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ORIGINAL ARTICLE

The effectiveness of additional lead-shielding drape and low pulse rate fluoroscopy in protecting staff from scatter radiation during cardiac resynchronization therapy (CRT)

Yoshiaki Morishima[1,2] · Koichi Chida[2] · Yoshiaki Katahira[3]

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Abstract

Purpose Cardiac resynchronization therapy (CRT) often requires a long fluoroscopic time and protection from scatter radiation. This study reports on scatter radiation levels during CRT, with and without additional shielding, and using standard or low pulse rate fluoroscopy.

Materials and methods Additional lead-shielding drape (0.35-mm lead equivalent) was used on the left side of the table and pulsed fluoroscopy was performed at rates of 10 pulses/s (usual rate) and 7.5 pulses/s (low pulse rate). Fluoroscopy scatter radiation was measured for both pulse rates using an acrylic phantom with a radiation survey meter, both with and without the additional lead-shielding drape.

Results With the additional lead-shielding drape, the fluoroscopy scatter radiation was reduced by 74.3% at 10 pulses/s and 78.6% at 7.5 pulses/s. If the fluoroscopy was changed from 10 pulses/s to 7.5 pulses/s, the scattered radiation at the primary physician's position was reduced by 24.0%. The combined use of additional shielding drape and low pulse rate fluoroscopy reduced scatter radiation by over 80%.

Conclusion Additional lead-shielding drape and low pulse rate fluoroscopy are effective in reducing the scattered radiation dose to physicians and nurses during CRT.

Keywords CRT procedure · Additional lead-shielding drape · Low pulse rate fluoroscopy · Radiation protection · Scatter radiation

Introduction

Cardiac resynchronization therapy (CRT) is a well-recognized interventional radiology (IR) procedure for treatment of heart failure. CRT is known to improve left ventricular (LV) ejection fraction and reduce mortality rates [1].

IR techniques such as CRT procedures are often complex and require long fluoroscopic times, thereby resulting in significant radiation exposure to the physician [2–4]. Therefore, radiation protection for IR physicians and nurses, is an important issue [5–12].

During fluoroscopically guided procedures, the physician must wear a lead apron. Nevertheless, physicians have been injured performing fluoroscopically guided procedures [13]. Lead aprons can provide radiosensitive organs (e.g., gonads) with some protection from scatter radiation; however, on their own they may not provide full protection from scatter radiation. Therefore, we considered that an additional lead-shielding device is necessary.

In our hospital, about 20 CRT procedures are implemented each year, and it is therefore necessary to pay attention to the radiation dose to the physician.

Previous studies have shown the utility of attaching additional lead-shielding drape around the catheter table for protecting the physician from radiation exposure in IR

✉ Yoshiaki Morishima
morishima@med.tohoku.ac.jp

[1] Department of Radiology, Tohoku Medical and Pharmaceutical University Hospital, 1-12-1 Fukumuro, Miyagino-ku, Sendai 983-8512, Japan

[2] Department of Radiological Technology, Tohoku University School of Health Sciences, 2-1 Seiryo Aoba-ku, Sendai 980-8575, Japan

[3] Department of Cardiovascular Center, Tohoku Medical and Pharmaceutical University Hospital, 1-12-1 Fukumuro, Miyagino-ku, Sendai 983-8512, Japan

procedures [14]. Currently, for IR procedures, additional lead-shielding drape is generally attached to the right side of the patient catheter table. However, in the case of CRT procedures, the physician stands on the left side of the patient, and despite the long fluoroscopy time, CRT procedures have generally been performed without additional lead shielding. In addition, protection from scattered radiation during the use of low pulse rate fluoroscopy has also been reported [15].

The aim of this study was to investigate the effectiveness of additional lead-shielding drape and to reduce pulse rate for dose reduction during CRT procedures for staff (physicians and nurses).

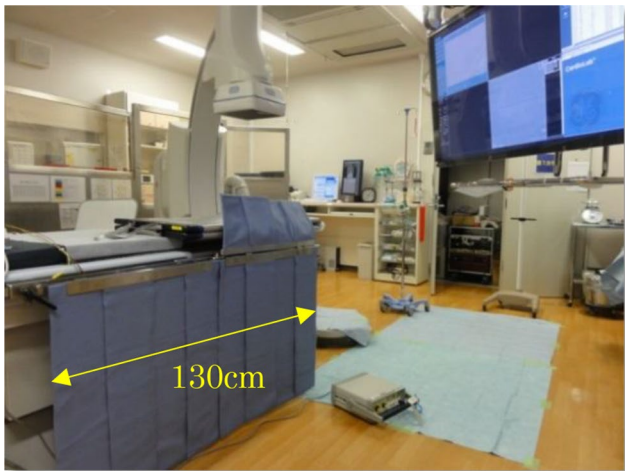

Fig. 1 The additional lead shielding drape used in our study. Additional lead shielding drape (0.35-mm lead equivalent, width = 130cm) attached to the opposite side of the table to that covered in usual IR procedures

Materials and methods

A digital cine single-plane angiography unit (Infinix celeve-i8000, Toshiba Medical Systems, Tokyo, Japan) with an under-tube X-ray tube system was used for the experiments described in this study. Pulsed fluoroscopy (usual rate of 10 pulses/s, or low rate of 7.5 pulses/s, 80 kv, 67 mA) was used with a 17-cm flat panel detector with a grid of 13:1, 70 lines/cm. The source to image receptor distance (SID) was 100 cm.

Additional lead-shielding drape (0.35-mm lead equivalent, width = 130 cm) was used during the CRT procedures (Fig. 1), with it being mounted on the opposite side to that shielded in the usual IR procedure. Additional lead-shielding drape on the side of the table is mainly intended to protect the parts of the physicians that are not protected from scattered radiation by personal lead aprons.

Fluoroscopy scatter radiation was measured using an acrylic phantom (30 × 30 × 20 cm, assuming the approximate thickness of a patient's body) with an ionization chamber radiation survey meter (ICS-321, HITACHI, ALOCA Medical, Ltd., Tokyo, Japan) with a measuring range of 1 μSv/h–300 mSv/h. This survey meter was used and calibrated on a regular basis.

The scattered radiation was measured both with and without the additional lead-shielding drape, at both 10 pulses/s and 7.5 pulses/s.

Figure 2 shows the measurement points used in the phantom study. The results show the mean of three measurements for each point. The seven measurement points represent the usual positions of medical staff during a CRT procedure (in particular P: primary physician, Q: assistant physician, R: 1st nurse, S: 2nd nurse). An ionization chamber radiation survey meter was placed 100 cm above the floor, corresponding to the height of the gonads, and measurements were made at seven points situated at 50-cm intervals, with these points representing

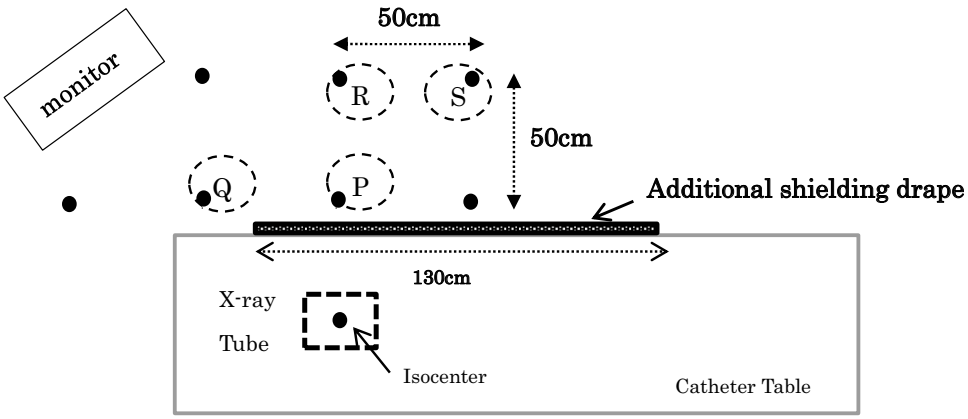

Fig. 2 Cardiac catheterization laboratory for a CRT procedure. The measurement plan for the phantom study (the points of measurement are made at 50-cm gaps indicated by the black points) showing representative positions of the physicians relative to the patient and X-ray tube during the CRT procedure. *P* primary physician, *Q* assistant physician, *R* 1st nurse, *S* 2nd nurse

the usual positions of medical staff during a CRT procedure. After measuring the scatter radiation, radiation maps were created using SS-3030 software (S.S. Techno-Engineering Co., Nagoya, Japan). This original software allows the creation of scatter radiation maps, which are graphically created based on the shielding calculation for the X-ray fluoroscopy room.

Results

Scatter radiation maps for 10 and 7.5 pulses/s fluoroscopy with and without additional lead-shielding drape are shown in Fig. 3a, b and Fig. 4a, b, respectively. When additional lead-shielding drape was used in the primary physician's position (P point), scatter radiation in the 10 and 7.5 pulses/s fluoroscopy was respectively reduced to about a quarter and one-fifth of that when additional lead-shielding drape was not used.

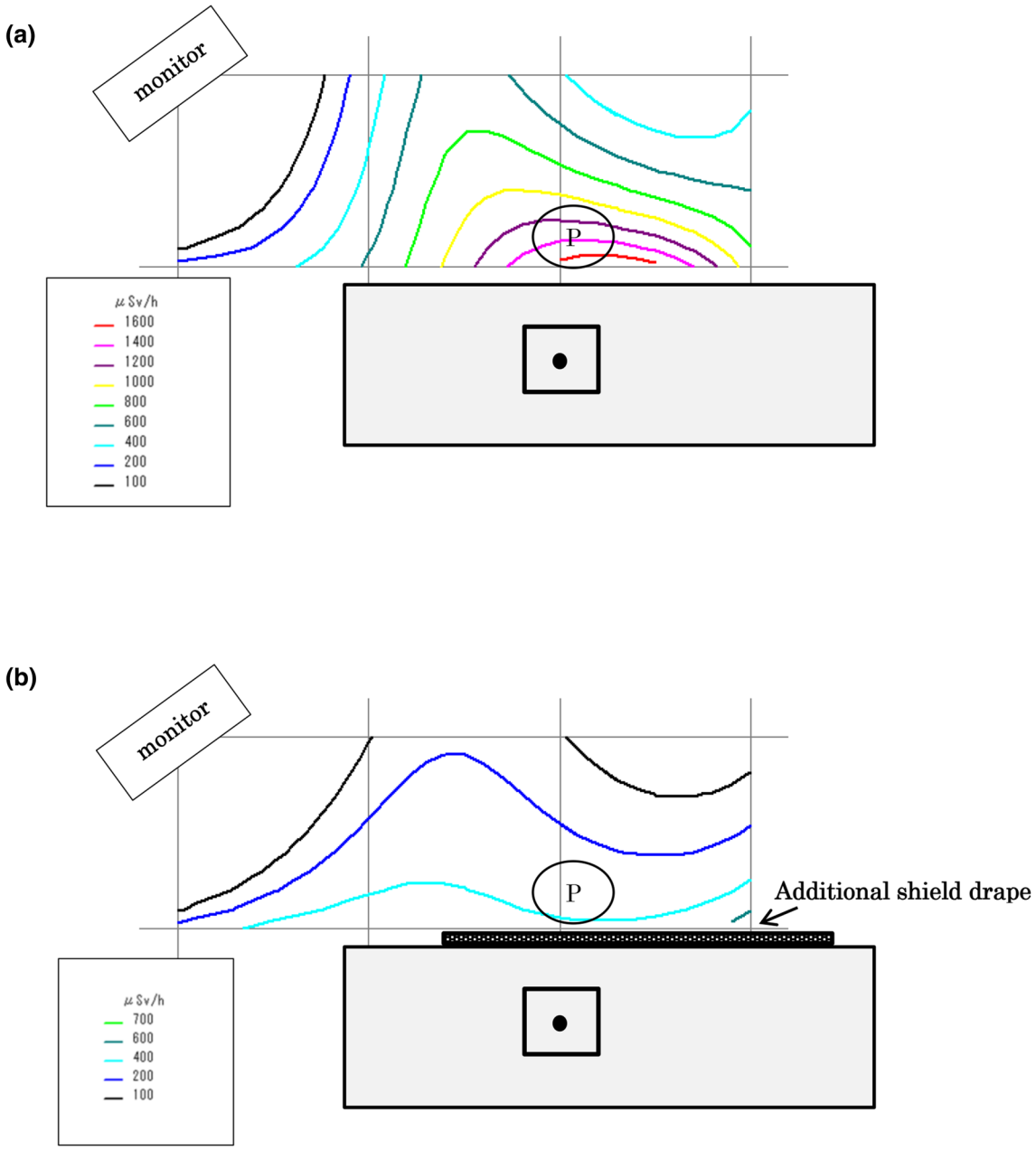

Fig. 3 Scattered radiation maps without additional shielding (**a**), and with additional shielding (**b**) at a usual rate of 10 pulses/s

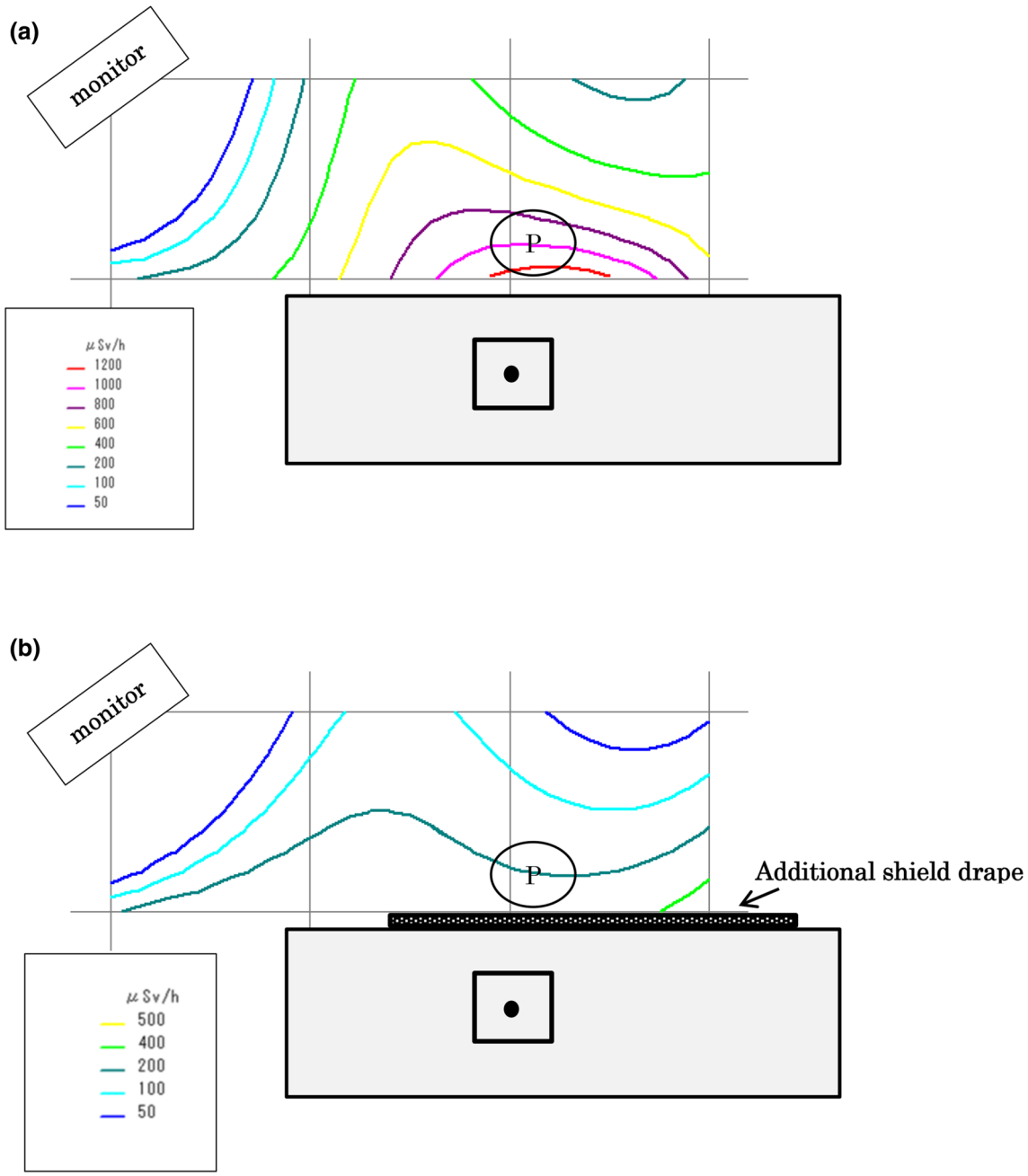

Fig. 4 Scattered radiation maps without additional shielding (**a**) and with additional shielding (**b**) at a low pulse rate of 7.5 pulses/s

Table 1 shows that if the fluoroscopy is reduced from 10 pulses/s (usual rate) to 7.5 pulses/s (low pulse rate), the scattered radiation is reduced by 24.0%. With 10 pulses/s and the additional lead-shielding drape, the scatter radiation measured with the acrylic phantom at the P, R, and S points was reduced to 74.3% from 80.9% of that without the additional lead shielding, while at 7.5 pulses/s, it was reduced to 78.4% from 82.7%. However, at the assistant physician's position (Q), the scattered radiation decreased by only 13.7% (10 pulses/s) or 19.2% (7.5 pulses/s).

Compared with the absence of additional shielding and 10 pulses/s fluoroscopy, the use of additional shielding and 7.5 pulses/s resulted in an 83.7% reduction in scatter radiation.

Discussion

Cardiac IR procedures have a lower risk than surgical procedures and their wide acceptance has led to an increasing number of them being performed [16, 17]; this

Table 1 Fluoroscopy scatter radiation (μSv/h) measured using an acrylic phantom (30 × 30 × 20 cm) at the physicians' (P, Q) and nurses' (R, S) positions, without (−) and with (+) lead shielding drape

	10 pulses/s			7.5 pulses/s		
	(−)	(+)	Reducing rate (%)[a]	(−)	(+)	Reducing rate (%)[a]
P	1670	430	74.3	1270	272	78.6
Q	630	544	13.7	501	405	19.2
R	420	105	75.0	310	67	78.4
S	335	64	80.9	255	44	82.7

[a]Scatter radiation dose-reducing rate (%) = (dose without additional shielding − dose with additional shielding)/dose without additional shielding × 100

is despite the fact that the radiation doses (to physicians and patients) from cardiac IR are the highest of any commonly performed diagnostic X-ray study [18, 19]. Therefore, radiation protection for the physician in cardiac IR is very important.

The effectiveness of additional lead shielding drape attached to the table on the right side of the patient is already reported [19, 20]. In this study, we therefore examined the protective effect of attaching a drape to the left side of the table during CRT procedures.

To the best of our knowledge, there have been only a few reports describing the use of additional lead shielding during CRT procedures [21], and there are also few previous reports discussing the scattered radiation doses received by operators during CRT procedures.

With the additional lead-shielding drape, the fluoroscopy scatter radiation measured with the acrylic phantom was reduced by over 70% in comparison with the dose without the additional lead shielding (at both 10 pulses/s and 7.5 pulses/s). However, at the assistant physician's position (Q), the scattered radiation decreased by only 13.7% at 10 pulses/s and 19.2% at 7.5 pulses/s. This is because the assistant physician is positioned slightly off from the additional lead shielding drape.

In the phantom study, the additional lead shielding drape was very effective at providing protection from fluoroscopy scatter radiation.

There are two types of radiation effect: stochastic and deterministic. The effective dose is used to estimate the risk of stochastic effects (e.g., cancer risk), and the regulatory effective dose limit (i.e., 20 mSv/y averaged over 5 consecutive years, 100 mSv in 5 years, and 50 mSv in a single year) is used to ensure that occurrences of stochastic effects are kept within acceptable levels [22]. The dose equivalent is used to estimate the risk of deterministic effects (e.g., cataracts), and the regulatory dose equivalent limit (e.g., 150 mSv/y to the lens of the eye) is used to ensure that deterministic effects (tissue reactions) are avoided [22]. To reduce the risk of stochastic effects, the radiation dose must be "as low as reasonably achievable", while ensuring that the procedure is of diagnostic utility and efficiently performed.

Abdelaal et al. [15] reported that diagnostic coronary angiography (DCA) and percutaneous coronary intervention (PCI) fluoroscopy at 7.5 pulses/s were associated with a significant reduction in operator dose of about 30% in comparison with 15 pulses/s.

In our study, we examined not operator dose, but scatted radiation, and found that if the fluoroscopy is reduced from 10 pulses/s (usual rate) to 7.5 pulses/s (low pulses rate), the scattered radiation at the primary physician's position is reduced by 24.0%. Even in an angiography room without additional lead-shielding drape, scatter radiation can be reduced by merely using fluoroscopy with a lower pulse rate. We recommend that low pulse rate fluoroscopy should be used as much as possible.

Furthermore, we examined the protection from scattered radiation obtained by combining the drape with low pulse rate fluoroscopy. Rate of 7.5 pulses/s with shielding reduced scatter radiation by 83.7% in comparison with 10 pulses/s without shielding; the combination of a low pulse rate and additional lead shielding can result in a further reduction in scatter radiation.

The radiation maps added clarity to the evaluation of the scattered radiation distribution; for example, the radiation dose at the primary physician's position was decreased to about a quarter to one-fifth.

Such information should lead to a greater awareness of the radiation exposure received by physicians and nurses [23]. If the measurement area is narrowed, more detailed radiation maps can be drawn. We believe that this is the first report to present a map of scattered radiation for CRT.

The ICRP established guidelines for radiation protection education and training for doctors and other medical staff [5]. Deterministic effects are defined as those occurring only above a certain dose threshold. Therefore, multiple levels of radiation protection such as thyroid neck shields and protective glasses are required to minimize radiation exposure. It is believed that the dose limit to which the lens may be exposed would not be exceeded with protective glasses and additional lead shielding in place.

When participating in CRT procedures, all staff should be aware of the radiation protection afforded by the inverse

square law. Nurses can stand at a distance from the patient to protect themselves from scattered radiation [23, 24]; however, physicians cannot do this [25], and protective aprons are therefore necessary for physicians. The additional lead-shielding drape examined in this study is highly effective in reducing the scattered radiation dose to physicians and nurses during CRT procedures. We believe that further protection against scattered radiation in CRT procedures can be achieved with the use of additional lead-shielding drape.

Limitations

This study used data from only a single angiography room, which therefore limits its generalizability. Furthermore, this is a phantom study, and it did not use actual clinical measurements.

Conclusions

We investigated the effectiveness of additional lead shielding drape and low pulse rate fluoroscopy for protecting staff from scattered radiation during CRT procedures.

With the fluoroscopy scatter radiation measured with the acrylic phantom being reduced by an average of 70% with the additional shielding. If the fluoroscopy rate is reduced from 10 pulses/s (usual rate) to 7.5 pulses/s (low pulses rate), the scattered radiation at the primary physician's position is reduced by 24.0%.

By combining a low pulse rate with additional lead shielding, a reduction in scatter radiation of over 80% can be expected 100-cm above the floor, which corresponds to the height of the gonads.

In CRT procedures, physicians should use additional lead-shielding drape on the opposite side (left side of the patient) of the catheter table to normal, where it is very effective.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethical statement Not applicable.

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