Physica Medica 94 (2022) 102–109

Contents lists available at ScienceDirect

Physica Medica

journal homepage: www.elsevier.com/locate/ejmp

Review paper

Systematic literature review on the benefit of patient protection shielding during medical X-ray imaging: Towards a discontinuation of the current practice

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ARTICLE INFO

Keywords:
Radiation protection
Patient shielding
X-ray imaging
Radiology

ABSTRACT

Purpose: Patient shielding during medical X-ray imaging has been increasingly criticized in the last years due to growing evidence that it often provides minimal benefit and may even compromise image quality. In Europe, and as also shown in a short assessment in Switzerland, the use of patient shielding is inhomogeneous. The aim of this study was to systematically review recent literature in order to assess benefits and appraise disadvantages related to the routine use of patient shielding.
Methods: To evaluate benefits and disadvantages related to the application of patient shielding in radiological procedures, a systematic literature review was performed for CT, radiography, mammography and fluoroscopy-guided medical X-ray imaging. In addition, reports from medical physics societies and authorities of different countries were considered in the evaluation.
Results: The literature review revealed 479 papers and reports on the topic, from which 87 qualified for closer analysis. The review considered in- and out-of-plane patient shielding as well as shielding for pregnant and pediatric patients. Dose savings and other dose and non-dose related effects of patient shielding were considered in the evaluation.
Conclusions: Although patient shielding has been used in radiological practice for many years, its use is no longer undisputed. The evaluation of the systematic literature review of recent studies and reports shows that dose savings are rather minimal while significant dose- and non-dose-related detrimental effects are present. Consequently, the routine usage of patient protection shielding in medical X-ray imaging can be safely discontinued for all modalities and patient groups.

Introduction

The urgent need of a consensus concerning the use of patient shielding in Europe was addressed in an article by Gilligan and Damilakis [1]. The authors referred briefly to advantages and disadvantages of the use of patient shielding and addressed the need of harmonization of practices among European countries [1]. This article corroborates previous publications addressing the same topic [2] as well as surveys showing the unsystematic use of patient shielding [3–5]. Several national authorities as well as societies of radiologists, medical physicists and radiographers suggest to abandon the practice of patient shielding in radiological examinations, among of which the Italian [6] and the American Association of Physicists in Medicine [7], the British Institute of Radiology [8], the Danish, Finnish, Icelandic, Norwegian and Swedish authorities [9]. Based on articles – published mainly between 1992 and 2012 – the German recommendations advise to use patient shielding only during some CT examinations and pelvis radiography. Moreover, the German recommendations specify that for fluoroscopy-guided procedures patient shielding can be used only when it is guaranteed that it stays out of the primary beam [10]. Overall, most of these

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https://doi.org/10.1016/j.ejmp.2021.12.016
Received 24 September 2021; Received in revised form 15 December 2021; Accepted 28 December 2021
Available online 11 January 2022

recommendations and national guidelines are based on selected publications that somehow represent the current state of knowledge and research. Furthermore, even among a single country or region there is currently a wide variety of recommendations and legislative documents on the use of out-of-field shielding [11].

In order to emphasize this situation we performed a survey about the current practice in Switzerland within the framework of this study. The usage of patient shielding in radiological examinations in Switzerland is addressed in article 24 of the Ordinance for X-rays [12]. According to this legislation, the authorization holder must provide adequate shielding for patients, but it is up to the health institution to judiciously regulate its use. The Federal Office of Public Health (FOPH) as the supervisory authority in the field of radiation protection introduced in 2003 (revised in 2018) a specific guideline "Directive R-09-02" aiming to harmonize the use of patient radiation shielding [13]. Unfortunately, this directive leaves space for different practices, as the formulation does not legally oblige the institutions to use patient shielding. Switzerland is a small country, with less than 10 million population but has four official languages (share of population: German speaking 63%, French speaking 23%, Italian speaking 8% and Romansh speaking 0.5%) [14]. On a smaller scale – compared to entire Europe -, the practice of use of patient shielding shows a great variety also in Switzerland. As an example, Fig. 1 presents the inhomogeneous use of in- and out-of-plan abdominal shielding during CT examinations of pregnant women. All details about this sub-study are given in the supplemental material. Similar to other attempts all over Europe, the Swiss Society of Radiobiology and Medical Physics (SSRMP) published a report, based on selected scientific publications, showing that the use of patient shielding has a negligible effect on patient dose and other techniques should be used for an efficient patient protection [15].

Despite all these facts, to the best of our knowledge, there is still no systematic literature review available, which investigates the benefits of patient protection means with respect to recent technical developments and the current state of the equipment present in European radiology departments and institutes. It was the aim of this study to evaluate the benefits and disadvantages from different type of patient shielding, considering scientific evidence based on systematic literature review of articles published in the past decade.

Methods

In order to assess the benefits and negative effects of patient protection means applied in radiological examinations, a systematic literature review of recent publications was performed. The literature review focused on peer-reviewed scientific original articles listed in the PubMed database that were published during the past 10 years (publication date January 1st 2010 – December 31st 2020) and title and abstract are available. Further inclusion criteria for the analysis were: (a) addressing benefits and/or negative effects of patient protection means for both pediatric and/or adult patients, (b) all X-ray based modalities (CT, fluoroscopy, radiography and mammography) that are available in radiological departments were considered but also including fluoroscopy application in other disciplines, e.g. cardiology, urology etc.). Articles were excluded if the investigated dose reduction due to patient shielding were related to applications in nuclear medicine, dental medicine or radiotherapy. Details of the literature search are summarized in Table 1. Results of the search were cleaned for duplicates based on PMID, and title and abstract were screened independently by two reviewers for eligibility in full text analysis. Reports from medical physics societies and reviews on the same topic were checked for references listed and included in the review if they met the inclusion criteria.

Results

In total, the literature search in PubMed resulted in 721 relevant articles (479 after cleaning for duplicates). After screening of title and abstract 410 articles were not included in the full text analysis. The most frequent reasons for exclusion were that the article was not patient oriented (220), not radiology oriented (nuclear medicine (30), radiation therapy (28), dental medicine (25)) or the dose reduction due to the protective means was not investigated (43). There were three review articles found that met the inclusion criteria [16–18]. Analysis of these reviews in combination with cross references from the national guidelines [6–10,19] revealed twelve more publications that were also included in the full text analysis [2,3,20–29].

The findings for each type of patient shielding are summarized in Tables 2–5 together with the respective literature referencing and

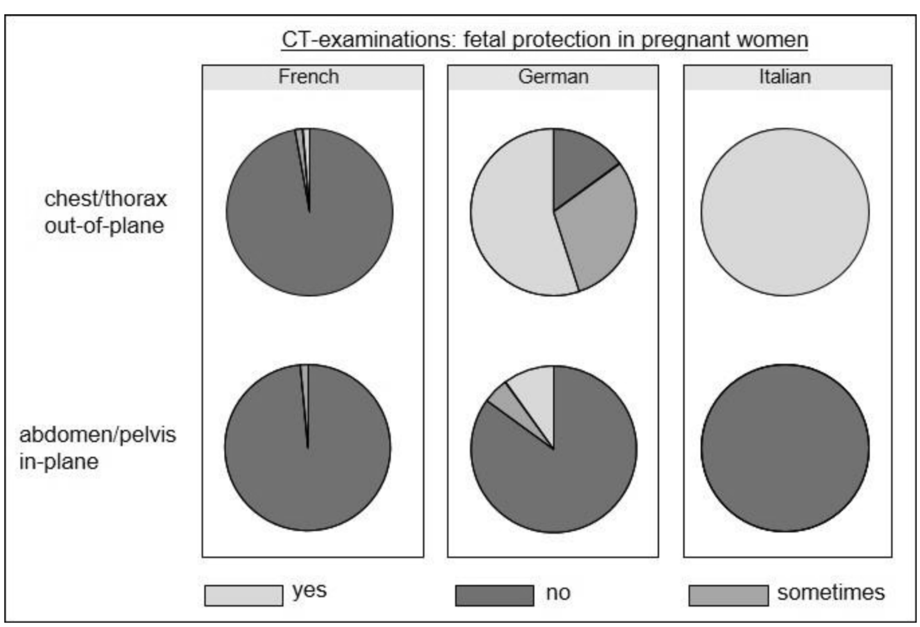

Fig. 1. Inhomogeneous use of out-of-plan and in-plane fetus shielding during CT examinations: in-plane shielding during CT examinations to pregnant patients is used rarely and only in ¼ of German-speaking centers, while out-of-plane shielding is used more frequently for CT examinations in the German- and Italian-speaking regions.

Table 1
PubMed search strategy with number of publications retrieved.

	Search criteria	
#1	"radiation protection"[MeSH Terms] AND "apron" [All Fields] OR "aprons" [All Fields])	172
#2*	"radiation protection"[MeSH Terms] AND "shield" [All Fields] OR "shielded" [All Fields] OR "shielding" [All Fields] OR "shieldings" [All Fields] OR "shields" [All Fields]	(758)
#3	#2 AND "radiology" [MeSH Terms] OR "radiology" [All Fields] OR "radiography" [MeSH Terms] OR "radiography" [All Fields] OR "radiology s" [All Fields]	371
#4	#2 AND "cardiologi" [All Fields] OR "cardiologie" [All Fields] OR "cardiology" [MeSH Terms] OR "cardiology" [All Fields] OR "cardiology s" [All Fields]	49
#5	#2 AND "urologie" [All Fields] OR "urology" [MeSH Terms] OR "urology" [All Fields] OR "urology s" [All Fields]	14
#6	#2 AND "orthopaedic" [All Fields] OR "orthopedics" [MeSH Terms] OR "orthopedics" [All Fields] OR "orthopedic" [All Fields] OR "orthopaedical" [All Fields] OR "orthopedical" [All Fields] OR "orthopaedics" [All Fields]	23
#7	#2 AND "fluoroscopy" [MeSH Terms] OR "fluoroscopy" [All Fields] OR "fluoroscopies" [All Fields]	92
	Total of publications	721
	Total of publications (excluding duplicates)	479

*not included in the review process.

presented according to:

- Imaging modality (CT, radiography, mammography, fluoroscopy)
- Body region exposed to primary radiation (i.e. head, thorax, abdomen, etc.)
- Specific organ-at-risk (i.e. eye lenses, breast, gonads, etc.)
- Location (i.e. in- or out-of-plane)

Absolute and relative dose reduction ranges as well as the effective dose reduction if reported by the authors are summarized in the third column of each table. The fourth column includes detrimental effects as reported in relevant articles.

Table 3
Summary of the literature review for mammography examinations.

Examined body part	Patient protection shielding	Dose reduction due to the usage of protective shielding	Detrimental effects due to the usage of protective shielding	Conclusive statement
Mammography examination	Contralateral breast [48]	Absolute dose reduction 29 μSv		Discontinue routine patient shielding
	Thyroid protection (out-of-plane) [25,88,19]	Range of absolute dose reduction 16–187 μGy	Displacement	Discontinue routine patient shielding

Table 2
Summary of the literature review for CT examinations.

Examined body part	Patient protection shielding	Dose reduction range due to the usage of protective shielding	Detrimental effects due to the usage of protective shielding	Conclusive statement
Head	Thyroid protection (out-of-plane) [20,28,30]	Range of absolute dose reduction 0.09–0.88 mGy, range of relative dose reduction 17.9% to 44.7%	Image quality	Discontinue routine patient shielding
	Thyroid protection (in-plane) [38,69-72]	Range of absolute dose reduction 0.16 to 56 mGy, range of relative dose reduction −6% to 48%, range of E reduction: 0.8 to 1.5 mSv		
	Breast shield (out-of-plane) [30]	Range of absolute dose reduction for thyroid between 0.04 and 0.19 mGy	Potential dose increase due to overscan	Discontinue routine patient shielding
	Eyes protection (in-plane) [18,29,32-38,69-71,73-76]	Range of absolute dose reduction 2 to 144 mGy, range of relative dose reduction 2% to 70%	Orbit shields can cause significant artefacts, significant HU increase, increasing image noise, unhygienic	Discontinue routine patient shielding
Neck	Thyroid shield (in-plane) [77,78]	Range of relative dose reduction 3.4% to 47%	Significant changes in HU, image quality	Discontinue routine patient shielding
	Breast shield (out-of-plane)[79]	No organ reduction estimations		
Chest	Surround-apron (out-plane) [59,60,62,80]	Range of absolute dose reduction 0.003 to 0.013 mGy, range of relative dose reduction –6.5% to 77.6%, E reduction: 4%	Dose increase, artifacts, risk of backscatter inside the apron, positioning, patient repositioning	Discontinue routine patient shielding
	Fetal protection for pregnant (out-of-plane) [81–84]	Range of absolute dose reduction 0.02 to 0.09 mGy, range of relative dose reduction 20% to 56%,	Possible artefacts, uncomfortable for patients especially in the later stages of pregnancy, possible problems with vena cava and blood circulation due to the heavy aprons, unhygienic	Discontinue routine patient shielding
	Breast shields (in-plane) [38–46,67,69,70,85,86]	Range of absolute dose reduction 0.23 to 31.8 mGy, range of relative dose reduction 12.4% to 57%, E reduction: 0.27 mSv	Possible artefacts, CT number inaccuracy, increased image noise, unhygienic	Discontinue routine patient shielding.
Abdomen/ Pelvis	Breast shield (out-of-plane) [79]	Range of relative dose reduction 16.2% to 26%		
	Fetal protection for pregnant women (in plane) [47]	Range of absolute dose reduction 3.6 to 4.8 mGy, range of relative dose reduction 16.2% to 26%	Potential artifacts	Discontinue routine patient shielding.
Lower limbs	Gonads protection (in-plane) [87]	Absolute dose reduction 5 mGy, relative dose reduction 61%	Artifacts, patient collaboration needed, patient discomfort, time consuming, hygiene	Discontinue routine patient shielding.

Table 4
Summary of the literature review for radiography examinations.

Examined body part	Patient protection shielding	Dose reduction due to the usage of protective shielding	Detrimental effects due to the usage of protective shielding	Conclusive statement
Thorax	Gonads apron (out-of-plane) [7,58]	Absolute dose reduction: 0.035 μGy, relative dose reduction: 4%		Discontinue routine patient shielding
	Shielding (out-of-plane) [89]-abstract only	Relative dose reduction: 20%		No statement
Brain	Thyroid [90]	Absolute dose reduction: 1.73 μSv		Discontinue routine patient shielding
Abdomen/ Pelvis/ Hip	Gonads protection (in-plane) [16,28,50,51,91]	Range of relative dose reduction: 16–67%	Increase of dose to other organs, misplacement, positioning, obscuring anatomical structures	Discontinue routine patient shielding
	Gonads protection (out-of-plane) [16,50,51,92]	Range of relative dose reduction: 26.4%	Dose increase, misplacement, positioning, hygiene	Discontinue routine patient shielding

CT examinations

Various articles discussed the use of contact shielding during CT examinations (Table 2). However, only few estimated dose reductions with out-of-plane shielding with the highest reported dose reduction to be equal to 0.2 mGy [30]. Most of the articles reported dose reduction for in-plane shielding estimated either using phantoms or with in-vivo measurements. The authors for the majority of the papers compared the dose reduction with in-plane shielding with other acquisition protocols and techniques to reduce organ doses. It is worth mentioning that the AAPM in its recent publication on bismuth shielding recommended that alternatives methods should be considered and implemented instead of bismuth shielding, as they can provide equivalent dose reduction maintaining the same or improving image quality without other limitations of bismuth shields [31]. The absolute eye dose reduction ranged between 2 and 144 mGy, corresponding to relative dose reductions between 2 and 70%. For eye protection, several authors reported more important dose reductions for the eyes (up to 92%) with gantry tilt so as to keep the eyes outside the primary beam [18,32,33] or if this is not possible they suggested organ-based tube current modulation (OBTCM) with comparable eye dose reduction to bismuth shielding and with better image quality [32-34]. Other authors reported image artifacts caused by the in-plane shielding and addressed the need for correct positioning and use [35,36]. Especially for CT head perfusion, Hakim et al. recommended not to use in-plane shielding as orbit shields cause significant artefacts appear if included in scan ranges during acquisition of CT perfusion and interfere with the diagnostic utility of whole brain CTP [37], while Poon et al. reported changes in CT HU [18]. In-plane shielding use was also studied for breast protection. The absolute breast dose reduction ranged between 0.23 and 31.8 mGy, corresponding to relative dose reductions between 12.4 and 57%. Catuzzo et al. calculated that the effective dose (E) decreased by 0.27 mSv for a breast dose reduction of 12.7 mGy (41%) [38]. Other authors proposed dose reduction with similar effects in dose and image quality (noise, altered HU) with techniques such as tube current reduction [39,40], tube voltage reduction [41,42], organ-based tube current modulation OBTCM [43,44] or for CT coronary angiography gating, reducing the acquisition window for the heart cycle [45]. One study reported even increase of doses for breast tissue for identical image quality when in-plane breast shielding was used, while different protocol settings could reduce breast dose maintaining image quality [46]. Moore et al. investigated the efficiency of in-plane shielding for fetal protection [47]. They reported dose savings of an average of 4 mGy for different gestation age and tube voltages with no qualitative difference in low contrast detectability; however, as the authors address the image quality evaluation was based on an anthropomorphic phantom.

Mammography examinations

Table 3 shows the articles for dose reduction in mammography examinations with the use of shielding. For thyroid gland protection, some dose reduction was observed (between16 μGy and 187 μGy). Most importantly, if thyroid shielding enters the X-ray field, it can cause artefacts that obscure breast tissue and may require mammography repetition [19]. Moreover, it is important to keep in mind that thyroid radiosensitivity decreases with age, thus, for older patients, thyroid shielding would make no sense [8,25]. Gonadal shielding is no longer recommended as radiation dose reduction is negligible since the X-ray field is far and the gonad exposure is particularly low [7]. When 0.25 mm Pb equiv. shielding is used for contralateral breast protection, a dose reduction from 41.4 to 0.01 μGy was observed [48].

Radiography examinations

The effectiveness of patient shielding in radiography examinations is summarized in Table 4. In-plane and out-of-plane shielding was also found to be used for this modality. Many reports conclude that gonad shielding for head/neck/shoulder and extremities radiography can be safely abandoned as the X-ray field is far from the sensitive organs

Table 5
Summary of the literature review for fluoroscopy-guided procedures.

Examined body part	Patient protection shielding	Dose reduction range due to the usage of protective shielding	Detrimental effects due to the usage of protective shielding	Conclusive statement
Heart	Pelvis shielding (out-of-plane) [23,21]		Increase of patient dose	Discontinue routine patient shielding
Spine (kyphoplasty/vertebroplasty)	Pelvis shielding (out-of-plane) [26]	No dose assessment reported		Discontinue routine patient shielding
Orthopedics (displaced supracondylar humerus fracture)	Thyroid, torso shielding (out-of-plane) [22]	No dose assessment reported		Discontinue routine patient shielding
Uteroscopy	Uterus [52]	0.96 mGy	Increase of other organ doses	Discontinue routine patient shielding
General fluoroscopy	Out-of plane[24]	No dose assessment reported		Discontinue routine patient shielding

[6–11,15]. Regarding, abdomen/pelvis radiography, shielding depends on patient gender with in-plane shielding being applied for female patients and out-of-plane shielding for male patients. For pelvic and hip radiography of female patients the shielding happens to be in the X-ray field then AEC cannot be used as the shielding will increase the exposure parameters considering the density of the irradiated structure. Moreover, the positioning of the shielding for ovaries it's not an easy task, indeed their position is generally unknown. If the shielding is placed, it is not is usually placed centrally above the pubic symphysis; however, according to more recent studies on the ovaries location, the shielding must be positioned laterally [49]. This information makes ovaries shielding use during pelvis and hip radiographies practically impossible, as the shielding will hide the anatomical region of interest. For the male patient there should be no particular problems, as the gonad shielding is positioned under the pubic symphysis and thus, the shielding should be out but rather close to the acquisition plane. According to a study by Lee et al., pelvic shields were misplaced in 49% of anteroposterior and 63% of frog lateral radiographs and shielding was misplaced for both girls and boys on frog lateral radiographs (misplacement for girls: 76% vs 51% for boys) [50]. Moreover, a review that focused on gonad shieling during pelvic radiography showed that shielding for male patients is controversial and stressed out that the current practice of gonad shielding during female pelvic radiography should be no longer considered as an effective method to reduce radiation exposure [16]. Larson et al. proposed posterior-anterior (PA) radiographs instead of anteroposterior (AP) that can significantly reduce exposure to the testes, thyroid, and breast for all routine screening radiographs [51].

Fluoroscopy guided procedures

Patient shielding during fluoroscopy and interventional procedures is quite rare. This is also reflected in the low number of articles investigating and discussing their effectiveness in Table 5. Only one article provided data on organ dose reduction (0.96 mGy) when shielding was used, but addressed the fact that other neighboring tissue doses were more irradiated [52]. The difficulty in positioning correctly the shielding to guarantee that it will stay outside the X-ray field, while X-ray tube constantly moves around the patient; the fact that the shielding is not visible under the sterile drape, and that the procedures are particularly long increasing the risk that the patient moves, make shielding use complicated. On the other hand, special shielding during fluoroscopy and interventional procedures is often used to decrease the radiation exposure of the operator and not that of the patient [21,23,26]. If this kind of shielding is correctly placed, outside the primary beam, the patient exposure remains the same, while in some cases the dose to the operator may decrease or remain the same [21,26]. However, there are bad practice when applying patient shielding was proven to increase the dose to the patient and personnel [23], hide important anatomical details [21], and increase the risk of infection [53]. Collimation, correct use of settings and other methods have been proven more effective to decrease patient dose than patient shielding [24].

Discussion

This literature review has shown that during the past 10 years a tremendous scientific effort has been made to investigate and quantify the benefit of different shielding techniques in order to optimize patient protection during medical X-ray imaging. In the beginning of this decade the benefit of patient shielding during medical X-ray imaging was almost undisputed, whereas in recent years some of publications began to scrutinize the importance of patient contact shielding used in routine with respect to the emerging technical improvements for almost all X-ray modalities. Options like automated exposure control (mainly for radiography), tube current modulation in z-direction as well as during gantry rotation – the latter initially developed to account for the non-cylindrical shape of the human body but soon developed further towards organ based tube current modulation – did show great potential to significantly decrease patient dose. In combination with iterative reconstruction and other methods of artificial intelligence, it was shown that the X-ray dose can be reduced even further without compromising or even improving image quality. However, it was also shown that the presence of patient shielding might lead to a detrimental effect and even and increase in patient dose when present in the imaged body region. Soon professional societies of physicians and physicists as well as national authorities became aware of these discussions leading to the current dispute about the benefits or disadvantages of routine use of patient protection means.

Based on the current hot topic debate about the significance of patient shielding, this review not only summarizes the evidence presented in the literature, but also puts it in the context of the technical developments in the same period [54-57]. In addition, non-dose-related aspects are considered in order to evaluate whether patient protection by means of contact shielding should be maintained or discontinued. Our conclusions for each of the investigated shielding type are given in the last column of Tables 2–5 as a brief statement and the reasoning for these recommendations are explained in the following paragraphs.

Out-of-plane shielding

The analysis of dose savings for out-of-plane shielding has revealed that absolute values are in the sub-mGy range. The highest value of 0.2 mGy was reported for thyroid protection during head CT-scans and mammography examinations. In case of CT, this number represents a rather low contribution compared to the total dose of a head CT. In addition, out-of-plane shielding does not protect from internal scattering, which is the main contributing source of the radiation dose to internal organs located outside of the field of view (FoV) [8,58,59]. For external scatter, the effectiveness of the shielding depends on its position relative to the beam edge. Ideally, the contact shielding should be placed exactly on the beam edge, which is practically impossible. If the shielding is positioned more than five cm away from the beam edge, the dose reduction is negligible [59,60]. Hence, any lowering of the dose due to protocol optimization, e.g. reducing tube current, will have a larger impact than shielding. On the other hand, if high-Z shielding enters the imaging FoV, besides compromising image quality, the X-ray system will drastically increase the output, resulting in higher radiation dose to the patient. This is particularly important for multidetector CT scans due to the corresponding over-ranging and over-beaming effects. According to recent research, these effects might contribute to extended exposure length of up to 83.1 mm for modern CT systems with a beam width of 80 mm in the z-direction. Thus, even when positioned outside of the selected scan range, high-Z material shielding can be exposed by the primary beam, adversely interfering with the imaging.

For thyroid shielding during mammography it has been reported that misplacement of the shield might have detrimental effects on dose and image quality. Moreover, it is important to keep in mind that thyroid radiosensitivity decreases with age, thus, for older patients- the major part of the patient population for this specific examination, thyroid shielding would have a low impact [8,25]. Furthermore, thyroid is placed at larger distance than 5 cm from the primary field, thus the dose reduction is negligible.

If the dose saving due to out-of-plane thyroid shielding is compared to other sources of ionizing radiation, e.g. sources of natural radiation, the maximal savings of 0.2 mGy is even lower than the annual dose received from cosmic radiation. According to the atlas of natural radiation from the European commission the lowest values measured are 0.3 mSv p.a.[61].

The application of contact shielding on a routine daily practice include also non-dose-related aspects that have to be taken into consideration: several publications point out that a proper placement in the daily practice is often not possible and/or might lead to significant patient discomfort [1,8,62]. In addition, contact shielding might represent a hygienic risk representing a source of bacterial or viral infections [63-65]. Nowadays, nosocomial infections in combination with increasing bacterial resistance to antibiotic medication and viral infections represent a significant challenge in the clinical daily routine and should be considered when applying patient contact shielding. Although, no article considered the psychological aspects, we can report from our experience that such effects can be either positive or negative since the use of shielding may provoke a false sense of safety to the patient or give the impression that the patient is exposed to great amounts of radiation dose outside the region of interest.

Overall, the literature analysis has shown that dose savings for all applications of out-of-plane shielding are low in terms of absolute values. Bearing in mind that for stochastic effects such as malignant cancer the absolute organ doses are important, dose savings well in the sub-mGy range could be classified as negligible. Considering the developments made in the field of imaging techniques and non-dose related aspects, we recommend that the routine practice out-of-plane shielding to be discontinued.

In-plane shielding

In-plane shielding is mainly applied to protect radiation sensitive and superficial organs, i.e. breast tissue, the thyroid and the eye lenses. This literature review has shown that considerable dose savings have been reported for in-plane shielding, both in relative as well as absolute values. It is noteworthy that most of the reviewed publications report the dose savings for different shielding applications without investigating the dose savings in relation to image quality. In addition, almost all publications mention that in-plane shielding is causing streak artefacts and significantly increase image noise due to beam hardening and photon starvation [34,37,39,40]. The issue of visible image artefacts can almost always be solved by introducing a spacer material between patient surface and shield. However, the fact of beam hardening leads to an unpredictable change of Hounsfield units, thereby challenging for any quantitative image analysis, e.g. for coronary CT angiography or iodine quantification [43,66,67]. In addition, if authors conclude that despite the shielding causing higher noise levels a sufficient diagnostic image quality was achieved, then, one has at least to reconsider whether the original protocol would allow for dose savings based on optimized scanning parameters instead of contact in-plane-shielding. Those papers that accounted for comparable image quality often concluded that similar dose savings can be achieved for optimized protocols without the drawback of altered HU units. Moreover, the main disadvantage of the shielding placed inside the X-ray field is that it can significantly obscure anatomy and compromise the diagnosis. In the worst case, it might even require the repetition of the radiological procedure and thus increase patient radiation exposure [34,37,40]. A major concern of in-plane shielding is the fact that it might interfere with all types of automated dose modulation techniques available. And even if the term “unpredictable” might be incorrect, it would require a fundamental understanding of the individual technique itself as well as the particular manufacturer’s implementation in order to account for possible detrimental effects. These considerations are not only true for CT examinations but apply also to modern X-ray systems, where it has been shown that automatic exposure control (AEC) can significantly increase the X-ray output and hence patient dose [39].

Based on the review of recent scientific literature and our analysis about dose- and non-dose related aspects of it is our opinion that the usage of routine contact shielding in medical X-ray imaging can be discontinued. This conclusion is in-line with several national medical physics societies including the American Association of Physicists in Medicine [7,68], the Nordic Society for Radiation Protection [9] and the Italian association of Medical physicists [6] that suggest to abandon the practice of patient shielding in medical X-ray imaging. The British Institute of Radiology has recently published an evidence-based guideline on why contact shielding for patients is no longer needed during conventional X-rays procedures, CT scans and interventional radiology [8]. To the best of our knowledge, only the German Commission on Radiological Protection still recommends the use of in-plane or out-of-plane organ shielding for CT examinations and the use of gonad shielding for abdomen/pelvis/hip radiographies [10]. However, the possible dose reduction are in the range of sub-mSv for the out-of-plane shielding, while for in-plane shielding other methods have been proved equally efficient as discussed above.

Lastly, it is also important to mention that discontinuing the use of routine patient shielding may confuse both the healthcare providers, who were used to employ patient shielding for several decades, as well as the patients, who were used to receive a radiation protection shielding – and especially those who undergo repetitive examinations. It is, therefore, crucial that healthcare practitioners are suitably informed about the scientific evidence and understand the complex influence of the shielding on patients’ safety and diagnostic capacity of the imaging. Radiographers and operators must keep up to date with current techniques and technologies in medical imaging. Finally, healthcare providers should be appropriately trained to listen to patients’ concerns and provide adequate information regarding the use of patient shielding, being aware that using patient shielding only to calm the patient may cause more harm than good.

Conclusions

With respect to the manifold technical dose optimization strategies, dose savings due to patient shielding are rather negligible in modern medical X-ray imaging, while significant dose- and non-dose-related detrimental effects are present. Thus, the usage of routine patient shielding can be safely discontinued in the large majority of examinations and patient groups.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejmp.2021.12.016.

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