4. GENERAL RADIOLOGY

The wide range of activities that constitute general radiology are considered in this section. They include film screen radiography, which was the staple of the field until recently. The subset of radiography practiced with mobile equipment and the conditions under which it is appropriate to use such systems are also considered. Dental radiography is a special case and is briefly reviewed in Section 4.3. In all cases, radiography is now commonly practiced using digital receptors to replace films and screens. The more widely used receptors in computed radiography (CR) and direct digital radiography (DR) are considered in Section 4.2.4. The section starts with a discussion of justification and the particular concerns it raises in pediatric radiology.

4.1. JUSTIFICATION IN FILM SCREEN RADIOGRAPHY, COMPUTED RADIOGRAPHY AND DIGITAL RADIOGRAPHY

As emphasized in Section 2.2, all radiographic examinations are required to be justified [2]. This gives rise to particular considerations in pediatric radiology. When doubt arises about whether or not a procedure is justified, the final decision will be made through consultation between the appropriately trained and/or experienced radiological medical practitioner and the referring medical practitioner, as appropriate. In this context, it is important to ask the referring practitioner, the patient and/or the family about previous procedures.

Examples of examinations which are often requested but which experienced pediatric radiologists will generally not advise as routinely indicated are listed in Table 7. In dealing with any request for an examination, it is important to consider the clinical history, previous examinations and the availability of alternative modalities that do not use ionizing radiation.

Excellent tools have been developed to assist in justification. They include referral or appropriateness guidelines for radiological examinations, such as those developed by various bodies [17, 28–30]. In these, a marker for the strength of the evidence base on which recommendations are made is provided. An updated version of the 2001 EC referral guidelines for pediatric radiology was published by the EC in 2008 and is reproduced in Appendix II [28, 29].

The guidelines are advisory rather than mandatory, and how they are applied may have evolved since their publication. They were developed for conditions that prevailed in Europe [62] at the time of publication and will need to be adapted to any specific circumstances to take due account of place and time. The issuing of a further revised set of guidelines is being planned by the EC.

TABLE 7. JUSTIFICATION PROCESS AND EXAMPLES OF EXAMINATIONS NOT ROUTINELY INDICATED

Justification
Justification is required for all radiographic studies.
The referring practitioner, patient and/or family need to be asked about previous procedures.
Referral guidelines need to be used where appropriate and available.
Alternative approaches, such as ultrasound or MRI, need to be used where appropriate.
Information needs to be provided to the patient in accordance with the BSS [2] or national standards.
Justification needs to be included in clinical audit.
Examples of examinations not routinely indicated
Skull radiograph in a child with epilepsy.
Skull radiograph in a child with headaches.
Sinus radiograph in a child, under 5 years of age, suspected of having sinusitis.
Cervical spine radiograph in a child with torticollis without trauma.
Radiographs of the opposite side for comparison in limb injury.
Abdominal radiographs in children with constipation.
Scaphoid radiographs in children under 6 years of age.

Similar recommendations are available in Canada, the United Kingdom, the USA and elsewhere, but can be difficult to access freely outside the professional bodies involved [15, 17, 30, 31]. There is much variability in the extent to which these tools are implemented in practice.

One of the more important ways of enhancing the justification process is through audit of referral patterns. In general radiology with adults, recent data suggest that 20–40% of examinations could be avoided if clinical decision guidelines were followed [63]. Use of guidelines has a significant impact on this, and with appropriate management, sustainable reductions in exposures can be achieved [5, 17, 33]. There is every reason to expect that guidelines and audit could be similarly effective in pediatric radiology. Thus, there is a compelling case for the wider use of both guidelines and audits.

For most purposes, the justification process followed for general radiography can be applied without much variation for CR and DR. The intent and outcome of the examinations is similar, and the major differences are variations in and the selectability of image quality and dose. These may need to be taken into account in the justification process in due course.

4.2. OPTIMIZATION AND GENERAL RADIOGRAPHY

4.2.1. Optimization in film screen radiography

Once exposures have been justified, protection and safety are required to be optimized [2]. A practical set of techniques for reduction of exposure and optimization of protection and safety in general pediatric radiography is provided in Table 8. This set is similar to the techniques used for radiography in general. However, there are special issues in pediatric radiology that need concerted attention.

One of these is the approach to manual exposure and AEC selection. In the late 1990s, 94% of exposures in pediatric radiography were performed using manual techniques, a much larger proportion than with adults [64]. This practice has to continue until such time as manufacturers provide AEC facilities and/or software based protocols for exposure that are appropriate for pediatric use. Currently installed AEC technology is generally not appropriate for children as the sensor size, geometry and software are normally designed or set up for adults.

Pending developments in design and in technical standards, it is, thus, preferable to use exposure charts specific to the radiographic technique, the patient's size and weight, and the presence or absence of a grid. Developments in exposure sensors and related software, and their intelligent application in pediatric radiology, are a significant challenge for the industry, standardization bodies and hospital staff. Considerable improvement could be achieved in this area with concerted cooperation.

It is important to have a standard type and number of projections for specific indications. Views in addition to the standard ones may only be performed on a case by case basis. For example, comparison radiographs in children for the assessment of trauma are not routinely necessary. It is also important, in practice, to consider the indication for the study. For example, in anintensive care setting, lines and catheters are inherently high contrast and there issignificant opportunity for dose reduction when the clinical indication for a studyis solely to confirm their position.

Beam output, filtration and focal spot size need to be known, to be appropriate for the application, and to be within acceptable limits [49, 59]. Doses can generally be reduced by using additional beam filtration and higher X ray tube voltage (kVp), but at some cost to contrast. Reliable, well managed film processing is essential. Use of fast film–screen combinations is possible for most radiography and allows a significant reduction in dose and exposure time [65]. The consequent reduction in resolution that is possible is insignificant for the majority of clinical indications.

TABLE 8. TECHNIQUES FOR REDUCTION OF EXPOSURE AND OPTIMIZATION OF PROTECTION AND SAFETY IN GENERAL RADIOGRAPHY

There needs to be a standard type and number of projections for specific indications.
Views in addition to standard may only be performed on a case by case basis.
Manual technique selection needs to be used pending equipment developments.
Where practical, a long (or the recommended) focal to skin distance needs to be used.
The X ray beam needs to be carefully collimated to the area of interest, excluding other regions, especially gonads, breast, thyroid and eyes.
Appropriate gonad, thyroid, ovary and breast shielding needs to be used.
Fast film screen combinations are acceptable for the majority of indications.
It needs to be ensured that film processing is working well.
An anti-scatter grid need not normally be used.
Postero-anterior projections need to be used, where practical, for radiographs of chest and spine.
It needs to be ensured that the correct filtration is used to reduce entrance surface dose.
As high an X ray tube voltage as is consistent with the examination requirements needs to be used.
Additional filtration at higher X ray tube voltage needs to be considered.
The use of a small focal spot size and short exposure times need to be balanced.
Quality assurance and audit programs need to be used for all aspects of the department'swork, including film processing.
A system needs to be introduced and used that allows patient dose to be assessed regularly.

Anti-scatter grids are normally not necessary because of the smaller size of children. Anti-scatter grids are usually not advisable for abdominal examinations in patients under 3 years of age or for skull radiographs on patients younger than 1 year old. Not using them avoids unnecessary exposure and results in an approximately 50% reduction in dose [65].

The use of postero-anterior projections, where possible, in performing radiographs of the chest and spine reduces breast dose but may not always be practical in smaller children who cannot fully cooperate. A system for periodic assessment of doses to the patient is needed, and this then enables comparisons to be made with relevant DRLs (see Section 4.2.2). This can become part of the system of quality assurance for medical exposures in the facility.

The beam has to be reliably collimated to the area of interest so that other regions are excluded. Accurate well adjusted collimation that is closely aligned with the light beam diaphragm is essential because of the small size and close proximity of a child's organs. In practice, it is not uncommon to see radiographs with wide open collimation. This practice is unacceptable and is a significant

contributor of avoidable doses. Additional shielding can be important for dose reduction. Gonad and breast shielding reduce the dose to these organs [66].

Each of these measures contributes systematic dose savings that often range from a factor of two to ten, with the result that their combined effect can dramatically reduce dose. Once good practice is established, it is important to sustain it through a quality assurance and constancy checking program. This is particularly so for film processing. The advice on dose reduction presented here is based on that from the third 'ALARA' conference organized by the Society for Pediatric Radiology [67].

4.2.2. Doses and reference values for plain film radiography

A valuable tool in the optimization of protection and safety is comparison of the doses employed in a department with DRLs (see Section 2.3.1). The EC has proposed a set of DRLs for common radiographic projections (see Table 2).

These DRL values are for 5 year olds and different values would beobtained for older or younger children. However, it is felt that providing results for even one group may act as a marker for a department's performance. Some additional data for these older and younger age groups, from three EC pediatric trials conducted in 1989–1991, 1992 and 1994–1995, are presented in Table 9 butDRLs drawing on these have not been adopted to date [62]. However, the large ratio of the maximum to the minimum values seen ranges from about 30 to almost100, and indicates the room available for improvement through optimization. DRLs are not dose limits but are, rather, intended as advisory action levels, whichwill trigger an investigation if exceeded (see Section 2.3.1).

Tables 2 [35] and 9 are taken from an EC publication of 1996. These tables are based upon practice prior to the heightened awareness of dosage in pediatric radiology and before CR and/or DR and exposure selection technology became dominant in some parts of the world. Hence, while they provide a useful upper bound, they need to be re-evaluated to take into account the developments in the past decade and a half.

In the meantime, most departments need to be able to achieve these levels. The United Kingdom Health Protection Agency reports that the dose at which reference levels might reasonably be set for adults have been reduced by a factor of at least two in general radiography since they started monitoring the area over two decades ago [68]. It is reasonable to assume that a similar level of attention to pediatric radiology might have a similar impact.

TABLE 9. VARIATIONS IN ENTRANCE SURFACE DOSE (μGy) IN EUROPEAN COMMISSION PAEDIATRIC TRIALS
(median, minimum–maximum values and corresponding ratio (minimum:maximum) [62])

Examination type	Infant			5 year old			10 year old		
	Median	Minimum–maximum	Minimum:maximum	Median	Minimum–maximum	Minimum:maximum	Median	Minimum–maximum	Minimum:maximum
Chest AP (1000 g newborn)	45	11–386	1:35						
Chest PA/AP	75	21–979	1:47	67	19–1347	1:71	71	17–1157	1:68
Chest AP (mobile)	90	34–718	1:21	68	29–333	1:11	91	29–760	1:26
Chest lateral				140	37–554	1:15	153	39–1976	1:51
Skull PA/AP	930	152–4514	1:30	967	242–4626	1:19	1036	130–5210	1:40
Skull lateral				703	138–2358	1:17	577	113–3787	1:33
Pelvis AP	260	18–1369	1:76	485	86–2785	1:32	812	89–4167	1:47
Full spine PA/AP	867	107–4351	1:41						
Thoracic spine AP							887	204–4312	1:21
Thoracic spine lateral							1629	303–6660	1:22
Lumbar spine AP							1146	131–5685	1:43
Lumbar spine lateral							2427	249–23 465	1:94
Abdomen AP/PA	440	77–3210	1:42	588	56–2917	1:52	729	148–3981	1:27

Note: AP: antero-posterior; PA: postero-anterior.

TABLE 10. ENTRANCE SURFACE DOSE PER RADIOGRAPH FOR DIFFERENT EXAMINATIONS AND AGES [1]

Examination	Age (a)	Mean entrance surface dose (μGy)
Abdomen AP	0	110
	1	340
	5	590
	10	860
	15	2010
Chest AP/PA	0	60
	1	80
	5	110
	10	70
	15	110
Pelvis AP	0	170
	1	350
	5	510
	10	650
	15	1300
Skull AP	1	600
	5	1250
Skull lateral	1	340
	5	580

Note: AP: antero-posterior; PA: postero-anterior.

Additional tables for the mean ESD for pediatric patients are provided fora limited number of projections in a range of age groups. The United Kingdom study (Table 10), also noted by UNSCEAR, is of value because it is more recent than the EC study [1]. The data from the Madrid study [69] are reported in Table 11 on CR and are cited in Section 4.2.4. The age cohorts and the projections are not exactly equivalent in the tables.

Notwithstanding this limitation, the data will be useful to those taking steps for optimization of protection and safety in their practice. A recent Bulgarian study compared the values with the EC DRLs where a large spread in values continues to be present [70]. The authors attribute this to a number of identifiable causes including widespread use of grids, use of low kVp values and, in some examinations, use of low speed film–screen combinations.

TABLE 11. COMPUTED RADIOGRAPHY MEDIAN ENTRANCE SURFACE DOSE FOR VARIOUS EXAMINATIONS AND AGE GROUPS [1]

Examination	Age range (a)	Sample size	Mean entrance surface dose (μGy)
Chest (no bucky)	0–1	1180	41
	1–5	309	34
	6–10	143	54
	11–15	92	10
Chest (bucky)	1–5	181	87
	6–10	255	105
	11–15	363	170
Abdomen	0–1	93	91
	1–5	30	225
	6–10	69	600
	10–15	150	1508
Pelvis	0–1	254	48
	1–5	128	314
	6–10	122	702
	11–15	137	1595

As noted in Section 2.3.1, DRLs may wrongly suggest that the optimization process is complete; continued attention to parallel means for optimization is necessary.

A survey from the EC SENTINEL Project of European pediatric doses in general radiography provides a wide range of information that is difficult to summarize, and some recommendations in respect of DRLs for both entrance doses and dose–area product values [71]. In the current international code of practice, dose–area product is now called kerma area product (KAP) [36]. This suggests that, in some countries, the aspiration to meet the EC DRLs is not being achieved. Additional data on these studies and others are presented in Appendix III. From the above, it is evident that there is a serious lack of current data for all forms of pediatric radiography in respect of one of the key markers for optimization, i.e. evidence based DRLs. It is essential that this be corrected.

4.2.3. Mobile radiography

Mobile radiography is valuable when it is impossible for the patient to come to the radiology department. However, it results in poorer quality images and can give rise to unnecessary exposures of staff and patients. For example, it is not

uncommon to find that inferior radiographs taken with a mobile unit need to be repeated on a fixed unit the next day, thereby increasing patient exposure. Thus, it is more difficult to warrant the use of mobile radiography when the alternative of a fixed unit is available. To minimize the problems involved, it is now widely accepted that, where practicable, X ray examinations need to be carried out with fixed units in an imaging department. Mobile units need to be used only for those who cannot safely be moved to such a fixed unit.

The principles outlined above for optimization in general radiography also need to be followed with mobile radiography, as far as it is practicable to do so. In addition, routine use may be made of portable lead shielding to protect nearby patients. The advice of the medical physicist and/or RPO needs to be obtained on how best to do this. For example, the risk may be minimal in an intensive care unit for newborns, where there is considerable space between the incubators. Tiny infants weighing as little as 500–600 g can be radiographed using very low exposure and there is very little scattered radiation.

4.2.4. Optimization with computed radiography and digital radiography

Film–screen radiography is now being superseded by a variety of digital technologies in many countries. In some western countries, this transition has been ongoing for over a decade and is now virtually complete. While several digital options are available, the most widely deployed are CR and DR, also sometimes known as direct DR [72, 73].

The most important distinction between the two is that CR involves an intermediate step in which the image is stored as a latent optical image, in a cassette-like device, before it is converted to electronic digital form, using laser technology. With DR, on the other hand, the image is created immediately in electronic digital form, in the image receptor. Images from both systems can be displayed on suitable high resolution monitors but in practice they are often printed out on film, particularly when resolution is a concern.

One of the driving forces in DR has been the possibility, indeed thepromise, of significant dose reduction without loss of necessary image quality. The key factors in creating these possibilities include greatly improved contrast resolution, accompanied by almost infinite possibilities of processing the image after acquisition, with a view to improving the features eventually displayed. However, the improvement in image quality often results in higher patient dose, and the tendency to use higher patient doses than are necessary needs to be avoided [74].

Clinical and phantom studies have been performed by comparing radiation dose, image quality and diagnostic accuracy of film–screen and hard and soft copy digital chest radiography [75–78]. Using the EC (1996) quality criteria as a

semi-objective means of assessing image quality in chest radiography in children, Hufton et al. were able to demonstrate a dose benefit of 33% for CR compared with analogue chest radiography with a film speed of 400 [79]. Many other studies have also demonstrated potential benefits in terms of reduced dose with both CR and DR systems [72, 80, 81]. For example, a Spanish study found that anexposure reduction by a factor of 2.5 was consistent with images of sufficient quality to maintain the standards set by the EC [69, 82].

However, in spite of this success, a note of caution has to be raised. In general, digital imaging has the potential for dose reduction while improving image quality and diagnostic accuracy — but only with much attention to staff training and careful, continuous monitoring of departmental parameters and practices. The key issue is that, with image processing, the image quality will continue to look good even if the dose increases well beyond that required for an acceptable image. This removes one of the warning signs that, inadvertently, are provided by film–screen technology [83, 84]. On the other hand, with digital systems, dose cannot be reduced indefinitely as increased electronic noise reduces image quality. In practice, there is a tendency among technologists to avoid the need for repeats by erring on the side of overexposure [84].

Appropriate image processing is, therefore, crucial for optimization in producing a pediatric CR or DR image. To date, there is little standardization in the methods of image processing or their nomenclature. Practitioners are faced with the choice of accepting the supplier's default processing options or undertaking the arduous 'trial and error' task of customizing the processing for their local conditions.

In view of all of the above, it is important that radiology departments prepare well for the introduction of digital technology or for a new system involving digital technology. In the first instance, this needs to involve in-depth staff training on the specific system to be introduced. Generic training on digital systems, while helpful, is not adequate as there are significant operational differences between suppliers. Well trained staff need to adopt a team approach, in cooperation with the suppliers, technical staff, the hospital's medical physicistand maintenance staff, to identify and maintain suitable exposure parameters when a new digital system is installed. In addition, a good, practical, wellintegrated quality assurance program is essential.

Exposure index (EI), which provides a method of monitoring dose, is an indicator of the radiation incident on the imaging plate, something which is essential. As illustrated in Table 12, different manufacturers have developed different indices [72]. Some of these can be confusing or misleading for end users as the index may be counter-intuitive (i.e. it increases when the dose required decreases).

TABLE 12. EXPOSURE INDICES FOR THREE MANUFACTURERS' DIGITAL SYSTEMS *(adapted from Ref. [72])*

Manufacturer	Exposure index	Unit	Mean receptor exposure		
			5 μGy	10 μGy	20 μGy
Agfa	lgM	bels	1.9	2.2	2.5
Fuji	S	No units	400	200	100
Kodak	EI	mbels	1700	2000	2300

By correlating ESD with the EI, a range of acceptable values for specific clinical indications for optimization can be obtained. Unfortunately, although the EI may appear on the image processing workstation and on hard copy radiographs, it may not transfer to the patient record and/or archive. The differentforms of EI used and the problems of interconnection are standardization problems. Significant developments are being achieved in this area, and it is expected that there will be notable improvements in the next generation of equipment [85].

Further developments in equipment may also contribute to possibilities of dose reduction. These include development of completely innovative technologies, such as approaches based on slit scanning [86]. In a 2008 study, this system demonstrated very large dose reductions for skull, spine, pelvis and abdomen, and more modest gains for chest. However, it remains to be seen whether these are sustainable. Beyond these dramatic developments, most CR and DR manufacturers, recognizing that pediatric patients are different, have developed or are developing special provisions for pediatric examinations, including image processing.

In addition, it is essential that pediatric radiology undergo some standardization, and this requires commitment from end users, organizations setting technical standards and manufacturers. The importance of a continuous effort in this regard cannot be overemphasized, as it can lead to significant systemic dose reductions. The possibilities parallel the well established dose savings achieved by fast film–screen combinations in traditional radiology departments or dual readout CR technology, each of which, on the basis of a one-off initiative, can offer reductions in exposure in the range of 50% [87, 88]. However, while these possibilities are real, in practice there is a risk that patient doses will increase where digital technology continues to be introduced with inadequate preparation [89].

The recommendations given in Table 13 are designed to aid dose reduction and image management for optimization with DR and CR. The table relies on transfer of many of the practices that provide for good general

TABLE 13. DOSE REDUCTION FOR END USERS AND MANUFACTURERS OF COMPUTED RADIOGRAPHY AND DIGITAL RADIOGRAPHY EQUIPMENT

Dose reduction for end users
Justification is required for computed radiography and digital radiography studies as it is for general radiography.
Positioning, collimation and selection of exposure factors, etc. are as essential for optimization as in conventional radiography. A team approach to dose management is essential.
Team participants may include: a radiologist, medical physicist, medical radiation technologist, clinical engineer from the hospital; and a service engineer, application specialist and imaging scientist from the manufacturer.
Training of the radiologist and medical radiation technologist in the specific operational features of the computed radiography and digital radiography system in use is essential.
Dose reduction for manufacturers of computed radiography and digital radiography equipment
Manufacturers need to provide adequate end user training as part of the equipment supply package.
Nomenclature for digital imaging processing algorithms and exposure indices needs to be standardized.
Dose assessment is absolutely necessary for successful dose saving programs. It is, thus, essential to standardize exposure indices.
It is essential to make provision for passing the information on exposures and doses from the radiological equipment to the picture archiving and communication system and/or the patient record in an accessible form [56, 81].
Dose measuring devices and dose indicators need to be calibrated and need to be protected from casual modification by the operator.
Manufacturers need to provide comprehensive training and guidance for the user on their version of exposure index or equivalent.
Manufacturers and organizations setting technical standards need to give particular attention to the special issues of pediatric radiology.

radiography, such as positioning, collimation, appropriate filtration and selection of suitable exposure factors (see Table 8). Recommendations directed to practitioners and the industry are included.

4.3. DENTAL RADIOGRAPHY

Much of intra-oral dental radiography, as in general radiography, involves capturing a two dimensional projected image of radiation distribution.

Furthermore, a wide range of digital facilities are now available for dental purposes although analogue film processing continues to be used. However, dental radiography normally involves a different group of professionals: dentists and dental assistants. It is addressed here briefly for completeness, and the reader is referred to the dental radiology literature for a fuller discussion [90].

4.3.1. Justification in dental radiography

Radiation protection in dental radiography, as with general radiography, begins with justification of the exposure. This may be seen as problematic where there is a tradition of routinely radiographing all patients. In addition, in dentistry, the referring medical practitioner and the radiological medical practitioner are frequently the same person. In other areas of practice, there is much criticism of this situation as it is regarded as leading to a form of 'self-referral' which results in systematic overutilization.

The absence of a tradition of well developed, evidence based guidelines for justification that have a high level of consensus among dentists is a further problem. Under normal circumstances, the risk from dental radiography is very low. Nevertheless, it is essential that all dental radiographic examinations have a clinical justification and show a net benefit to the patient. This is particularly true in the case of cephalometric radiography and orthopantomographic examinations. Table 14 summarizes guidelines that have been developed by the EC, and the following text also draws on this [90].

Obtaining bitewing radiographs for caries diagnosis needs to be based on a risk assessment. Intervals between subsequent bitewing examinations need to be reassessed on each occasion, as individuals move into and out of caries risk categories over time. In high caries risk children, there is good evidence to support taking posterior bitewing radiographs at the initial examination, even in the absence of clinically detectable decay. Where a child is classified as being at high caries risk, a subsequent bitewing examination may be made after six months. Radiographs ought not to be taken more frequently than this and it is important to reassess caries risk.

Evidence of no new or active lesions is an indication that the child has entered a moderate or low risk category. It is recommended that when children are designated as having moderate caries risk that they may have annual posterior bitewing radiographs. This may continue until no new or active lesions are apparent and the child has entered a low risk category. Radiographs for caries diagnosis in low caries risk children need to take into account the population prevalence of caries. Intervals of 12–18 months (deciduous dentition) and 24 months (permanent dentition) are appropriate, although longer intervals may be appropriate where the risk continues to be low.

TABLE 14. GUIDELINES TO FACILITATE JUSTIFICATION IN DENTAL RADIOGRAPHY [90]

All X ray examinations need to be justified on an individual basis. Anticipated benefits may include new information to aid patient management.
Referrals for radiography to hospitals or other dentists need to be accompanied by sufficient clinical information to permit the new practitioner taking clinical responsibility for justification of the examination.
No radiographs ought to be performed without obtaining a history and conducting a clinical examination.
Routine radiography of all patients in particular categories is unacceptable.
Obtaining bitewing radiographs for caries diagnosis needs to be based on a caries risk assessment.
Careful consideration needs to be given to the radiographic requirements for orthodontic treatment.
Careful consideration needs to be given to any requirement for cephalometric radiography.
Cross-sectional tomography and CT in children ought to be used rarely and only after rigorous justification with a view to answering specific clinical question(s).

When orthodontic treatment is required, most children are appropriately treated at approximately 12–13 years of age and require radiographs to confirm the presence and condition of all of the teeth. The radiographic examination will frequently include a panoramic or right and left oblique lateral radiographs. Upper anterior occlusal films are required to supplement the oblique lateral radiographs but not the panoramic study. Limiting the field size to the area required for diagnosis is important for panoramic radiography.

Cephalometric radiography may be required in very specific circumstances, such as to assess the third molar or the position of the lower incisors at the end of treatment with a functional appliance, and it needs to be performed only if the information is going to change the orthodontist's decision on treatment. Where possible, lateral cephalograms need to be collimated to limit the field to the area required for diagnosis.

Newer techniques, including CT based systems, are finding significant application in dental practice and are considered in the CT section (Section 6.4).

4.3.2. Optimization in dental radiography

The considerations already mentioned in Section 3 in connection with procurement, management and quality assurance for equipment hold, with appropriate adjustment, for dental radiography. The principal adjustments arise

from the fact that the equipment is less expensive, and that both the output and the workload are lower.

Notwithstanding this, significant accidents can and do happen even with new dental equipment [18]. The tradition of quality assurance is less well developed and protocols for some equipment types, such as orthopantomograms, need further work. In addition, there is a need for careful consideration of what may be achieved in remotely based quality assurance programs, without sightof the equipment or the circumstances in which it is housed.

Practical advice usually offered for intra-oral dental radiography equipment is summarized in Table 15. Intra-oral DR offers a potential for further dose reduction, subject to the considerations raised in the section on CR and DR above. Additional literature on the quality assurance and performance levels necessary to ensure dose reduction with digital dental systems is, however,scarce.

In the absence of more fully developed pediatric guidelines, more detailed advice from adult practices will, for the present, have to be taken and suitably adapted for pediatric use from publications such as EC 136 [90]. However, the national reference dose of 1.5 mGy introduced in the United Kingdom forpediatric intra-oral radiography provides a useful benchmark [91]. DRLs of60 mGy · mm for the dose–width product and 82 mGy/cm^2 for the KAP per radiograph for panoramic views are also recommended.

TABLE 15. GUIDELINES TO FACILITATE OPTIMIZATION OF PROTECTION AND SAFETY IN DENTAL RADIOGRAPHY [90]

Only equipment adequate to meet current standards is to be employed for pediatric dental radiography.
Optimal recommended X ray tube voltage for dental radiography is subject to some debate but 60–70 kVp is considered reasonable in terms of limiting entrance surface dose and general efficacy.
Short cone collimators ought not to be used.
Long collimators are an effective means of dose reduction and ought to be used.
Use of film holding devices may be considered.
Where use of film holders is not possible or practicable, rectangular collimation (which is now advised in both the United Kingdom and the USA) needs to be considered.
The fastest widely available films (F speed) will significantly reduce dose and ought to be used.
Intra-oral digital radiography offers the potential for further dose reduction; a reference dose of 1.5 mGy has been introduced in the United Kingdom.

It should be noted that there is a tradition in some areas of dental practice of providing protection over and above that which is strictly necessary, even where there is no evidence to require its use on technical grounds. For example, with good practice, there is no evidence of a requirement for gonad lead apron protection with general dental radiography. Lead shielding of the thyroid gland may be used in those cases where the thyroid is in the line of, or very close to, the primary beam. This advice is based on the assumption that good practice with good equipment prevails. Where this assumption might not be warranted, a good case can be made for continuing practices that may appear unduly cautious.