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Prevalence of Shielding in Diagnostic X-ray Centers in the Islamic Republic of Iran: A Systematic Review

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Abstract

Shielding has been recommended as an effective tool against radiation exposure. Several studies have published on the availability and use of shielding tools in diagnostic X-ray centers across the country and contradictory results been reported. Therefore, the aim of this systematic review was to find out the status of radiation protection in term of availability and use of shielding tools in diagnostic X-ray centers in Iran. An extensive literature search was conducted in the PubMed/Medline, Embase, ISI, Cochrane Library, SID, Magiran, IranMedex, Irandoc and Google-Scholar search engine. We also manually searched the reference lists of the relevant studies. Two authors independently assessed the eligibility of all studies and extracted data. Thirty-seven studies published from 1998 to 2019 were included in this systematic review. In all, 1089 diagnostic X-ray centers, 4439 radiographs and performance of 1472 radiographers were covered in these studies. The availability of lead apron, gonad shield and thyroid collar were ranged from 7 to 95.5%, 26.6 to 94% and 7 to 94%, respectively. Moreover, their usage was ranged from 0 to 85.5%, 0 to 35% and 0 to 38.4%, respectively. In addition, lens shield was discussed in one study with availability of 0%. During 1998 to 2019, the status of shielding had not improved across the country. Therefore adherence to the safety guideline as far as possible is required to protection patients from undue exposure to radiation.

Keywords: prevalence, shielding, diagnostic X-ray, radiation exposure, Iran

1. Introduction

In the recent years, there has been a remarkable increase in the number of patients undergoing diagnostic X-ray procedures [1-5]. It is estimated that more than 471 million diagnostic X-ray procedures were performed in the United States in 2008, up from 267 million in 1998 [3]. While ionizing radiations has revolutionized medical diagnosis, their use is associated with adverse health effects, especially increasing the life time risk for developing cancer [1, 2, 6-12]. Therefore, it is necessary to reduce radiation exposure of patients as low as possible [13-16].

Shielding is one of the fundamental methods used to reduce radiation exposure in patients undergoing diagnostic X-ray procedures [2, 17-21]. Several radiosensitive tissues such as the lens of the eye, thyroid gland, breast and gonad may benefit from shielding [22]. Traditionally, lead and bismuth-based radiation shields have been used for radiation dose reduction during X-ray procedures [22-24]. Lead shields intended to reduce radiation exposure from tissues that located outside from the radiation field and therefore, are not under diagnostic evaluation (e.g. gonad shielding during pediatric chest radiography or breast shielding during computed tomography (CT) of the head) [25]. In contrast, bismuth shields reduce radiation exposure from tissues that located within the radiation field and should be appear in the resultant image (e.g. gonad shielding during pelvic radiography or breast shielding during thoracic CT) (25). Shielding provides substantial protection against radiation exposure. Evidence showed that 1-mm lead can reduce radiation exposure by 99.4% [26]. Similarly, bismuth shields could reduce radiation exposure by 17 to 62%, based on anatomical region and X-ray tube setup [18, 27]. Although the effectiveness of shielding

has been documented for some X-ray examinations, evidence showed that shielding tools are not available in some X-ray centers and if so, their use is frequently ignored [17, 28]. Several studies have focused on the availability and use of shielding tools in diagnostic X-ray centers across the country and contradictory results been reported. Moreover, their availability and usage differ from city to city and center to center. Therefore, the aim of this systematic review was to find out the status of radiation protection in term of availability and use of shielding tools in diagnostic X-ray centers in Iran. This study would be benefit to address the existence status, current problems and plans for the future.

2. Method

This study was performed according to the preferred reporting items for systematic review and meta-analysis (PRISMA) statements [29]. The ethic committee of Dezful University of Medical Sciences has approved the concept and context of the study.

2.1 Literature Search

The electronic search was performed in the national and international databases of PubMed/Medline, Embase, ISI web of knowledge, Cochrane Library, SID, Magiran, IranMedex, Irandoc and Google-Scholar search engine. The following key worlds and their Persian equivalents (for national databases) were searched with assistance an experienced librarian: ‘‘shielding, gonad shield, thyroid collar, lead apron, lens shield, bismuth shield, X-ray, radiation protection, patient, radiography, computed tomography, CT, mammography, dental radiography and Iran’’. Moreover, the reference list of the potentially relevant studies, reviews and book chapters were screened to identify additional relevant studies. Posters presented at two Iranian radiology conferences [30, 31] were screened to contribute ‘‘gray literatures’’ as well. Finally, we contact with corresponding author of the retrieved studies that met our inclusion criteria to nominate missing studies.

2.2 Inclusion and Exclusion Criteria

We included studies that reported data on the availability, use or both the availability and use of shielding tools (lens shield, thyroid shield, breast shield, gonad shield, lead gloves and lead aprons) in diagnostic X-ray centers (conventional radiography, CT, mammography and dental radiography) in Iran. Both English and Persian language studies were included without any time limitation. Other non-relevant studies that did not met our inclusion criteria were excluded from the study.

2.3 Study Selection

First, the title and abstract of the study form the original search were independently reviewed by two authors (M.C and A.A). If paper identified as eligible by at least 1 author, the full text was retrieved and evaluated. The reference lists of the retrieved studies were imported to Endnote software (Thompson Reuters, CA) to remove duplicate studies. The inclusion criteria were independently applied by two authors (Y.B and M.N) and disagreements were resolved by discussion. If agreement was not reached, the disputes were resolved by the third author (R.N).

2.4 Data Extraction

The following data were extracted by two authors (Y.B and M.N) in consensus: (a) authors name, (b) type of publication, (c) city/province where the study was performed, (d) year of publication, (e) sample size, (f) availability and use of shielding tools in X-ray centers and (g) any additional relevant information.

3. Results

3.1 Characteristics of Identified Studies

The search flowchart is shown in figure 1. In all, 37 studies comprising 32 research papers and 5 gray literatures (3 conference paper and 2 thesis) published from 1998 to 2019 were included in this systematic review. Studies were performed in conventional radiography (n=24), dental radiography (n=11), mammography (n=1) and CT (n=1) centers. One study was covered both the conventional radiography and dental radiography centers, as well. Studies were originated from 11 different cities, 6 different provinces and 2 studies across the country. In all, 1089 diagnostic X-ray centers, 4439 radiographs and performance of 1472 radiographers were covered in these studies. In term of methodology, 16 studies were used of questionnaire for data collection and 13 studies were based on direct observation. Moreover, in six studies, the archived radiographs were retrospectively assessed for investigating the evidence of shielding.

3.2 Prevalence of Shielding

The lead and bismuth-based radiation shields were discussed in 34 and 3 out of 37 studies, respectively. The availability of lead apron, gonad shield and thyroid collar were ranged from 7 to 95.5%, 26.6 to 94% and 7 to 94%,

respectively. Moreover, their usage was ranged from 0 to 85.5%, 0 to 35% and 0 to 38.4%, respectively. In addition, lens shield was discussed in one study with availability of 0%. Eight studies provided data regarding total availability or use of shielding tools without clarification the type of shielding tools. Table 1 shows the details of the studies.

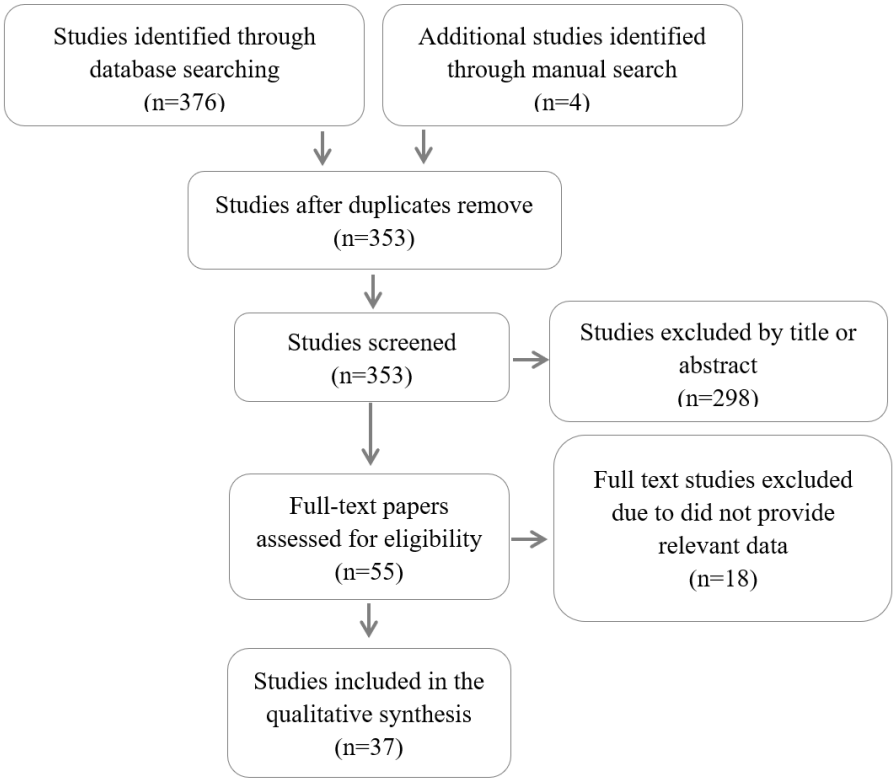

Figure 1. Study flowchart

Table 1. Characteristic of the studies reported the prevalence of shielding in diagnostic X-ray centers in Iran.

Study location (Published Year)	**X-ray center**	**Methodology**	**Sample size**	**Main results**	**Ref**
Dezful (2019)	CR	Retrospective	498 [a]	Of 498 evaluated chest and abdomen radiographs, only 0.4% had evidences of shielding.	[61]
Ahvaz (2018)	CR	Retrospective	380 [a]	Bismuth shield was present in 154 out of 198 radiographs of the boys and 170 out of 182 radiographs of the girls.	[24]
Ahvaz (2017)	CR	Retrospective	238 [a]	Lead and bismuth-based gonadal shields were presented in 47 (19.75%) and 61 (25.7%) out of 238 pelvic x-rays of the boy patients, respectively. 34% of lead shields and 80% of bismuth shields were protected the gonads without compromising image quality.	[18]
Kermanshah (2017)	CR	Questionnaire	38 [b]	Shielding tools was never applied for patients. The frequency use of shielding tools for the radiographers and non-radiographer personnel were 100% and 28.9%, respectively.	[62]
Ahvaz (2017)	CR	Observational	25 [c]	Lead apron, gonad shield and thyroid collar was available in 96%, 94% and 94% of X-ray rooms, respectively. 28% of radiographers were applied shielding tools for the pregnant mothers and children.	[42]
Ahvaz (2016)	CR	Retrospective	348 [a]	76.5 % of radiographers never used any shielding tools	[19]

Ahvaz (2016)	CR	Retrospective	1230 [a]	Gonad shield was present in 6.6% of radiographs evaluated.	[37]
Ahvaz (2016)	CR	Retrospective	1745 [a]	Gonad shield was present in 2.9% of the girls' radiographs and 7.6% of the boys' radiographs.	[38]
Ahvaz (2015)	CR	Observational	30 [c]	More than 97% of the hospitals evaluated benefited from adequate shielding tools. The prevalence use of shielding tools in hospitals where shielding was available, varied from 5.2% to 14%.	[17]
Ahvaz (2015)	CR	Observational	5 [c]	In 64.3% of X-ray rooms, at least one flat contact gonad shield with large size was available. Only large size of gonad shields was available. The prevalence use of gonad shielding was less than 0.2%.	[28]
Khuzestan (2015)	CR	Questionnaire	185 [b]	During portable radiography, 85.5% of the radiographers were used of lead apron. In stationary radiography, 31.35% of the radiographers were used of gonad shield.	[49]
Kermanshah (2015)	CR	Observational	8 [c]	Lead apron, gonad shield and thyroid collar were available in 87.5%, 75% and 75% of X-ray rooms, respectively.	[43]
Ahvaz (2013)	CR	Observational	5 [c]	Thyroid collar and gonad shield was never applied for the patients.	[34]
Yazd (2013)	CR	Questionnaire	17 [b]	The prevalence use of gonad shield was 43.59%.	[36]
Zahedan (2012)	CR	Observational	29 [c]	The availability of lead apron, thyroid collar and gonad shield were 95.5%, 79% and 62%, respectively. 34/48% of radiographers were used lead apron only for pregnant patients and children.	[44]
Hamadan (2011)	CR	Questionnaire	71 [b]	The prevalence use of shielding tools was 78.9%.	[63]
Kerman (2009)	CR	Observational	-	The availability and prevalence use of shielding tools was 90% and 1%, respectively.	[64]
Sanandaj (2007)	CR	Questionnaire	4 [b]	Gonad shield was available in 37% of X-ray centers.	[41]
Mazandaran (2007)	CR	Observational	20 [c]	The prevalence use of thyroid collar and gonad shield for patients was 0.3%.	[45]
Shiraz (2006)	CR	Questionnaire	51 [b]	The availability and prevalence use of shielding tools was 80% and 91.8%, respectively.	[65]
Mazandaran (2005)	CR	Questionnaire	15 [b]	The availability of shielding tools was 26%.	[66]
Hamadan (2004)	CR and DR	Questionnaire	5 [b]	The prevalence use of lead apron was 58.3% and 4.5% in conventional radiology and dental radiography, respectively.	[60]
Kerman (2003)	CR	Observational	39 [c]	Shielding was never regarded in clinical practice.	[35]
Azerbaijan (2001)	CR	Observational	81 [c]	Of 81 hospitals evaluated, the frequency use of lead apron and lens shield for patients were 25.5% and 2.8%, respectively.	[48]
Boshehr (2001)	CR	Observational	30 [c]	Of 30 X-ray rooms evaluated, lead apron and gonad shield were not available in 5 and 22 X-ray rooms, respectively. Lead apron was never applied for the patients as well.	[46]
Mashhad (2018)	DR	Questionnaire	232 [c]	Lead apron and thyroid gland were not applied for the patients in 54.7% and 61.6% of x-ray centers.	[57]
Kerman (2014)	DR	Questionnaire	106 [c]	Lead apron and thyroid gland were available in 12..3% and 10.4% of X-ray centers, respectively. Only 5.7% of X-ray centers were used of lead apron for the patients.	[56]
Iran (2012)	DR	Questionnaire	700 [b]	1% of practitioners were used of thyroid collar and lead aprons regularly and 34% occasionally.	[58]

Rasht (2011)	DR	Questionnaire	110 [b]	The prevalence use of lead apron and thyroid collar was less than 1%.	[59]
Isfahan (2011)	DR	Questionnaire	184 [b]	The prevalence use of lead apron and thyroid collar was 10% and 4.5%, respectively.	[55]
Iran (2009)	DR	Questionnaire	18 [b]	The availability and prevalence use of thyroid collar and lead apron were 16.7% 22.2%, respectively.	[53]
Tehran (2006)	DR	_	_	The prevalence use of lead apron was 21.9%.	[54]
Tehran (2004)	DR	Observational	200 [c]	In 93% of x-ray centers, there was no lead apron and thyroid collar. In the remaining 7%, their use was 5% and 2%, respectively.	[52]
Yazd (2004)	DR	Questionnaire	40 [b]	Lead apron and thyroid collar was never applied for patients.	[51]
Isfahan (1998)	DR	_	274 [c]	The prevalence use of lead apron was 16%.	[50]
Shiraz (2012)	MG	Questionnaire	5 [b]	In 80% of the mammography divisions, there was no special radiation protection shield used for the patients	[67]
Ahvaz (2015)	CT	Observational	5 [c]	No bismuth shield was available. The availability of lead-based gonadal, thyroid collar, lens and breast shields was 70, 62, 0 and 100%, respectively. Their prevalence of use was 3.6, 0, 0 and 2.6%, as well.	[25]
CR, conventional radiography; DR, dental radiography; CT, computed tomography; MG, mammography a, number of radiographs; b, number of practitioners; c, number of x-ray rooms					

4. Discussion

To our knowledge, our study is the first systematic review on the prevalence of shielding in diagnostic X-ray centers in Iran. In this study, the availability and use of various shielding tools such as lead apron, gonad shield, thyroid collar and lens shield, originated from 1089 diagnostic X-ray centers, 4439 radiographs and performance of 1472 radiographers is covered.

The germ cells within the gonads are highly sensitive to radiation and therefore, it is necessary to reduce their received dose as low as possible [18, 32, 33]. Traditionally, when the gonads located at or closer (5-cm) to the primary radiation field, gonad shielding should be perform, unless its presence compromise diagnostic image quality [32]. According to literatures, gonad shielding was discussed in 14 studies with availability and prevalence use of 26.6 to 94 % and 0 to 35 %, respectively. Two studies reported that gonad shielding was never applied for patients [34, 35]. Similarly, one another study reported even if gonad shields were available in 64.3% of X-ray rooms, their use was ignored [28]. In opposite, one questionnaire-based study showed that 35% of radiographers were used of gonad shield for the patients [36]. Two retrospective studies were focused on the use of gonad shield during pelvic radiography and reported the prevalence use of no more than 7.6% [37, 38]. Moreover, two studies were assessed frequency use of bismuth-based gonadal shields for pediatric pelvic radiography [18, 24]. The first study reported the prevalence use of 93.4% for the girls and 77.7% for the boys, without compromising image quality [24]. In the second study, the frequency use of 25.7% for the boys with satisfactory protection rate of 80% was reported [18]. The difficulty associated with accurate positioning of the shield may be the main source for omission of gonad shielding in procedures that the gonads included in the primary radiation field [39]. This drawback is more problematic for female patients than males due to complex anatomical position of the ovaries [40]. However, data from 9 studies are ambiguous in term of inclusion or exclusion of the gonads in the primary radiation field and patients' sex [34-36, 41-46].

Lead apron is an effective tool against radiation exposure. It can cover 75 to 80% of the bone marrow [32] and reduce the scatter radiation by approximately 98% [47]. Lead apron was discussed in as vastly as 18 studies in the literatures with distribution of 7 studies in conventional radiography [17, 42-44, 46, 48, 49], 10 studies in dental radiography [50-59] and 1 study in both conventional and dental radiography [60]. The availability and prevalence use of lead apron was 87.5 to 97% and 25.5 to 85.5% in conventional radiography and 7 to 44.3% and 0 to 22.2%

in dental radiography, respectively. However, some radiographers believe that frequent use of lead apron would result in back pain and ergonomic disease.

During head, neck and dental radiography and neck and thoracic CT in particular, thyroid gland receives unavoidable radiation exposure. Therefore, thyroid shielding is of great value to reduce thyroid gland dose, when its presence does not compromise diagnostic image quality [22]. The availability and use of thyroid shield was varied between studies and X-ray centers. Its availability and usage was ranged from 75 to 94% and 0 to 0.3% in conventional radiography and 10.4 to 16.7% and 0 to 38.4% in dental radiography, respectively. Moreover, one study was identified in the literatures discussed thyroid shielding in CT centers [25]. However, results are concerning due to thyroid shielding was never applied for the patients.

The lens of the eye is highly radiosensitive, especially in children [23]. Bismuth-eye-shield has shown to be effective at reducing radiation dose during CT exams [22, 23]. The radiation dose reduction up to 50% with no effect on image quality has been reported during head CT [23]. However, eye shielding was not covered as many as other radiosensitive organs. Only one study was identified in the literatures discussed lens shielding during CT exams with availability of and usage of 0% [25].

CT exposes patients to much more radiation than other diagnostic imaging modalities. It is estimated that CT constitute 67% of the effective dose from all medical X-ray examinations [1]. However, it was not covered as many as other imaging modalities. Therefore, a better evaluation of shielding in CT centers is required to occur in the future studies. There was a gap between data from observational and retrospective studies with questionnaire studies. The availability and prevalence use of shielding tools was more common in questionnaire than in observational and retrospective studies. It is assumed that data from observational and retrospective studies may be more reliable than studies who their authors used questionnaire to data collection. Therefore, more care is required in applying the findings of these studies. Even if various radiation protection training courses has been annually performed in the country, the statues of shielding does not improved across the country over two past decades. This fact may be due to ineffectiveness of these training courses. Karami et al. believed that most of the radiographers do not follow the professional ethical issues [8].

Among the limitations of the current study, the following could be mentioned: 1) different methodology, 2) type of X-ray examinations, patients' age and sex were not reported in several studies.

In conclusion it can be said that during 1998 to 2019, the status of shielding had not improved across the country. Therefore adherence to safety guidelines as far as possible is required to protection patients from undue exposure to radiation.

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