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A New Practical Model of Testes Shield: The Effectiveness During Abdominopelvic Computed Tomography

AHMET ALI SANCAKTUTAR,* YAŞAR BOZKURT,* HAKAN ÖNDER,† HALUK SÖYLEMEZ,* MURAT ATAR,* NECMETTIN PENBEGÜL,* TEVFIK ZIYPAK,‡ GÜVEN TEKBAŞ,† AND ABDÜLKADIR TEPELER§

*From the Departments of *Urology and †Radiology, Faculty of Medicine, Dicle University, Diyarbakır, Turkey; the ‡Department of Urology, Faculty of Medicine, Ataturk University, Erzurum, Turkey; and the §Department of Urology, Faculty of Medicine, Bezmialem University, Istanbul, Turkey.*

ABSTRACT: The goal of our prospective study was to measure the effect of a new standard model male gonad shield on the testicular radiation exposure during routine abdominopelvic computed tomography (CT). Two hundred male patients who underwent upper abdominal and pelvic CT examinations were included in our study. To prepare the testes shield (TS), 2 No. 8 fluoroscopy radiation-protection gloves made of bismuth (0.35 mm lead equivalent) were used. These gloves were invaginated into one another and their fingers were turned inside out. Scrotums of all patients were pushed into these lead-containing gloves. Upper abdominal CT (n = 6), pelvic CT (n = 9), and abdominopelvic scanning (n = 185) were performed. Immediately after the CT examinations and at postprocedural day 1, the scrotal examinations were repeated. None of the patients exhibited scrotal laceration, edema, eruption, erythema, tenderness, or pain. During the CT examinations, 22 patients (11%) felt unrest because of their exposed genital regions, without any adverse effect on the procedure. Dosimetric measurements of radioactivity inside the TS (dosimeter I) and outside it (dosimeter II) were 6.8 and 69.00 mSv, respectively. Accordingly, the TS we used in our study reduced the radiation exposure of the testes by 90.2% (10.1 times). We think that the use of this radioprotective TS during radiological diagnostic and therapeutic procedures is an appropriate approach from both a medical and legal perspective. Therefore, we recommend this user-friendly, practical, low-cost, and effective TS for all radiologic procedures.

Key words: Radiation exposure, abdominopelvic CT.
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Since the discovery of x-rays by Roentgen in 1895, the application of radiological techniques has become an almost indispensable tool in the field of medicine (Rogers, 2002). Ionizing radiation has come to be employed as a first choice in the diagnosis of many diseases, as well as in the treatment of some types of malignancies (Heyer et al, 2010; Chun-Sing et al, 2012). Thus, imaging techniques using ionizing radiation are being used more frequently in various fields. Especially in the diagnosis and treatment of diseases requiring uninterrupted monitoring (ie, vesicoureteral reflux) or those progressing with recurrences (ie, urolithiasis), radiological imaging modalities must be used more often. For example, in the United States, the number of computed tomography (CT) scans performed increased from 3.6 million in 1980 and 13 million in 1990 to 33 million in 1998 (Rogers, 2002). In addition, at present, the number of routine CT scans is continually increasing (Task Group on Control of Radiation Dose in Computed Tomography, 2000).

Beneficial as well as deleterious effects of radiation have been demonstrated in the diagnosis and treatment of diseases (Goodhead, 2009). Because of the cumulative effects of radiation, especially in the pediatric and reproductive age groups, this issue is very important (Almen and Mattsson, 1995). Frequent use of radiological examinations exposes the urogenital system (especially the testes-ovaries) to the hazards of radiation. In terms of the human body's tissues, gonads are one of the most vulnerable to radiation. Even with the doses used in radiological examinations, exposure to radiation might result in gonadal damage and genetic mutation (Richardson, 1990; Boehmer et al, 2005; Mazonakis et al, 2006). In addition, experimental and clinical studies have demonstrated both transient and permanent adverse effects of radiation on male and female fertility (Besse et al, 2010). Therefore, in all radiological studies, the routine use of a testis shield (TS) is recommended in male patients (Wall and Hart, 1997). TSs may protect the gonads from the harmful effects of radiation. With these protective methods, testes are exposed to doses of radiation that are decreased by 8–10-fold (Price et al, 1999; Hohl et al, 2005).

Correspondence to: Dr Ahmet Ali Sancaktutar, Department of Urology, Faculty of Medicine, Dicle University, 21100, Diyarbakır, Turkey (e-mail: aasancaktutar@gmail.com).

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Figure 1. **(A)** Two gloves were invaginated into one another. **(B)** Dosimeters were placed both inside and outside the shield. **(C)** Patients' scrotums were covered with these lead-containing gloves. Color figure available online at www.andrologyjournal.org.

The goal of our prospective study was to measure the effect of a new standard model male gonad shield on testicular radiation exposure during routine abdominopelvic CT.

Materials and Methods

Study Design

For this study, the approval of the ethics committees of Dicle University was obtained. Informed consent forms were also procured from patients.

Among patients hospitalized between February and June of 2011 in the urology clinics of our hospital, 200 male patients who underwent upper abdominal and pelvic CT examinations were included in this study. Two radiology technicians were trained in the placement of TSs on a human model. Every patient was informed visually, using a virtual male genital system model, about TSs before each CT examination. The scrotal regions of the patients were optimally prepared for CT examination in the preparatory room. Then, the patients were placed in a supine position on the radiology table, and a TS was placed over them. This procedure took about 3–5 minutes.

Patients referred from the emergency room and pediatric patients were not included in the study. All patients underwent physical scrotal examinations. Patients with bilateral orchiectomies, solitary testes, scrotal masses, scrotal skin infections, or lesions were excluded from the study. Gonad protection from the radiation exposure is important in the pediatric and reproductive age groups; however, we excluded the pediatric age group from the study because of the difficulty of obtaining children's parental approval, as found in our previous experience.

TS Model

The standard radioprotective protocol for surgical teams consists of 0.35-mm-thick lead overalls, a thyroid sheath, and 0.25-mm-thick protective lead shields (Synowitz and Kiwit, 2006). Currently, lead gloves are widely used in operating rooms with fluoroscopies designed for orthopedic, neurosurgical, and urological operations. Thus, the frequently used and easily accessible lead gloves constituted a starting point for our study.

To prepare the TS, 2 No. 8 fluoroscopy radiation-protection gloves made of bismuth (0.35-mm lead equivalent; Protec, Oberstenfeld, Germany) were used. These gloves were invaginated into one another and their fingers were turned inside out (Figure 1A and B).

Firstly, the scrotums of all patients were placed in disposable gloves for hygienic purposes. Secondly, their scrotums were pushed into the lead-containing gloves (Figure 1C). For patients with small scrotums, a nonopaque plastic clip was used so as to wrap all scrotums snugly with the glove.

Thermoluminescence Dosimetry: Dosimetry Recording

Two thermoluminescence dosimeters (TLD) (UD-802AS2; Panasonic, Tokyo, Japan) were used to measure the exposure to ionizing radiation; these were provided by the Turkish Atomic Energy Institute (TAEK). Dosimeter I was placed between the disposable lead gloves. Dosimeter II was placed at the same level, over the lead gloves (Figure 2). Following CT examination, the gloves and dosimeters were gently removed from the scrotal skin. Dosimeters were not kept in the radiation room after CT examination; instead, they were stored in a radiation-free environment. The dosimeters were not included in the field of view, and secondary exposure to radiation was measured.

After the completion of the CT procedures of 200 patients, dosimeters I and II were sent to TAEK in accordance with the official protocols described in our correspondence with the institute. For the evaluation of TLDs, a Model 3500 (Harshaw Chemical, Erlangen, Germany) TLD reader was used. The TLD reader was kept at a stable temperature.

CT Protocol

All patients were screened according to the standardized abdominopelvic CT protocol. For screening, a Philips Brilliance 64-Slice CT (Philips, Eindhoven, Netherlands) was used. All upper abdominal and pelvic regions were examined using 120 KV and 250 mA, as per the protocol. For the entire abdomen, 400–450 images with contiguous 1-mm-thick sections or 300–350 images with 1-mm-thick sections were obtained. For each section, a dose of 14.7 mGy was delivered.

Results

The mean age of the patients was 45.6 (range, 19–72) years. Mean characteristics of the patients in terms of height, body weight, and body mass index were

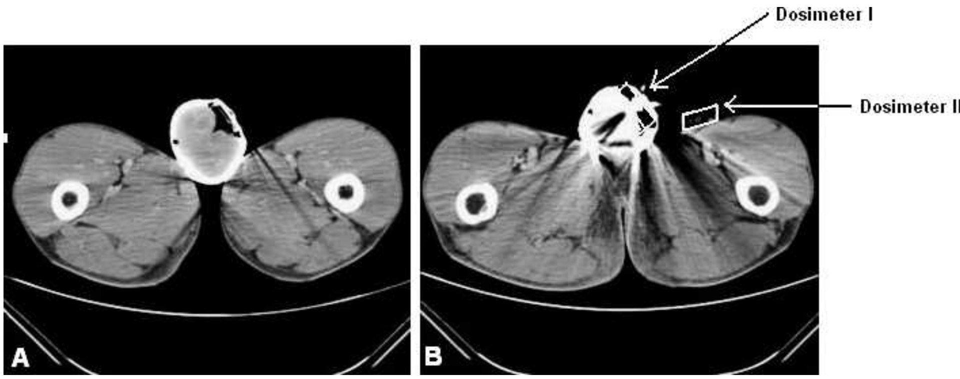

Figure 2. Appearance of **(A)** lead gloves and **(B)** dosimeters at the pelvic computed tomography.

determined to be 170 cm (range, 151–199 cm), 72.4 kg (range, 44–102 kg), and 25.1 (range, 17.3–33.5), respectively. Upper abdominal CT (n = 6), pelvic CT (n = 9), and abdominopelvic scanning (n = 185) were performed. All CT examinations were performed uneventfully. Immediately after the CT examinations and at postprocedural day 1, the scrotal physical examinations were repeated. None of the patients exhibited scrotal laceration, edema, eruption, erythema, tenderness, or pain. During the CT examinations, 22 patients felt uneasy because of their exposed genital regions, without any adverse effect on the procedure. The durations of the upper abdominal CT (35 seconds), pelvic CT (30 seconds), and abdominopelvic CT (70 seconds) examinations were also measured.

Among the 200 patients, 122 (61%) had not undergone an abdominal CT scan before, whereas 78 patients (39%) had had at least one abdominal or pelvic scan previously. The history of these patients revealed that no TS model was used during their prior CT scans.

Results of TLD

Dosimetric measurements of radioactivity inside (dosimeter I) and outside (dosimeter II) the TS were 6.8 mSv and 69.00 mSv, respectively. This demonstrates that the TS used in our study reduced the radiation exposure of the testes by 90.2% (10.1 times).

Discussion

Patients are exposed to higher radiation doses during CT examinations than in conventional x-ray procedures. The number of CT scans performed has increased dramatically in the last decade (≈10-fold). In a study conducted by Berrington de Gonzalez et al (2009), the authors claimed that 29 000 cases of radiation-related cancer would develop as secondary results of the 72 million CT scans performed in 2007. These findings indicate that CT scans are very frequently used, and also suggest that patients are exposed to high doses of radiation, which necessitates protective measures.

The testes are more vulnerable to lower doses of ionizing radiation than the ovaries. Exposure of the testes to a radiation dose of 15 Gy causes oligospermia, whereas a dose of 30 Gy induces transient azoospermia. These doses have a lower impact on ovogenesis (Ogilvy-Stuart and Shalet, 1993). The higher sensitivity of the testes to radiation relative to other organs forces urologists to be more attentive to this issue. Based on the "as low as reasonably achievable" principle, exposure to radiation should be avoided unless it is deemed necessary (Musolino et al, 2008). According to data provided by the National Radiological Protection Board (NRPB), the use of a gonadal shield is recommended as far as possible in all interventional procedures. Based on the declaration of this committee, there is no such thing as a "harmless radiation dose" (Wall and Hart, 1997). Accordingly, every radiological examination carries a risk, even those using a minimal level of radiation.

TSs of various shapes and materials have been designed and used to protect the testes from radiation (Figure 3). Among them, there are many lead-containing protective shields in the form of capsules, plaques, blankets, and dressings (Sikand et al, 2003; Hohl et al, 2005; Fawcett and Barter, 2009). In the literature, these methods have been shown to decrease testicular exposure to radiation by 70%–90%. The study conducted by Hidajat et al (1996) was the most remarkable and influential of these studies. It demonstrated a 95% decrease in radiation exposure using a 1-mm-thick lead capsule model. On the other hand, Hohl et al (2005) displayed an 87% decrease in the testicular radiation dose using a capsule model TS. In one of the recent studies performed on this subject, TS use reportedly reduced testicular radiation exposure by 58%. In our study, the TS model decreased the testicular radiation dose by

Figure 3. The other models of currently used testis shields. Color figure available online at www.andrologyjournal.org.

90.2%, as demonstrated in our results. Therefore, we achieved similar, even relatively higher, rates of gonadal protection with our TS model. This outcome is not surprising. In fact, Synowitz and Kiwit (2006) demonstrated a 75% decrease in radiation exposure using a 0.25-mm-thick lead glove during vertebroplasty. We used 2 invaginated 0.25-mm-thick lead gloves. The results of our study, and some exemplary studies cited in the literature, are shown in the Table (Hidajat el al, 1996; Price et al, 1999; Hohl et al, 2005; Dauer et al, 2007).

Despite the deleterious effects of radiation on the testes and the effective level of gonadal protection offered by TSs, however, the frequency of TS usage is not at a desirable level (Fawcett and Barter, 2009). This lower prevalence of TS use is an interesting phenomenon, leading us to ask what could be preventing the use of this protective measure. We suggest that the designs of current TSs are not user friendly. During interventions directed at the urogenital region, necessary manipulations are hindered by the currently used gonadal protective devices, masking the urogenital area from view (Price et al, 1999; Sikand et al, 2003). However, during extracorporeal shock wave lithotripsy, retrograde intrarenal surgery, ureteroscopy, percutaneous nephrolithotomy, voiding cystourethrography (VCUG), and intravenous pyelography, any interference with extraneous opacities or artifacts that cover the urogenital area from view are not allowed.

What would the shape and design of an ideal TS be? To the best of our knowledge, an ideal TS would be practical

Table. *Comparison of literature reports and present study for scattered dose reduction with the use of gonadal shields during abdominal computed tomography scans (with the testes not in the direct beam)*

Study	Study Type	Scanning Protocol	Total Testicular Dose (mSv)		Reduction, %
			Without Shielding	With Shielding	
Hidajat et al, 1996	Phantom study, 1-mm testicular capsule	Single-slice sequential, 10-mm slice thickness, 250 mAs/slice, 120 kV	1.46	0.07	95
Price et al, 1999	Phantom study, 1-mm wraparound apron	Single-slice spiral, 10-mm slice thickness, 220 mA, 120 kV	0.82	0.19	77
Hohl et al, 2005	Patient study, 1-mm testicular capsule	16-slice spiral, 16 $\times$ 1.5-mm collimation, 150 mAseff, 120 kV	2.40	0.32	87
Dauer et al, 2007	Phantom study, 1-mm wraparound canvas	16-slice spiral, 16 $\times$ 1.25-mm collimation, 194 mAseff, 120 kV	0.62	0.26	58
Present study	Phantom study, 0.7-mm wraparound circular	64-slice spiral, 16 $\times$ 1.25-mm collimation, 250 mAseff, 120 kV	69.00	6.80	90

Abbreviations: mA, milliampere; mAs, milliampere values; mAseff, effective milliampere values.

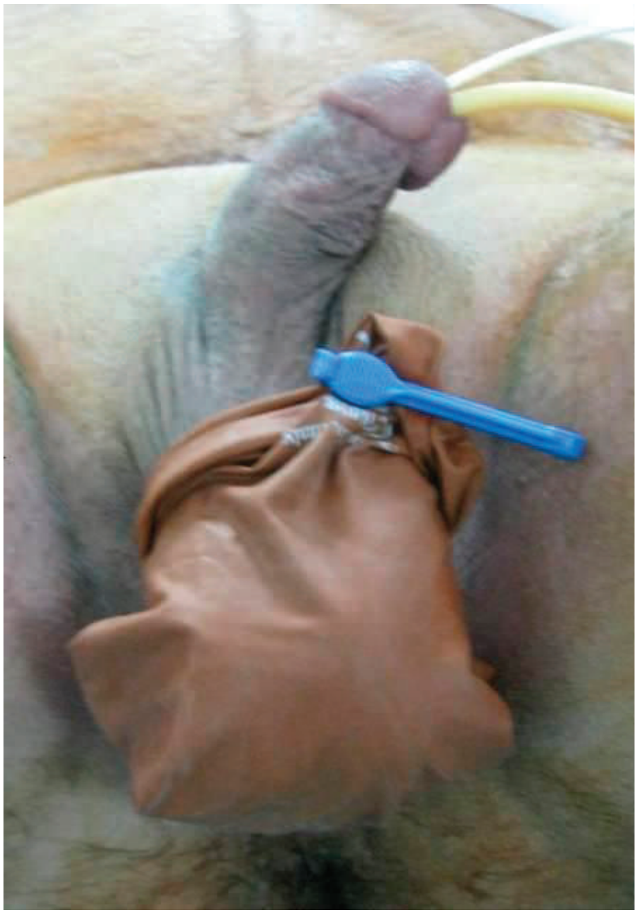

Figure 4. Appearance of the testes shield during an endourological procedure. Color figure available online at www.andrologyjournal.org.

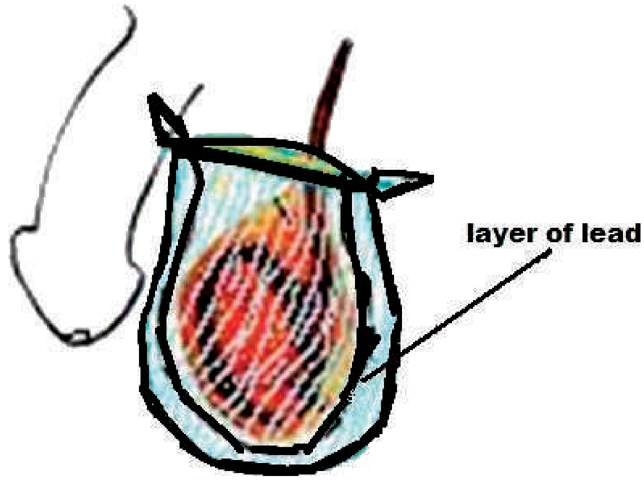

Figure 5. Drawing of an aesthetically better-modified model. Color figure available online at www.andrologyjournal.org.

and ergonomic. Additionally, it should contain an adequate amount of lead for satisfactory protection, without covering the urogenital region. It should also be capable of being used for a patient in the lithotomy position, and at the same time, it should not prevent intraurethral access. Furthermore, an ideal TS should fully protect the testes against exposure to laterally oriented x-rays. Thus, we submit that an ideal TS should enclose the testes from all sides without covering the urogenital region.

In CT scans, lateral x-rays expose patients to the risk of 3–7-fold higher radiation doses than anteroposterior scan (Theocharopoulos et al, 2003). Therefore, TSs fabricated in plaque or sheet forms cannot provide optimal prevention from lateral x-rays (Wainwright, 2000). Our circular TS model can adequately protect the scrotum from laterally oriented radiation exposure, in compliance with operational CT principles.

Because of their design, the TSs mentioned in the literature are not suitable for use in the lithotomy position. These shields cannot remain fixed when patients are placed in the lithotomy position; moreover, they do not allow intraurethral access (Price et al, 1999; Theocharopoulos et al, 2003; Fawcett and Barter, 2009). Therefore, the use of TSs is challenging during endoscopic procedures performed on patients placed in the lithotomy position under the guidance of fluoroscopy. Additionally, in dynamic tests such as VCUG, in which intraurethral interventions are required, the usage of TSs is compulsory (Fawcett and Barter, 2009). Our TS design can be conveniently used with patients placed in the lithotomy position. When situated so as to leave the penis exposed, it can allow for every endourological intervention (Figure 4).

The NRPB recommends the use of gonad-protective devices in all interventional procedures in which it is possible (Wall and Hart, 1997). Because of the increased awareness of patients' rights, as well as the potential risks and adverse effects of radiation exposure, refraining from TS use can give rise to lawsuits against health care providers. Harming patients because the necessary measures are not implemented will cause legal problems. To elucidate this issue further, collaborations between urological scientific platforms and judiciary boards might encourage future attempts.

Regarding the practicability of our TS, we recommend the mass production of an aesthetically better-modified model (Figure 5). Our clinic has given orders to a specialized radiological equipment manufacturer for the production of this model.

In summary, the currently available TSs are not routinely used for various reasons. Firstly, they have awkward and impractical shapes that mask the urogenital region during procedures. Additionally, they are not suitable for patients placed in the lithotomy position. In addition to their high costs, they do not allow intraurethral access or provide protection from laterally oriented x-rays. Our proposed TS model can be widely used because of its efficiency, practicability, and suitability for every endourological procedure.

Conclusion

The TS model we used in this study decreased the radiation dose exposure of the testis by 10-fold. We think that the use of this radioprotective TS during radiological diagnostic and therapeutic procedures is an appropriate approach from both a medical and legal perspective. Therefore, we recommend this user-friendly, practical, low-cost, and effective TS for all radiological procedures. New scientific publications and research and development investigations should be conducted on this issue.

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