chest examinations, the greatest risk is during spinal examinations, and here PA-examinations must replace AP.

It should also be remembered that thyroid tissue should be protected, whenever possible, e.g. during dental and facial examinations.

7. Radiographic Exposure Conditions

Knowledge and correct use of appropriate radiographic exposure factors, e.g. radiographic voltage, nominal focal spot value, filtration, film-focus distance is necessary because they have a considerable impact on patient doses and image quality. Permanent parameters of the apparatus such as total tube filtration and grid characteristics should also be taken into consideration.

(a) Nominal focal spot value

Usually a nominal focal spot value between 0.6 and 1.3 is suitable for paediatric patients. When bifocal tubes are available, the nominal focal spot value which allows the most appropriate setting of exposure time and radiographic voltage at the chosen focus film distance should be used. This may not always be the smaller one.

(b) Additional filtration

The soft part of the radiation spectrum which is completely absorbed in the patient is useless for the production of the radiographic image and contributes unnecessarily to the patient dose. Part of it is eliminated by the inherent filtration of the tube, tube housing, collimator etc., but this is insufficient. Most tubes have a minimum inherent filtration of 2.5 mm Al. Additional filtration can further reduce unproductive radiation and thus patient dose.

For paediatric patients, total radiation dose must be kept low, particularly when high speed screen film systems or image intensifying techniques are used. Not all generators allow the short exposure times that are required for higher kV technique. Consequently, low radiographic voltage is frequently used for paediatric patients. This results in comparatively higher patient doses.

Adequate additional filtration allows the use of higher radiographic voltage with the shortest available exposure times, thus overcoming the limited capability of such equipment for short exposures. This makes the use of high speed screen film systems and image intensifier photography possible.

filter materials (molybdenum, holmium, erbium, gadolinium or other rare-earth material) with absorption edges at specific wavelengths have no advantages compared to simple and inexpensive aluminium-copper (or aluminium-iron) filters, which can easily be home-made. All tubes used for paediatric patients in stationary, mobile or fluoroscopic equipment should have the facility for adding additional filtration and for changing it easily, when appropriate. Usually, additional filtration of up to 1 mm aluminium plus 0.1 mm or 0.2 mm copper can be appropriate. For standard diagnostic radiographic-voltages, every 0.1 mm copper equals about 3 mm aluminium.

c) Anti-scatter grid

In infants and younger children the use of a grid or other anti-scatter measures is often unnecessary. The examples for good radiographic technique specify when grids are superfluous. Not using grids will then avoid excessive patient dose. Where anti-scatter measures are necessary, grid ratios of 8 and line numbers of 40/cm (moving grid) are usually sufficient even at higher radiographic-voltages. Grids incorporating low attenuation materials such as carbon fibre or other nonmetallic material are preferable. Moving grids may present problems in very short exposure times (< 10 ms); in these cases stationary grids with high strip densities (≥ 60 /cm) should be used. Quality control of moving grid devices for paediatric patients must take this into consideration. The accurate alignment of grid, patient and X-ray beam, as well as careful attention to the correct focus-grid distance is of particular importance.

In the supplementary fluoroscopic examinations of the urinary tract, a grid is rarely necessary. Only fluoroscopic equipment with the potential for quick and easy removal of the grid should be used in these age groups. Removable grids are not only desirable for fluoroscopic work; ideally, all equipment used for paediatric patients should have this facility.

d) Focus-film distance (FFD)

Regarding this item there are no differences from adult patients. The FFD is usually approximately 115 cm for over-couch tubes with grid tables and 150 cm for vertical stands. The correct adjustment of the grid to FFD must be observed. When no grid is used and the cassette is placed upon the table, an FFD of about 100 cm should be chosen (so that the same tube-table distance as with a grid is obtained). Longer distances of FFD — indicated in parentheses — may be used for special reasons.

In all fluoroscopic examinations, patient to film and patient to image intensifier distances should be kept as short as possible to reduce patient dose. This has particular significance when using automatic brightness control.

e) Radiographic voltage

As already mentioned, in spite of recommended high voltage techniques lower radiographic voltage is still often used in paediatric patients. Lower settings than the voltages specified in these Guidelines should be avoided wherever possible.

It must be remembered that the effective radiographic voltage depends on the type and age of the generator. Considering the very short exposure times, a nearly rectangular radiation waveform and a minimal amount of ripple are desirable for paediatric patients. 1-, 2- and 6-pulse generators cannot provide this. 12-pulse or high frequency multi-pulse (so-called converter) generators are required. This means — and this is often misunderstood — that the smallest patients need the most powerful machines.

For mobile equipment converter generators are preferable. The disadvantage of capacitor discharge generators is that radiographic voltage decreases over the exposure time (for common exposure times, approximately 1 kV/mAs). One and two-pulse generators should no longer be used. For a 10 month old infant, a chest X-ray with identical film blackening



requires an exposure nearly 20-times longer and gives 2.15-times higher entrance surface dose, when a 1-pulse generator is used instead of a converter generator.

The preset radiographic voltage and effective radiographic voltage may not be identical. In very short exposure times even small discrepancies may have an impact on image quality. When short exposure settings are inconstant, they will effectively influence film blackening and patient dose. Quality control programmes should be meticulous in this regard when assessing equipment for paediatric patients. Generators which do not fulfil requirements for proper and stable calibration (within a tolerance range of about $\pm 10\%$) should not be used for paediatric patients and should be replaced as soon as possible.

The radiation emitted by the tube requires a certain time to reach its peak voltage. With the longer exposures used in adult patients, this pre-peak time radiation is insignificant. With the very short exposure times in paediatric radiography, pre-peak times must be taken into consideration. Some old generators have pre-contact phases in which soft radiation may be emitted. Added filtration eliminates this which is another reason for advocating its use.

(f) Automatic exposure control

Adult patients vary in size, but their variation is minimal compared to the range in paediatric patients: premature infants, weighing considerably less than a thousand grammes, to adolescents approaching 70 kg. Those investigating paediatric patients must be able to adapt to this range. One would expect that a device for automatic exposure control (AEC) would be helpful. However, many of the systems commonly available are not satisfactory. They have relatively large and fixed ionisation chambers. Neither their size nor their shape nor their position is able to compensate for the many variations of body size and body proportion in paediatric patients. In addition, the usual ionisation chambers of AECs are built in behind a grid. Consequently, AEC-use may be associated with the use of the grid (where the grid is not removable) which — as previously mentioned — is frequently unnecessary.

The optimal adaptation of the radiographic technique to the clinical needs requires the use of screen film systems of different speeds and different switch-off doses at the image receptor. Screens and AEC chambers are wavelength dependant, particularly in the lower range of radiographic voltage, but these dependencies do not correspond with each other. AECs lengthen the minimal exposure times. All these factors must be considered when AECs are used in paediatric patients. They are complicated to use and result in many unsatisfactory examinations.

Specially designed paediatric AECs have a small mobile detector for use behind a lead-free cassette. Its position can be selected with respect to the most important region of interest. This must be done extremely carefully, as even minor patient movement may be disastrous. The high speed of modern screens allows a minute dose at the cassette front. Consequently, the detector behind the cassette has to work in the range of a fraction of 1 mGy. It is nearly impossible to provide constancy and reproducibility in this range.

Much safer, easy-to-use and less expensive are exposure charts corresponding to radiographic technique and patient's weight — the so-called body index — when X-raying the trunk, or patient's age for the extremities. In the future, small and simple computers may incorporate multifactorial parameters for this purpose. A learning "intelligent" unit would be ideal for paediatric patients.

The EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE indicates when the AEC may be used and which chamber should be selected.

(g) Automatic brightness control

Automatic brightness control has to be switched off during fluoroscopic examinations where there are relatively large areas of positive contrast material to avoid excessive dose rates, e.g. full bladders.

h) Exposure time

In paediatric imaging, exposure times must be short because young patients do not cooperate and are difficult to restrain. These short times are only possible with powerful generators and tubes, as well as optimal rectification and accurate time switches. The equipment must work and provide constancy in the shortest time range. For old generation generators, exposure time settings lower than 4 ms — although desired — should not be used: the pre-peak times (> 2 ms) interfere, to a relatively greater degree, with short preset exposures; therefore, under the Example of Good Radiographic Technique, exposure times are indicated for the more recent generation of generators such as 12-pulse and converter generators.

For these extremely short exposure times, the cable length between the transformer and the tube is important. The cable works as a capacitor and may — depending on its length — produce a significant surge of radiation after the generator has been switched off. This post-peak radiation may last for 2 ms or more.

Accurately reproducible exposure times around 1 ms with a rectangular configuration of dose rate and wavelength of radiation — practically without pre- and post-radiation — may be achieved with grid controlled tubes.

There are problems associated with the lower limits of the exposure time. For most equipment used for paediatric patients, however, the difficulty is in obtaining optimal short exposure times. Unless it is possible to adapt the available equipment to use the recommended range of exposure times, the equipment should not be used for paediatric patients.

8. Screen Film Systems

Among the technical parameters, the selection of higher speed classes of the screen film system has the greatest impact on dose reduction. In addition, it allows shorter exposure times that minimise motion unsharpness, which is the most important cause of blurring in paediatric imaging. The reduced resolution of higher speed screens is comparatively insignificant for the majority of clinical indications. For special purposes (e.g. bone detail) speed classes of 200 - 400 are preferable. When different sets of cassettes are available, the one — for special indications — with screens of the lower speed and higher resolution, the other for general use, they should be clearly marked.

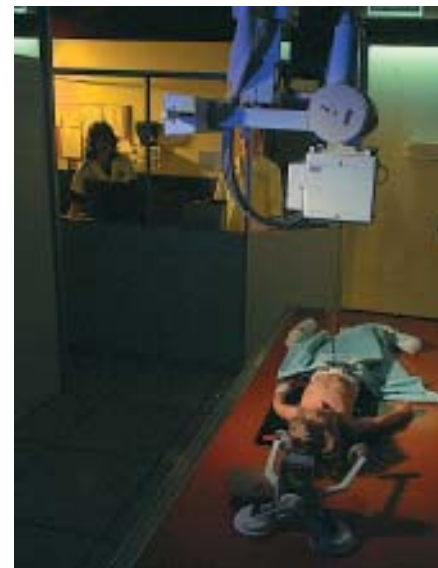
The relationship between the speed class of the screen film system, the dose requirement at the image receptor (μGy), and the lower limit of visual resolution, is described in the norms of ISO and DIN (see ISO 9236 - 1; DIN 6867 - section 1, 1995, see also (18)).

It must be emphasised, that similar screen film systems vary between manufacturers and that intermediate values of the speed classes are common. Therefore, the indicated nominal speed classes in this Document can only give approximate guidance.

The variation in speed which can occur with changes in X-ray beam energy, especially below 70 kV, for individual screen film systems [BIR Report 18 (12)], is recognised. Users should be encouraged to measure the real speeds of their screen film systems under standard conditions resembling those used in practice, to see how closely they match up to the manufacturers' quoted values. Speed classes of 200 and above usually require the use of rare-earth or equivalent intensifying screens. Users are also encouraged to measure the resolution of their screen film systems since this varies with any speed class.

9. Film Blackening

Film blackening (optical density) has a major influence on image quality. For the same radiographic projection it depends on many factors: radiation dose, radiation quality, patient size, radiographic technique, image receptor sensitivity and film processing. It determines the optical densities of a radiographic film. The range of the mean optical density (D) of a clinical radiograph should normally lie between $D = 1.0$ and $D = 1.4$ and the optical densities of fog and film base should not exceed $D = 0.25$. For the diagnostically relevant parts of the film the overall range of optical densities should lie between 0.5 and 2.2.



Whereas the total density above base and fog can be easily - and should be routinely - measured, objective measurement of the mean optical density of the film of a patient requires some expenditure and is not practicable in daily work. Even in external quality control programmes assessors usually base their judgement on subjective and global impressions rather than measurements. For a more precise assessment, the definition of one or a few critical points of the particular radiographic projections would be desirable where the optical density of a specific anatomical feature — and its contrast relative to the surrounding image — could be measured.

Film blackening is subject to the personal preference of the individual radiologist. A darker film may be associated with a relatively higher patient dose. In this respect the preference for darker films should be supported by rational arguments. A film which has been found too dark should be viewed with a bright spot light before a decision is made to repeat the examination.

10. Radiographic Exposures Per Examination

The number of radiographic exposures within one examination must be kept to a minimum consistent with obtaining the necessary diagnostic information.

11. Film Processing

Optimal processing of the radiographic film has important implications both for the diagnostic quality of the image and for the radiation dose to the patient. Film processors should be maintained at their optimum operating conditions as determined by regular and frequent (i.e. daily) quality control procedures. Consistent imaging performance is not necessarily an indication of optimal performance, e.g. the developer temperature may well be set too low.

12. Viewing Conditions

The proper assessment of image quality and accurate reporting on the diagnostic information in the radiographs can best be achieved when the viewing conditions meet the following requirement:

(a) The light intensity incident on the viewer's eye should be about 100 cd/m². To achieve this, the brightness of the film illuminator should be between 2000 and 4000 cd/m² for films in the density range 0.5 to 2.2.

(b) The colour of the illumination should be white or blue and should be matched throughout a complete set of film illuminators.

(c) Means should be available to restrict the illuminated area to the area of the radiograph to avoid dazzling.

(d) Means for magnifying details in the displayed radiographic image should be available. These means should magnify by a factor of 2 to 4 and contain provisions to identify small image details of sizes down to 0.1 mm.

(e) For viewing exceptionally dark areas in the radiographic image an additional spotlight with iris diaphragm providing a brightness of at least 10 000 cd/m² should be available.

(f) A low level of ambient light in the viewing room is essential.

13. Reject Analysis

Rejected films should be collected, the reasons for rejection should be analysed and corrective action should be taken.

GUIDANCE ON IMPLEMENTATION

Quality Criteria are presented for a number of selected radiographic projections used in the course of routine types of X-ray examination. They apply to paediatric patients with the usual presenting symptoms for the type of examination being considered. These Quality Criteria are to be used by radiologists, radiographers, and medical physicists as a check on the routine performance of the entire imaging process.

However, the Quality Criteria cannot be applied to all cases. For certain clinical indications a lower level of image quality may be acceptable, but this should ideally always be associated with a lower radiation dose to the patient.

Under no circumstances should an image which fulfils all clinical requirements but does not meet all image criteria ever be rejected.

Consequently, the decision to repeat an exposure must be made by a physician responsible for that imaging procedure after critically viewing the film and, if necessary, consulting the referring colleague. All rejected films should be retained so they can be used for the planning of appropriate optimisation.

For each selected radiographic projection the quality criteria are divided into three parts:

1. DIAGNOSTIC REQUIREMENTS

Image criteria

These list image criteria which in most cases specify important anatomical structures that should be visible on a radiograph to aid accurate diagnosis. Some of these criteria depend fundamentally on correct positioning and co-operation of the patient whereas others reflect technical performance of the imaging system. A qualitative guide to the necessary degree of visibility of these essential structures is provided in the following Description of Terms. These criteria can be used by radiologists as they report on radiographs to make a personal visual assessment of the image quality: (See Chapter 3: Quality Criteria Implementation and Audit Guidelines).

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Reference values of the Entrance Surface Dose (ESD) are provided, as far as available, for a standard five year old child, for the most frequently performed examinations in these Guidelines. The dose data collected during the Trials have shown that, because of the similarity of Entrance Surface Dose values between infants, 5 year and 10 year old children, the values derived for the 5 year old child can tentatively be used as a reference dose value for all age groups until more representative dose values will become available. A more detailed description on the derivation of the reference dose values is given in Chapter 2: Summary of the Evaluations of the European Trials of the Quality Criteria.

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

This provides an example of one set of radiographic technique parameters that has been found to result in good imaging performance that is capable of meeting all the above Quality Criteria. Information is also given on a suitable combination of accessory devices, geometrical conditions and loading factors using current X-ray imaging technology. If radiologists and radiographers find that Diagnostic Requirements or Criteria for Radiation Dose to the Patient are not met then the Example of Good Radiographic Technique can be used as a guide to how their techniques might be improved. One possibility might also be the use of equipment that fulfils as closely as possible basic requirements to radiographic equipment in paediatric radiology. Guidelines on such basic requirements are presented in Chapter 3.

1. DIAGNOSTIC REQUIREMENTS

Image Criteria

These refer to characteristic features of imaged anatomical structures with a specific degree of visibility. At present time there are no internationally accepted definitions. For the purpose of this Document the degree of visibility is defined as follows:

Visualisation:

Characteristic features are detectable but *details are not fully reproduced*; features just visible

Reproduction:

Details of anatomical structures are visible but not necessarily clearly defined; details emerging

Visually Sharp Reproduction:

Anatomical *details are clearly defined*; details clear.

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

The reference value for the entrance surface dose for a patient is expressed as the absorbed dose to air (μGy) at the point of intersection of the X-ray beam axis with the surface of a paediatric patient, backscatter radiation included. For further information see Appendix 1.

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- 3.0. **Patient position** — upright, supine, prone or lateral.
- 3.1. **Radiographic device** — device supporting the film-screen cassette and the anti-scatter grid.
- 3.2. **Nominal focal spot value** — as indicated by the manufacturer.
- 3.3. **Total filtration** — the aluminium equivalence in mm of the inherent and added filtration.
- 3.4. **Anti-scatter grid** — described in terms of grid ratio “r” and number of absorbing strips per cm for moving grid.
- 3.5. **Screen film system** — the sensitivity of screen film systems is defined in terms of speed [see ISO 9236-1, DIN 6867- section 1, (1995)]. The speed of the screen film system is one of the most critical factors affecting the radiation dose to the patient. For convenience in these Guidelines only broad speed categories — nominal speed classes — are indicated.
- 3.6. **FFD — Focus-to-film distance** (cm). If a focused grid is used, FFD must be within the range indicated by the manufacturers.
- 3.7. **Radiographic voltage** — expressed as the peak kilo-voltage (kV) applied to the X-ray tube, preferably 12-pulse or high frequency multi-pulse (so-called converter) generators.
- 3.8. **Automatic exposure control** — the recommended selection of the measurement chamber in the automatic exposure control device.
- 3.9. **Exposure time** — the time indicated for the duration of the exposure (ms).
- 3.10. **Protective shielding** — protection devices additional to existing standard equipment, in order to further reduce exposure of sensitive organs and tissues.

Values in parentheses indicate options which are less desirable but acceptable for special conditions and indications.

LIST OF REFERENCES FOR CHAPTER 1

The following is a limited reference list. References (11) to (15) contain extensive reference lists.

- 1) ICRP Publication 60, 1990 Recommendations of the International Commission on Radiological Protection, (Pergamon Press, Oxford), 1991.
- 2) ICRP Publication 34, Protection of the Patient in Diagnostic Radiology, (Pergamon Press, Oxford), 1982.
- 3) ICRP Publication 73, "Radiological Protection and Safety in Medicine", in press.
- 4) Council Directive of 3 September 1984 laying down basic measures for the radiation protection of persons undergoing medical examination or treatment (84/466 EURATOM) O.J. Nr L 265, p. 1, 05.10.1984, under revision: COM 95-560 final, 1995.
- 5) WHO Technical Report 689 "A Rational Approach to Radiographic Investigations", (World Health Organisation, Geneva), 1986.
- 6) WHO Technical Report 757 "Rational use of Diagnostic Imaging in Paediatrics", (World Health Organisation, Geneva), 1987.
- 7) Booklet on "Making the Best Use of a Department of Radiology", (Royal College of Radiologists, London), 3rd Edition, 1995.
- 8) Quality Criteria for Diagnostic Radiographic Images, (Office for Official Publications of the European Communities, Luxembourg), Report EUR 16260, 1996.
- 9) Quality Criteria for Computed Tomography, (Office for Official Publications of the European Communities, Luxembourg), Report EUR 16263, in press.
- 10) WHO Report "Quality Assurance in Diagnostic Radiology", (World Health Organisation, Geneva), 1982.
- 11) Criteria and Methods for Quality Assurance in Medical X-ray Diagnosis, BJR Supplement No 18, 1985.
- 12) Technical and Physical Parameters for Quality Assurance in Medical Diagnostic Radiology; Tolerances, Limiting Values and Appropriate Measuring Methods", BIR Report 18, 1989.
- 13) "Optimisation of Image Quality and Patient Exposure in Diagnostic Radiology", BIR Report 20, 1989.
- 14) Test Phantoms and Optimisation in Diagnostic Radiology and Nuclear Medicine; Radiation Protection Dosimetry, Vol. 49, Nos 1-3, 1993.
- 15) Quality Control and Radiation Protection of the Patient in Diagnostic Radiology and Nuclear Medicine; Radiation Protection Dosimetry, Vol. 57, Nos 1-4, 1995.
- 16) National Council on Radiation Protection and Measurements (NCRP). Radiation Protection in Pediatric Radiology. Report No 68. Bethesda: NCRP Publications 1981.
- 17) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR): Sources, Effects and Risks of Ionising Radiation, Report 1988.
- 18) BÄK, Bundesärztekammer. Leitlinien der Bundesärztekammer zur Qualitätssicherung in der Röntgendiagnostik. Dt. Ärztebl. 92. Heft 34-35, 1995.
- 19) Schneider K, Fendel H, Bakowski C, Stein E, Kellner M, Kohn MM, Schweighofer K & Cartagena G. Results of a Europe-wide Dosimetry Study on Frequent X-ray Examinations in Paediatric Populations. Radiation Protection Dosimetry VOL.43, pp 31-36 (1992).

LIST OF QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES IN PAEDIATRICS

PA/AP PROJECTION

(Beyond the newborn period)

For co-operative patients PA projection;
AP projection for non-co-operative patients.

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Performed at peak of inspiration, except for suspected foreign body aspiration
- 1.2. Reproduction of the thorax without rotation and tilting
- 1.3. Reproduction of the chest must extend from just above the apices of the lungs to T12/L1
- 1.4. Reproduction of the vascular pattern in central 2/3 of the lungs
- 1.5. Reproduction of the trachea and the proximal bronchi
- 1.6. Visually sharp reproduction of the diaphragm and costo-phrenic angles
- 1.7. Reproduction of the spine and paraspinal structures and visualisation of the retrocardiac lung and the mediastinum

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 100 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|--------------------------------------|---|
| 3.0. Patient position | : upright, supine position possible |
| 3.1. Radiographic device | : table or vertical stand, depending on age |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid: r = 8; 40/cm | : only for special indications and in adolescents |
| 3.5. Screen film system | : nominal speed class 400 - 800
3.6 FFD 100 - 150 cm |
| 3.7. Radiographic voltage | : 60 - 80 kV (100 - 150 kV with grid for older children) |
| 3.8. Automatic exposure control | : chamber selected - lateral; preferably none in infants and young children |
| 3.9. Exposure time | : <10 ms |
| 3.10. Protective shielding | : lead-rubber coverage of the abdomen in the immediate proximity of the beam edge |

REMARKS There are circumstances where the cervical trachea should be included (e.g. foreign body aspiration, tube position, etc.).

LATERAL PROJECTION

Beyond the newborn period)

This projection must not be done routinely,
and usually only when indicated after evaluation of the PA/AP film

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Performed at the peak of inspiration
- 1.2. True lateral projection
- 1.3. Visualisation of the trachea from the apices of the lungs down to and including the main bronchi
- 1.4. Visually sharp reproduction of the whole of both domes of the diaphragm
- 1.5. Reproduction of the hilar vessels
- 1.6. Reproduction of the sternum and the thoracic spine

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 200 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|---|
| 3.0. Patient position | : upright, supine position possible |
| 3.1. Radiographic device | : table or vertical stand depending on age |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu
(or equivalent) |
| 3.4. Anti-scatter grid | : r = 8; 40/cm; only for special indications and in adolescents |
| 3.5. Screen film system | : nominal speed class 400 - 800 |
| 3.6. FFD | : 100 - 150 cm |
| 3.7. Radiographic voltage | : 60 - 80 kV (100 - 150 kV with grid for older children) |
| 3.8. Automatic exposure control | : chamber selected - lateral; preferably none in infants and young children |
| 3.9. Exposure time | : < 20 ms |
| 3.10. Protective shielding | : lead-rubber coverage of the abdomen in the immediate proximity of the beam edge |

REMARKS: There are circumstances where the cervical trachea should be included (e.g. foreign body aspiration, tube position, etc.).

AP PROJECTION

(Newborns)

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Performed at peak of inspiration
- 1.2. Reproduction of the thorax without rotation and tilting
- 1.3. Reproduction of the chest must extend from the cervical trachea to T12/L1 (part of the abdomen may be included for special purposes)
- 1.4. Reproduction of the vascular pattern in central half of the lungs
- 1.5. Visually sharp reproduction of the trachea and the proximal bronchi
- 1.6. Visually sharp reproduction of the diaphragm and costo-phrenic angles
- 1.7. Reproduction of the spine and paraspinal structures and visualisation of the retrocardiac lung and the mediastinum

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for newborns: 80 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|---|
| 3.0. Patient position | : supine |
| 3.1. Radiographic device | : bedside (table), depending on clinical condition |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : none |
| 3.5. Screen film system | : nominal speed class 200 - 400 |
| 3.6. FFD | : 80 - 100 (150) cm |
| 3.7. Radiographic voltage | : 60 - 65 kV |
| 3.8. Automatic exposure control | : none |
| 3.9. Exposure time | : < 4 ms |
| 3.10. Protective shielding | : lead-rubber masking of the abdomen in the immediate proximity of the beam edge; if direct placement not possible, then masking on the incubator lid |

PA/AP PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Symmetrical reproduction of the skull, particularly cranium, orbits and petrous bones
- 1.2. Projection of the upper margins of the petrous temporal bones into the lower half of the orbits in AP projection
- 1.3. Reproduction of the paranasal sinuses and structure of the temporal bones consistent with age
- 1.4. Visually sharp reproduction of the outer and inner tables of the entire cranial vault consistent with age
- 1.5. Visualisation of the lambdoid and sagittal sutures

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 1500 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|--|
| 3.0. Patient position | : supine, upright position possible |
| 3.1. Radiographic device | : table, grid table, special skull unit or vertical stand with stationary or moving grid |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : r = 8; 40/cm, only for special indications and in adolescents |
| 3.5. Screen film system | : nominal speed class 400 - 800 (200) |
| 3.6. FFD | : 115 (100 - 150) cm |
| 3.7. Radiographic voltage | : 65 - 85 kV |
| 3.8. Automatic exposure control | : chamber selected - central |
| 3.9. Exposure time | : < 50 ms |
| 3.10. Protective shielding | : lead-rubber coverage of the body in the immediate proximity of the beam edge |

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Visually sharp reproduction of the outer and inner tables of the entire cranial vault and the floor of the sella consistent with age
- 1.2. Superimposition of the orbital roofs and the anterior part of the greater wings of the sphenoid bones
- 1.3. Visually sharp reproduction of the vascular channels and the trabecular structure consistent with age
- 1.4. Reproduction of the sutures and fontanelles consistent with age

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 1000 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|--|
| 3.0. Patient position | : supine, upright position possible |
| 3.1. Radiographic device | : table, grid table, special skull unit or vertical stand with stationary or moving grid |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$; 40/cm; only for special indications and in adolescents |
| 3.5. Screen film system | : nominal speed class 400 - 800 (200) |
| 3.6. FFD | : 115 (100 - 150) cm |
| 3.7. Radiographic voltage | : 65 - 85 kV |
| 3.8. Automatic exposure control | : chamber selected - central |
| 3.9. Exposure time | : < 20 ms |
| 3.10. Protective shielding | : lead-rubber coverage of the body in the immediate proximity of the beam edge |

AP PROJECTION

Infants)

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. No tilting: reproduction of the tri-radiate cartilages is in the same horizontal line as the 5th sacral segment or the upper margins of the ischial and pubic ossification centres superimposed
- 1.2. No rotation: a vertical line passing through the middle of the sacrum must pass through the middle of the pubic symphysis or the iliac wings and obturator foramina must be perfectly symmetrical
- 1.3. Reproduction of the necks of the femora in a standard position which should not be distorted by foreshortening or external rotation (patellae parallel to the table top). If a functional study for instability is required, it should be taken in full internal rotation and 45° abduction of the thighs
- 1.4. Visualisation of the peri-articular soft tissue planes

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for infants: 200 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | | |
|-------|----------------------------|--|
| 3.0. | Patient position | : supine |
| 3.1. | Radiographic device | : table |
| 3.2. | Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. | Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. | Anti-scatter grid | : r = 8;40/cm; only for special indications and in adolescents |
| 3.5. | Screen film system | : nominal speed class 400 - 800 |
| 3.6. | FFD | : 100 cm |
| 3.7. | Radiographic voltage | : 60 - 70 kV |
| 3.8. | Automatic exposure control | : none |
| 3.9. | Exposure time | : < 10 ms |
| 3.10. | Protective shielding | : gonad capsules should be employed for male patients and gonad masks or shields for female patients, when diagnostically possible |

AP PROJECTION

(Older children)

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1 Symmetrical reproduction of the pelvis
- 1.2 Visualisation of the sacrum and its intervertebral foramina depending on bowel content (not to be considered in presence of female gonad shielding)
- 1.3 Reproduction of the lower part of the sacroiliac joints (not to be considered in presence of female gonad shielding)
- 1.4 Reproduction of the necks of the femora which should not be distorted by foreshortening or external rotation
- 1.5 Reproduction of spongiosa and cortex
- 1.6 Visualisation of the trochanters consistent with age
- 1.7 Visualisation of the peri-articular soft tissue planes

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 900 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | | |
|------|----------------------------|--|
| 3.0 | Patient position | : supine |
| 3.1 | Radiographic device | : grid table |
| 3.2 | Nominal focal spot value | : 0.6 (≤ 1.3) |
| 3.3 | Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4 | Anti-scatter grid | : $r = 8$; 40/cm |
| 3.5 | Screen film system | : nominal speed class 400 - 800 |
| 3.6 | FFD | : 115 (100 - 150) cm |
| 3.7 | Radiographic voltage | : 70 - 80 kV |
| 3.8 | Automatic exposure control | : chamber selected - central or both laterals |
| 3.9 | Exposure time | : < 50 ms |
| 3.10 | Protective shielding | : gonad capsules should be employed for male patients and gonad masks or shields for female patients, when diagnostically possible |

PA/AP PROJECTION

Only performed for strict clinical indications.)

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Must include the base of the skull and the coccyx, and also the iliac crests
- 1.2. Reproduction of vertebral bodies and pedicles
- 1.3. Visualisation of the posterior articular processes
- 1.4. Reproduction of the spinous and transverse processes consistent with age

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|---|
| 3.0. Patient position | : supine or upright |
| 3.1. Radiographic device | : table, grid table or vertical stand with stationary or moving grid, or vertical stand with special cassettes or special devices |
| 3.2. Nominal focal spot value | : ≤ 1.3 |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$; 40/cm or special cassettes; no grid for infants < 6 months of age |
| 3.5. Screen film system | : nominal speed class 600 - 800 |
| 3.6. FFD | : 150 - 200 cm |
| 3.7. Radiographic voltage | : 65 - 90 kV |
| 3.8. Automatic exposure control | : none |
| 3.9. Exposure time | : < 800 ms |
| 3.10. Protective shielding | : gonad capsules should be employed for male patients. (see also remarks) |

REMARKS: PA Projection is recommended in order to reduce radiation exposure to the radio-sensitive breast tissue. Edge filters should be used when possible and are preferable to graded screens. Follow-up examinations on scoliotic patients can often be limited to C7 to iliac crests.

PA/AP PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Reproduction as a single line of the upper and lower plate surfaces in the centre of the beam
- 1.2. Visualisation of the intervertebral spaces in the centre of the beam area
- 1.3. Visually sharp reproduction of the pedicles, dependent on the anatomical segment
- 1.4. Visualisation of the posterior articular processes (for lumbar spine examinations)
- 1.5. Reproduction of the spinous and transverse processes consistent with age
- 1.6. Visually sharp reproduction of the cortex and trabecular structures consistent with age
- 1.7. Reproduction of the adjacent soft tissues

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|--|
| 3.0. Patient position | : supine or upright |
| 3.1. Radiographic device | : table, grid table or vertical stand with stationary or moving grid, depending on age |
| 3.2. Nominal focal spot value | : 0.6 (≤ 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$; 40/cm or special cassettes, no grid for infants < 6 months of age |
| 3.5. Screen film system | : nominal speed class 400 - 800 |
| 3.6. FFD | : 115 (100 - 150) cm |
| 3.7. Radiographic voltage | : 60 - 85 kV |
| 3.8. Automatic exposure control | : chamber selected - central |
| 3.9. Exposure time | : < 50 ms |
| 3.10. Protective shielding | : gonad capsules should be employed for male patients |

REMARKS: Dispersion of overlying bowel gas can be obtained in examinations of lumbar spine and sacrum by compression of the abdomen. This will also reduce movement blurring and radiation exposure.

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Reproduction as a single line of the upper and lower plate surfaces in the centre of the beam
- 1.2. Full superimposition of the posterior margins of the vertebral bodies
- 1.3. Reproduction of the pedicles and the intervertebral foramina
- 1.4. Visualisation of the posterior articular processes
- 1.5. Reproduction of the spinous processes consistent with age
- 1.6. Visually sharp reproduction of the cortex and trabecular structures consistent with age
- 1.7. Reproduction of the adjacent soft tissues

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- 3.0. Patient position : supine or upright
- 3.1. Radiographic device : table, grid table or vertical stand with stationary or moving grid, depending on age
- 3.2. Nominal focal spot value : 0.6 (≤ 1.3)
- 3.3. Additional filtration : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent)
- 3.4. Anti-scatter grid : r = 8; 40/cm no grid for infants <6 months of age
- 3.5. Screen film system : nominal speed class 400 - 800
- 3.6. FFD : 115 (100 - 150) cm
- 3.7. Radiographic voltage : 65 - 90 kV
- 3.8. Automatic exposure control : chamber selected - central
- 3.9. Exposure time : < 100 ms
- 3.10. Protective shielding : gonad capsules should be employed for male patients

AP/PA PROJECTION WITH VERTICAL/HORIZONTAL BEAM

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Reproduction of the abdomen, from the diaphragm to the ischial tuberosities, including the lateral abdominal walls
- 1.2. Reproduction of the peritoneal fat lines consistent with age
- 1.3. Visualisation of the kidney outlines consistent with age and depending on bowel content
- 1.4. Visualisation of the psoas outline consistent with age and depending on bowel content
- 1.5. Visually sharp reproduction of the bones

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: 1000 μ Gy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|---|
| 3.0. Patient position | : supine, prone or decubitus |
| 3.1. Radiographic device | : table, grid table |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$; 40/cm, no grid for infants < 6 months of age; grid cassettes for decubitus views |
| 3.5. Screen film system | : nominal speed class 400 - 800 |
| 3.6. FFD | : 100 - 115 cm |
| 3.7. Radiographic voltage | : 65 - 85 kV (100 - 120 kV for older children) |
| 3.8. Automatic exposure control | : chamber selected - central or both lateral; preferably none in infants and young children |
| 3.9. Exposure time | : < 20 ms |
| 3.10. Protective shielding | : gonad capsules should be employed for male patients. Lead-rubber coverage of the thorax in the immediate proximity of the beam edge will reduce radiation exposure to radiosensitive breast tissue and the bone marrow in sternum and ribs. |

REMARKS: Depending on the stature of the child, it is not always possible to satisfy image criteria No 1.1 on a single film. PA projection is recommended for decubitus views.

AP/PA PROJECTION

(Without or before administration of contrast medium)

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Reproduction of the area of the whole urinary tract from the upper pole of the kidney to the base of the bladder and the proximal urethra
- 1.2. Visualisation of the kidney outlines consistent with age and depending on bowel content
- 1.3. Visualisation of the psoas outline consistent with age and depending on bowel content
- 1.4. Visually sharp reproduction of the bones

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- 3.0. Patient position : supine or prone
- 3.1. Radiographic device : table, grid table
- 3.2. Nominal focal spot value : 0.6 (≤ 1.3)
- 3.3. Additional filtration : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent)
- 3.4. Anti-scatter grid : r = 8; 40/cm, no grid for infants < 6 months of age
- 3.5. Screen film system : nominal speed class 400 - 800
- 3.6. FFD : 100 - 115 cm
- 3.7. Radiographic voltage : 65 - 85 kV (100 - 120 kV for older children)
- 3.8. Automatic exposure control : chamber selected - central or both lateral
- 3.9. Exposure time : < 20 ms
- 3.10. Protective shielding : gonad capsules should be employed for male patients. Lead-rubber coverage of the thorax in the immediate proximity of the beam edge will reduce radiation exposure to radiosensitive breast tissue and the bone marrow in sternum and ribs.

REMARKS: Bowel preparation is recommended for patients over one year of age. Displacement of overlying bowel gas and faeces is essential for adequate urinary tract reproduction and can be obtained by compression of the whole abdomen and by oblique or prone views, or by tube angulation, making tomography unnecessary. Compression of the abdomen will also reduce movement blurring and radiation exposure; no compression in suspected tumours, trauma or acute obstruction.

AP/PA PROJECTION

(After administration of contrast medium)

Contrast medium should rarely be administered without a preceding evaluation by a sonographic examination. Image criteria refer to a sequence of radiographs determined by an experienced qualified physician who will restrict their number to the minimum necessary for solving the clinical problem. There is no need for conventional tomography.

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. Visualisation of the outline of the kidneys by the increase in parenchymal density (nephrographic effect) in the early film(s) which should be collimated to include the whole of both renal areas
- 1.2. Visually sharp reproduction of the renal pelvis and calyces (pyelographic effect)
- 1.3. Reproduction of the pelvi-ureteric junction
- 1.4. Visualisation of the area normally traversed by the ureter
- 1.5. Reproduction of the whole bladder and the proximal urethra

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---------------------------------|--|
| 3.0. Patient position | : supine or prone |
| 3.1. Radiographic device | : table, grid table |
| 3.2. Nominal focal spot value | : 0.6 (≤ 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$; 40/cm; no grid for infants < 6 months of age |
| 3.5. Screen film system | : nominal speed class 400 - 800 |
| 3.6. FFD | : 100 - 115 cm |
| 3.7. Radiographic voltage | : 65 - 80 kV |
| 3.8. Automatic exposure control | : chamber selected - central or both lateral |
| 3.9. Exposure time | : < 20 ms |
| 3.10. Protective shielding | : gonad capsules should be employed for male patients. Lead-rubber coverage of the thorax in the immediate proximity of the beam edge will reduce radiation exposure to radiosensitive breast tissue and the bone marrow in sternum and ribs. Coverage of the lower abdomen for the nephrographic film |

REMARKS: Bowel preparation is recommended for patients over one year of age. Displacement of overlying bowel gas and faeces is essential for adequate urinary tract reproduction and can be obtained by compression of the whole abdomen and by oblique or prone views, or by tube angulation, making tomography unnecessary. Compression of the abdomen will also reduce movement blurring and radiation exposure; no compression in suspected tumours, trauma or acute obstruction.

MICTURATING CYSTOURETHROGRAPHY (MCU)

Fluoroscopic control is recommended. Fluoroscopy should be intermittent and brief using small fields. Spot films of the base of the bladder should be taken at the end of the filling phase, except in cases of filling defects, when they should be taken early.

1. DIAGNOSTIC REQUIREMENTS

Image criteria

- 1.1. True lateral or steep oblique projection is recommended for bladder outlet and urethra
- 1.2. Reproduction at the peak of voiding of the bladder outlet and proximal urethra and of the entire male urethra in cases of flow disturbances or other penile pathology
- 1.3. Visualisation of any vesico-ureteric reflux for grading
- 1.4. Visualisation of any intrarenal reflux
- 1.5. Reproduction of the refluxing uretero-vesical junction in appropriate oblique projections
- 1.6. Visualisation of the ureter for evaluation of ureteric function after voiding
- 1.7. Reproduction of the whole extent of any duplication

2. CRITERIA FOR RADIATION DOSE TO THE PATIENT

Entrance surface dose for standard five year old patient: no values as yet available

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

- | | |
|---|--|
| 3.0. Patient position | : filling phase in supine position, voiding phase in supine, lateral or upright position |
| 3.1. Radiographic device | : tilting fluoroscopic table |
| 3.2. Nominal focal spot value | : 0.6 (\leq 1.3) |
| 3.3. Additional filtration | : up to 1 mm Al + 0.1 or 0.2 mm Cu (or equivalent) |
| 3.4. Anti-scatter grid | : $r = 8$, 40/cm; no grid for infants < 6 months of age |
| 3.5. Screen film system | : nominal speed class 400 - 800 or image intensifying fluorography |
| 3.6. Object-to-film/-image intensifier distance | : as short as possible |
| 3.7. Radiographic voltage | : 65 - 90 kV (120 kV for older children) |
| 3.8. Automatic exposure control | : measuring chamber should not be covered by the contrast filled urinary bladder |
| 3.9. Exposure time | : < 20 ms |
| 3.10. Protective shielding | : testicle capsules for boys |

REMARKS: Slow dilute contrast medium instillation (\leq 30%) using drip infusion.