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Use of patient contact shielding in the diagnostic application of X-rays in humans

Recommendation by the Commission on Radiological Protection

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**Verwendung von Patienten-Strahlenschutzmitteln bei der diagnostischen
Anwendung von Röntgenstrahlung am Menschen**

Empfehlung der Strahlenschutzkommission

This translation is for informational purposes only, and is not a substitute for the official statement. The original version of the statement, published on www.ssk.de, is the only definitive and official version.

Preface

Patient radiation protection equipment such as contact shielding for diagnostic imaging utilizing X-ray-radiation has increasingly become a topic of debate over the past few years. In its recommendation “Use of patient radiation protection equipment in the diagnostic application of X-rays on humans” published in 2018, the Commission on Radiological Protection (SSK) recommended eliminating the use of contact shielding for almost all projection X-ray modalities in patients. Additionally, numerous international publications have suggested to largely discontinue the use of patient contact shielding for diagnostic X-ray imaging. This in response has prompted the SSK to initiate a critical review and update of its recommendation from 2018.

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1 Introduction

Diagnostic application of X-ray-radiation in humans constitutes, by a significant margin, the single largest source of artificial radiation exposure in the German population (> 92 %, BfS 2019). The use of patient contact shielding can be a valuable asset in the protection of patients against high X-ray-radiation exposure during selected examinations.

The type and use of contact shielding from X-ray, however, are topics that remain controversial among international experts:

- Improper use of contact shielding may increase patients' exposure to radiation.
- When compared to more crucial factors in conventional X-ray diagnostics such as correct patient positioning, parameter settings and collimation, patient contact shielding contributes far less to X-ray dose reduction.
- Unnecessary or incorrect use of patient contact shielding may reduce their acceptance by both the patients and the medical staff using the equipment.
- Hygiene issues, a greater workload and economic reasons may also be arguments against the use of shielding.

Consequently, international expert associations and authorities/expert bodies have modified the recommendations on patient contact shielding in recent years (BIR 2020, Hiles et al. 2021, KSR 2021, The Nordic Radiation Protection co-operation 2015).

In its letter from 26 January 2022, the Federal Environment Ministry requested advice from the German Commission on Radiological Protection (SSK) and requested the SSK revise its recommendation on the use of patient contact shielding from 2018 and to incorporate the latest findings on the consequences of its use. Taking state-of-the-art technology into account, the decision to use contact shielding should be based on whether it can – with reasonable effort – significantly reduce exposure of anatomical regions beyond the region of interest. In particular, the recommendation should take into consideration the specific characteristics of the various X-ray imaging modalities (such as computed tomography (CT), dental imaging and interventional radiology), as well as different anatomical regions and special protection needs of certain patient groups (e.g. radiosensitive, paediatric or pregnant patients).

When assessing contact shielding equipment, the effort involved in its usage, hygiene concepts, patient compliance (for example, when applying a testicle protection capsule), as well as its feasibility should all be taken into account. For example, the use of a thyroid collar for newborns, infants and toddlers, is not feasible as their necks are too short.

2 Recommendations

It is considered prudent to align the recommendation with the European consensus paper (Hiles et al. 2021). However, a general abandonment of the use of contact shielding for patient is not recommended. The recommendation introduces a concept with three recommendation categories that will help professionals decide in which cases patient radiation protection equipment should be used. The use of patient contact shielding for the various imaging modalities is categorised using the following three symbols:



The use of contact shielding is recommended. In the case that no patient contact shielding is applied, a rationale explaining this choice should be provided on an individual basis for each examination.



Patient contact shielding may be used, after all aspects have been taken into account and as long as no practical reasons contradict its application (radiation protection, radiation sensitivity, technical reasons).



The use of patient contact shielding is not recommended. If shielding is applied correctly, however, it may be used after careful consideration and on an individual case-by-case basis.

The Commission on Radiological Protection recommends

- using patient contact shielding as detailed in Table 1 in line with the above categorisation and documenting deviations from the recommendations,
- using organ-based tube current modulation¹ for CT scans of organs close to the body surface such as the eye lens and the thyroid, where available,
- not using patient contact shielding within or close to the primary beam path during fluoroscopy,
- drawing up work instructions on the use of patient contact shielding in coordination with a medical physics expert (MPE),
- taking into account the higher risk of radiation exposure when deciding whether to use patient contact shielding in paediatric, adolescent and pregnant patients,
- closely following the recommendations of manufacturers or the responsible medical physics expert when using patient contact shielding for CT, as incorrect application can lead to excess exposure or a lower image quality,
- ensuring sufficient and regular training for staff with regards to advances in equipment technology and their influence on dose reduction in general and on the use of patient contact shielding in particular to minimise the potential for mistakes,
- using patient contact shielding if it is the patient's wish, if it is clinically feasible and if it has no disadvantages for the examination.

¹ While the X-ray tube is rotating around the patient, the electricity generating the radiation, and thus the radiation inside the X-ray tube, is reduced every time the tube reaches certain angles during rotation. During tube current modulation, the electricity varies in line with the expected attenuation of radiation by the patient's body in order to achieve similar doses at the image receptor.

Tab. 1: Use of patient contact shielding for various imaging modalities and potential organ dose reduction.²

Imaging modality	Patient contact shielding	Recommendation	Comment	Achievable dose reduction (organ-equivalent dose)
Computed tomography				
CT of cranium (CCT ^{a)})	Eye lens shielding		Prioritisation: 1. Forward flexion of the head or gantry tilt (most efficient radiation protection), or 2. shielding, or 3. organ-based tube current modulation	Eye lens: 1. up to 40 mSv (SSK 2011) 2. up to 20 mSv (Kim et al. 2017) 3. up to 12 mSv (Kim et al. 2017)
	Thyroid shielding for younger patients up to approx. 40 years		Shielding or organ-based tube current modulation; thyroid close to scanning field	Thyroid: up to 1 mSv (Abuzaid et al. 2017, Liebmann et al. 2014)
	Thyroid shielding for patients 40 years and older		Shielding or organ-based tube current modulation; thyroid close to scanning field	Thyroid: up to 1 mSv (Abuzaid et al. 2017, Liebmann et al. 2014)
	Breast shielding for female patients		Breast not located within the scanning field, a significant albeit not relevant dose reduction is possible; may be used (cf. Chapter 2)	Breast: up to 0.19 mSv (Liebmann et al. 2014)
CT, paranasal sinuses ^{b)}	Thyroid shielding		Thyroid could be within primary beam path; may be used if not within the scanning field and if there is no dose increase due to technical reasons	Thyroid: up to 1 mSv (Pauwels et al. 2019)
	Eye lens shielding		Possible if the distance to the eye lens is sufficient; organ-based tube current modulation or shielding	Eye lens: up to 3 mSV (assessment based on DLRs)

² As dose reduction depends strongly on the examination device, examination technique and situation, the use of patient contact shielding should be clarified on site with a medical physics expert.

Imaging modality	Patient contact shielding	Recommendation	Comment	Achievable dose reduction (organ-equivalent dose)
DVT ^(c) , paranasal sinuses, dentistry	Thyroid shielding		PA projection, highly error-prone with low potential for dose reduction	Thyroid: up to 0.1 mSv (Schulze et al. 2017a)
	Eye lens shielding		PA projection, highly error-prone with low potential for dose reduction	
CT visceral cranium	Thyroid shielding		Highly error-prone with low potential for dose reduction; often located in the direct field of scout images and the scanning field	Thyroid: up to 1 mSv (Pauwels et al. 2019)
	Eye lens shielding		Caution: Shielding may result in additional artifacts; organ-based tube current modulation achieves only low dose reduction	Eye lens: up to 8 mSv (assessment based on DRLs)
Thoracic CT	Thyroid shielding		Potential for error is higher than potential benefit; the lower thyroid pole is usually located within the scanning field	Thyroid: up to 2.5 mSv (Buchgeister et al. 2012)
	Lead shielding around the abdomen		Taking all aspects into account, there is no benefit from shielding	Uterus: up to 0.02 mSv (Danova et al. 2010, Iball and Brettle 2011, Samara et al. 2022)
CT abdomen/pelvis/lumbar spine	Males: circumferential testicular shielding		Only if outside of scanning field	Gonads: up to 1 mSv (Dauer et al. 2007, Hohl et al. 2005)
	Females: ovarian shielding		Limited benefit due to central position of ovaries, which are exposed to radiation from all angles	
CT/DVT extremities	No shielding necessary		Limited benefit due to low dosage and large distance to radiosensitive organs, low potential for dose reduction	

Imaging modality	Patient contact shielding	Recommendation	Comment	Achievable dose reduction (organ-equivalent dose)
Projection radiography				
Head	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	Effective dose up to 0.002 mSv (Samara et al. 2022)
Shoulder	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	No reliable data available
Thorax AP/PA ^{d)} and laterally	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	Gonad dose: up to 0.000035 mSv (Samara et al. 2022)
Thoracic and lumbar spine	No shielding necessary		Taking all aspects into consideration, not expedient, especially in case of narrow collimation	Breast: approx. 0.3 mSv (Mekis et al. 2013) for supine position
Pelvis and hip joint	Males: testicular shielding		When used, the area of interest must not be overlaid and there must be no interference with an automatic exposure control system	Testes: up to 0.8 mSv (within primary beam path, otherwise approx. 0.08 mSv)
	Females: ovarian shielding		Potential loss of diagnostic information and frequently incorrect positioning of ovarian shield	Ovaries: up to 0.150 mSv (Clancy et al. 2010, Doolan et al. 2004, Frantzen et al. 2012, ICRP 2013, Liu et al. 2008)
Abdomen	Males: testicular shielding		Taking all aspects into account, there is no benefit from shielding	Testes: up to 0.08 mSv (Njeh et al. 1997, Roth et al. 2001)
	Females: Ovarian shielding		Positioning of ovarian shield is highly error-prone	
Extremities	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	
Mammography	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	Thyroid: approx. 0.001 mSv (Sechopoulos et al. 2008, Sechopoulos and Hendrick 2012)

Imaging modality	Patient contact shielding	Recommendation	Comment	Achievable dose reduction (organ-equivalent dose)
Dentistry	No shielding necessary		Taking all aspects into account, there is no benefit from shielding	Thyroid: up to 0.01 mSv for an orthopantomogram (Rottke et al. 2013a, Rottke et al. 2013b), considerably lower for intraoral imaging

- a) cranial computed tomography (CCT)
- b) paranasal sinuses
- c) digital volume tomography (DVT)
- d) anterior-posterior (AP) / posterior-anterior (PA)

3 Technical basis

Radiation protection requires limiting the exposure to radiation during medical imaging to the fullest extent possible, while still meeting the requirements of medical science. Anatomical areas that do not have to be exposed to primary radiation during the intended application of X-ray imaging must be protected from radiation exposure as far as reasonably possible. An adapted use of patient contact shielding can support this process but should in most cases be considered a supporting measure for other processes, for example narrow collimation during X-ray imaging or fluoroscopies or limiting the scan length for CT examinations. If patient contact shielding is used within the direct beam, it is especially important to assess beforehand how the use of protective equipment will impact the automatic exposure control which may potentially be in use.

In projection radiography, it is of the utmost importance to ensure good positioning (which can also influence the choice of patient contact shielding), immobilisation (if required), fine-tuning of imaging parameters and that collimation is correctly adjusted to the area of interest and examination goals. This holds true especially for children and adolescents, as the increase in field size in percent is inversely proportional to the initial format, in particular for newborns, infants and toddlers. The image must clearly show the collimation and must not be overlaid by digital collimation³. When examining male patients, a circumferential testicle shield may be used after testicular descent has occurred, provided it appears beneficial with a view to the expected dose reduction and there are no artifacts, dose increase or overlay of the exposure chamber.

Newborns, infants, toddlers and school children are more sensitive to radiation. Provided there is no risk of interfering with the automatic exposure or negative impacts on the quality of the image, medical staff may deviate from the recommendations and opt to use contact shielding if the legal guardians consents. Taking into consideration all of the above, this is all the more important the less physically developed the child and/or the higher the frequency of examinations is (e. g. X-ray imaging of the thorax or abdomen in extremely premature babies). Paediatric radiology experts may be consulted in individual cases. The frequency of examinations should also be taken into consideration for other patient groups.

Whenever possible, dorsoventral (PA) projection should be used in female patients when imaging the thoracic region and the abdomen in the left lateral position due to the radiosensitivity of the mammary tissue and the thyroid.

In pregnant women, the risk associated with radiation exposure for the unborn child must be taken into account (e. g. through the use of shielding equipment in CT examinations of the thorax, as the uterine X-ray dose for the pregnant women is assumed to be the body dose for the unborn child).

The position of the patient (e. g. standing up or lying down) and its impact on the correct placement of contact shielding should also be taken into consideration when assessing its use.

Some computer tomography scanners use one or two overview images (termed differently depending on the manufacturer of the CT, for example, scout image, topogram, scanogram) to determine the attenuation by the patient, modulate the dose accordingly and to select the relevant area for the examination. Patient contact shielding in the area of interest during an overview scan could lead to higher exposure from some examination devices. This should be

³ For digital collimation, the digital X-ray image is overlaid with black areas in order to cover lighter areas that would distract the eye when evaluating the images.

evaluated critically, especially in paediatric radiology. The resulting disadvantages must be weighed against the benefits of using patient contact shielding. One option is therefore to apply contact shielding only after the overview image has been taken (e. g. covering the eye lens during CCT).

Using contact shielding is seldom possible during radiological interventions, since, depending on the angulation in the X-rays, the shielding could be located within the primary beam path. In such cases, automatic exposure control might increase the dose applied to the patient. Furthermore, since PA projection is commonly used, organs, such as the eyes, the thyroid and the breasts, that are at risk due to their close proximity to the body's surface would only minimally benefit from dose reduction through contact shielding.

Information on the requirements for patient contact shielding can be found in the established standards. Qualified patient contact shielding must meet the requirements of DIN EN 61331-1:2016-09 (Determination of attenuation properties of materials) and DIN EN 61331-3:2016-09 (Protective clothing, eyewear and protective patient shields). The above standards take into account the use of lead-reduced or lead-free protective clothing. Patient contact shielding is usually manufactured with lead equivalents⁴ between 0.25 mm and 1.0 mm. A lead equivalent value of at least 0.5 mm is required for gonad aprons, which are considered shielding outside the field of the useful beam. For testicle protection capsules, regarded as shielding within the field of the useful beam, a lead equivalent value of at least 1 mm is required.

In addition to the protective effect of the contact shielding equipment, consideration must also be given to how their use affects the workflow and which hygienic requirements must be observed.

The use and placement of patient contact shielding should be coordinated with a medical physics expert.

This recommendation applies only to the use of X-ray imaging in radiological diagnostics and interventions. Dose reduction during the use of X-rays in image-guided radiation therapy is covered by the SSK recommendation on radiation hygiene requirements for image-guided radiotherapy (IGRT) (SSK 2010).

4 Potential sources of error in patient contact shielding

The SSK has identified the following sources of error when patient contact shielding is used:

- If patient contact shielding is not applied correctly, it may not achieve a protective effect and/or may cover the anatomical region of interest.
- Since anatomical conditions vary from patient to patient (e. g. ovaries), the effect of contact shielding may not be sufficient.
- The materials of the contact shielding may interfere with automatic exposure control (dose modulation in CT or exposure chambers in radiography and fluoroscopy), leading to an unwanted increased exposure of the patient to radiation.
- Contact shielding may cause artifacts that lower the quality of the image, thus requiring a retake of the diagnostic imaging.

⁴ The lead equivalent describes the protective effect of a material compared to the protective effect of lead.

Over the past years, several recommendations (Hiles et al. 2021, KSR 2021, The Nordic Radiation Protection co-operation 2015, BIR 2020) have come to the conclusion that the benefits of dose reduction achieved through the use of patient contact shielding is low and are outweighed in comparison with the additional exposure that could occur when used incorrectly. In addition, problems with regard to hygiene, costs and workflow need to be considered when using protective equipment. In principle, the SSK agrees with this assessment. At the same time, provided these sources of error are taken into account and identified, the SSK believes that the use of contact shielding is indicated for individual examinations, particularly CT scans.

5 Rationale for the use of patient contact shielding in frequently performed CT examinations

5.1 CT of the cranium (CCT)

In most hospitals and doctor's offices, cranial CT scans represent the most frequently performed cross-sectional diagnostic imaging procedure. Compared with examinations of other body parts, cranial CT scans have the highest local exposure rates. When using multi-slice spiral CT scanners with wide detector arrays in spiral mode, the lens of the eye is often in the direct beam path as a result of over-ranging or over-beaming. If no protective measures are taken and if the eye lens is positioned within the scanning field, it is often exposed to a dose of 50 mSv or more. This is considered a high dose according to the new assessment of eye lens sensitivity to radiation with regard to cataract formation. Therefore, measures should be taken to reduce the dose exposure to the lens of the eye. Ideally the eye lens should be positioned outside the primary beam path either through gantry tilt (if possible) or by using a foam wedge to position the head slightly higher and with a forward incline (SSK 2011). Especially in case of smaller objects (e. g. a child's head) a spiral CT with narrow collimation or a sequential CT should be used (this should be coordinated with a medical physics expert on site).

Eye lens shielding can be generally used. In the case that artifacts do arise as a result of lens shielding, diagnostic image quality is not necessarily reduced as long as said artifacts occur at a sufficient spatial distance away from the neurocranium (Raissaki et al. 2010). Tube current modulation is a viable alternative, as no direct or very little radiation reaches the eye lens. Eye lens shielding reduces the eye lens dose by approx. 50 %. Tube current modulation that is organ-based for the upper angular range reduces the eye lens dose to the same degree (Bulla et al. 2012, Keil et al. 2008, May et al. 2012, Kim et al. 2017). In some cases, eye lens shielding can be placed over the eyes after the overview image has been taken.

Thyroid shielding lowers the dose for the thyroid (approx. 1 mSV) by 45 % without impairing image quality. This type of protection is therefore beneficial for patients under the age of 40 (Brenner and Hall 2007, HPA 2011, Iglesias et al. 2017). In female patients, breast shielding reduces the dosage for the breast (approx. 0.3 mSv) by up to 75 % (Liebmann et al. 2014, Ngaile et al. 2008). Shielding of the female breast is considered beneficial in children as well as in adult patients depending on age.

5.2 CT and DVT examinations of the paranasal sinuses and the visceral cranium

The scanned area of paranasal sinuses down to the maxillary teeth can be spatially smaller than that of an examination of the visceral cranium which includes the mandible. Furthermore, the

CTDI_{vol}⁵ for paranasal sinuses is approximately three times lower than that for the visceral cranium (compare diagnostic reference levels (DRL) of the Federal Office for Radiation Protection, BfS; Schegerer et al. 2019).

The use of patient contact shielding is not considered necessary for most examinations.

Eye lens protection can be used for CT imaging as long as it does not impair the diagnostic quality of the image. Tube current modulation is a viable alternative, as no direct radiation reaches the eye. Eye lens shielding reduces the level of radiation by approx. 50 % (Keil et al. 2008). The dose can also be reduced by up to 50 % through organ-based tube current modulation in the upper angular range (Bulla et al. 2012). When eye lens shielding is used, care must be taken that the distance between the attenuating shield and the visceral cranium is large enough. Relevant artifacts can otherwise be expected to occur in the image of the visceral cranium. If the image is used for surgical planning, it must be verified whether the navigational system will be able to process an image that includes shielding.

With DVT systems, a rotation of 180° over the back of the head should be used to prevent exposure of the eye lenses to the unattenuated useful beam (Güldner et al. 2013).

The use of thyroid shielding may be beneficial for CT examinations of the paranasal sinuses, since an effect on automatic exposure control can be ruled out due to the distance between the thyroid and the field of radiation.

Thyroid shielding during DVT examinations can lower the thyroid dose from 1.6 mSv to 0.9 mSv (Goren et al. 2013, Liebmann et al. 2014). However, during CT examinations of the visceral cranium and corresponding DVT examinations, when contact shielding is applied close to the throat, the shielding material may extend into the direct beam. As a result, the automatic exposure control would lead to an increase of the tube current, which would have a negative impact on both radiation exposure and image quality. For this reason, contact shielding in the throat region is not recommended for examinations of the visceral cranium.

5.3 CT examinations of the thorax and thoracic spine

During CT examinations of the thorax, shielding of the neighbouring thyroid and upper abdominal organs is generally possible.

In recent years, however, it has become apparent that shielding materials close to the area of interest can impair exposure parameters modulated by the CT scanner during examinations where dose modulation is used. Also, contact shielding achieves only a low dose reduction (23 µSv). For these reasons, and taking into consideration the additional workload, costs and hygiene concerns associated with it, contact shielding is not recommended for thoracic CT examinations (Danova et al. 2010, Iball and Brettle 2011).

Thyroid shielding on the other hand can lower the organ dose by 31 % from 8.4 mSv to 5.8 mSv (Buchgeister et al. 2012). Experience from the recent past has shown that thyroid shielding often results in shielding material extending into the upper area of the lungs. For this reason, thyroid shielding is not recommended.

5.4 CT examinations of the pelvis, abdomen and lumbar spine

Circumferential shielding of the male gonads or a testicle protection capsule reduces radiation exposure of the gonads by up to 1 mSv, when the gonads are not located directly within the

⁵ Volume computed tomography dose index

primary beam path. (Dauer et al. 2007, Hohl et al. 2005). Especially for examinations of the pelvis, contact shielding should not be located within the primary beam as artifacts may occur and the dose may be increased (Dauer et al. 2007). If activated, tube current modulation would also lead to an increase in the gonadal dose. If exposure of the gonads cannot be avoided in examinations of the pelvis, tube current modulation should be used, as it reduces radiation exposure by up to 40 % (May et al. 2012).

A circumferential testicle shield for men may be beneficial as long as the testicles are not in the scanned area. A circumferential testicle shield may be used for boys depending on their stage of development as long as it is outside the primary beam.

5.5 CT and DVT examinations of the extremities

Studies on the reduction of radiation exposure through contact shielding during CT and DVT examinations of the extremities are not available. However, the use of contact shielding does not appear to be beneficial in this situation. This is due to the low doses used and the large distance to the torso, where most radiosensitive organs are located. As a result the potential to lower the dose is only minimal.

6 Rationale for the use of patient contact shielding in more frequently performed projection imaging

The most important, and one of the most effective measures to lower the radiation dose – in addition to correct positioning and, where necessary, immobilisation of the patient – is to ensure the correct collimation with regard to the examination object and clinical question being investigated. This is particularly important in children because the smaller the original format, the greater the percentage increase of the field size – especially in neonatal radiology (Seidenbusch and Schneider 2015). The collimation must be discernible on the image. The additional use of aprons (e. g. gonads, lead rubber mats or protective clothing) of torso regions directly bordering the field of radiation can be useful in the examination in children and younger patients.

6.1 Radiography of the head

There are few indications that would justify the implementation of this type of examination (SSK 2019). If necessary, however, patient contact shielding is not necessary (effective dose reduction: < 0.002 mSv (Samara et al. 2022)).

6.2 Radiography of the shoulder or clavicle

There are currently no studies available on the reduction in X-ray exposure achieved through the use of patient contact shielding during examinations of the shoulder or clavicle. A rough estimate based on similar examination areas, such as the thorax and the thoracic spine, shows however that the dose reduced through the use of contact shielding is negligible.

6.3 Radiography of the thorax

Studies show that the gonadal dose of PA projection is approx. 0.0002 mSv, i. e. very low. In thoracic examination of adults using a PA projection and in a vertical stand, the use of a gonad apron on the side of the body facing the detector can reduce the testicular dose by 75 % (approx. 0.0002 mSv) and the ovarian dose by 10 % (0.00002 mSv). The gonad apron on the side of the

body facing the tube however would only reduce the testicular dose by 12 % and the ovarian dose by only 5 % (Roth et al. 2001, Samara et al. 2022). Since the dose outside the area of interest is low, it is not necessary to use patient contact shielding.

If patient contact shielding is used in neonatal radiography, the lead rubber shielding should be placed on top of the incubator. Concerns regarding hygiene (nosocomial infections) and compression of the abdomen leading to impaired breathing are arguments against its use inside the incubator.

Since AP X-ray imaging of the thorax is commonly performed on younger children as well as school aged children (Seidenbusch and Schneider 2015). Therefore, it may be beneficial to place contact shielding (such as a lead apron or gonad protection) on the ventral side of the patient's body.

6.4 Radiography of the thoracic or lumbar spine

In thoracic or lumbar spine imaging, the dose is approx. 0.5 mSv for the uterus and approx. 0.04 mSv for the testicles. Placing contact shielding at the lower end of the radiation field achieves only minor dose reductions (Clancy et al. 2010, Liu et al. 2008). Breast shielding reduces the dose approx. from 0.4 mSv to 0.08 mSv for images with wide collimation taken in a supine position (Mekis et al. 2013). However, correct collimation has a much stronger protective effect.

6.5 Radiography of the pelvis or hip joint

Gonad shielding within the primary beam path reduces the gonadal dose by approx. 95 % in men (0.8 mSv) and by more than 50 % in women (0.2 mSv). Outside the useful beam, the gonadal dose amounts to less than 0.1 mSv, but this can be further reduced with a testicle pouch in men (Clancy et al. 2010, Liu et al. 2008).

Ovarian shielding is often placed incorrectly, which can lead to faulty images and require repeated diagnostic imaging (Warlow et al. 2014). It is therefore not recommended.

Testicle shielding can reduce low to medium testicular dose in male patients and can be used if there are no reasons contradicting its application, for example if the testicles situated within the scanned area or if relevant parts of the image would be obscured.

6.6 Radiography of the abdomen

The reduction of the gonadal dose achieved through the use of patient contact shielding in this type of examination is comparable to that of pelvic X-ray imaging. Here, the testicles are not located within the direct beam path (< 0.1 mSv). However, the ovaries are located within the area of interest; therefore, they cannot be shielded. For these reasons, contact shielding is not recommended.

6.7 Radiography of the extremities

There are no studies available on the dose reduction achieved through the use of patient contact shielding for examinations of the extremities. A rough estimate shows that the gonadal dose reduced through contact shielding is negligible. Patient positioning and collimation should be optimised to protect at-risk organs to the fullest extent possible.

6.8 Mammography

Studies show that a higher frequency of mammographies does not lead to a significant increase in thyroid cancer (Sechopoulos and Hendrick 2012). The average thyroid dose is reported to be 0.002 mSv (Sechopoulos et al. 2008). The use of thyroid shielding is therefore not recommended. The average organ dose is 0.002 mSv for the eye, 0.02 mSv for the contralateral breast and < 0.00003 mSv for the uterus. For this reason, contact shielding is not recommended for mammography (Sechopoulos et al. 2008).

6.9 Radiography in dentistry

The energy and field sizes of radiation used in dentistry only generate scattered radiation fields with small doses. For this reason, patient contact shielding is not necessary.

The application of an apron does not achieve significantly lower doses even in examinations such as panoramic images or dental DVT (Rottke et al. 2013a, Rottke et al. 2013b, Schulze et al. 2017b). A study (Qu et al. 2012) has shown a reduction of the organ dose for the thyroid of 0.015 mSv when a dorsal rotation of 180° is used for the examination. Thyroid shielding can be applied for special reasons or in case of extraoral images (e. g. cephalogram).

7 References

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8 List of abbreviations (frequently used terms)

AP	anterior-posterior
CCT	cranial computed tomography
CT	computed tomography
DRL	diagnostic reference levels
DVT	digital volume tomography
MPE	medical physics expert
mSv	millisievert
PA	posterior-anterior