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SHORT COMMUNICATION

# Personnel dose reduction in $^{90}$Y microspheres liver-directed radioembolization: from interventional radiology suite to patient ward

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**Objective:** To describe a method to reduce the external radiation exposure emitted from the patient after liver-directed radioembolization using $^{90}$Y glass microspheres, to quantitatively estimate the occupational dose of medical personnel providing patient care to the patient radioembolized with the use of the method and to discuss radiation exposure to patients who are adjacent if the patient radioembolized needs hospitalization.
**Methods:** A lead-lined blanket of lead equivalence of 0.5 mm was used to cover the patient abdomen immediately after the $^{90}$Y radioembolization procedure, in order to reduce the radiation emitted from the patient. The interventional radiologist used a rod-type puncture site compressor for haemostasis to avoid direct contact with possible residual radioactivity at the puncture site. Dose rates were measured at the interventional radiologist chest and hand positions during puncture site pressing for haemostasis with and without the use of the blanket. The measurement results were applied to estimate the occupational dose of colleagues performing patient care to the patient radioembolized. The exposure to patients adjacent in the ward was estimated if the patient radioembolized was hospitalized.
**Results:** The radiation exposures measured at the radiologist chest and hand positions have been significantly reduced with the lead-lined blanket in place. The radiologist, performing puncture site pressing at the end of radioembolization procedure, would receive an average hand dose of 1.95 µSv and body dose under his own lead apron of 0.30 µSv for an average $^{90}$Y microsphere radioactivity of 2.54 GBq. Other medical personnel, nurses and porters, would receive occupational doses corresponding to an hour of background radiation. If the patient radioembolized using $^{90}$Y needs hospitalization in a common ward, using the lead-lined blanket to cover the abdomen of the patient and keeping a distance of 2 m from the patient who is adjacent would reduce the exposure by 0.42% of dose limit for the general public.
**Conclusion:** By placing a lead-lined blanket on the patient abdominal region after $^{90}$Y radioembolization, hospital staff receive minimal radiation exposure in order to comply with the radiation protection “as low as reasonably achievable” principle. There will be no increase in radiation level in ward if the patient radioembolized using $^{90}$Y needs to be hospitalized. Therefore, the patient radioembolized can be accommodated alternatively at a corner bed of a common ward if an isolation room with private toilet facility is not available.
**Advances in knowledge:** To reduce exposure to personnel providing patient care to patients radioembolized using $^{90}$Y.

## INTRODUCTION

$^{90}$Y microsphere radioembolization is an emerging modality for the treatment of liver malignancies.[1,2] Radioembolization involves placing radioactive microspheres, tiny $^{90}$Y-coated resin or glass beads,[3,4] directly at the tumour *via* the interventional radiology technique. It is based on the unique pattern of hepatic blood flow by which the majority of the tumour blood supply is derived from the hepatic artery, whereas hepatic parenchymal blood flow largely comes from the portal vein. When $^{90}$Y microspheres are introduced through the hepatic artery with the use of a catheter, $^{90}$Y microspheres will preferentially localize in the peritumoral and intratumoral arterial vasculature, delivering a high dose of radiation to the tumours.[1,2] At the completion of the radioembolization procedure, the catheter is removed and the patient is returned to the ward for observation before discharge.[3,4] The existing radiation protection measures in $^{90}$Y microsphere radioembolization include the use of low atomic number materials of acrylic or plastic in $^{90}$Y microsphere dose preparation and administration as well as a radiation survey to personnel and areas after each administration. Proper waste storage and disposal of radioactive items should also be performed according to local radiation usage guidelines.

With better understanding of the treatment dosimetry,[5,6] there is a trend to administer higher $^{90}$Y radioactivity for better patient efficacy.[7] This raises a concern about the occupational radiation dose received by medical personnel caring for patients who undergo radioembolization,[8] particularly for interventional radiologists performing puncture site pressing for haemostasis because the radiologist stands close to the patients treated using $^{90}$Y. If the patient is hospitalized after the $^{90}$Y radioembolization, further concern about the radiation safety to patients adjacent in a common ward has to be addressed. Although there are local guidelines and regulations regarding the safe use of radioisotopes in hospitals, further measures to reduce radiation dose to staff and to patients who are adjacent are useful in order to comply with the "as low as reasonably achievable" principle.[9]

$^{90}$Y is a pure β-emitting radioisotope of an average energy of 0.94 MeV with a maximum radiation range of 11 mm in the tissue and physical half-life of 64 h. Following treatment with $^{90}$Y microspheres, the patient becomes a source of radiation that could potentially affect other persons *via* bremsstrahlung emission as a result of $^{90}$Y β-particles interacting with the surrounding body tissues *in vivo*.[10] The production of *in vivo* bremsstrahlung of $^{90}$Y microspheres is sufficient in external detection and imaging.[1,2] Therefore, the resulting external radiation hazard to interventional suite personnel has to be evaluated and minimized immediately after the patient radioembolization procedure.

In this article, we describe the use of a lead-lined blanket to cover the patient abdomen to reduce the bremsstrahlung radiation emitted from patients treated using $^{90}$Y. A rod-type puncture site compressor for haemostasis was also used by the interventional radiologist to avoid direct contact with possible residual radioactivity at the puncture site. The radiologist was dressed in a lead apron of lead equivalence of 0.5 mm during puncture site pressing. Dose rates at the radiologist hands and at chest position in front of his lead apron were measured during the puncture site pressing after radioembolization with and without the use of the lead-lined blanket.

## METHODS AND MATERIALS

Since mid-2014, there have been 18 patients treated with $^{90}$Y glass microspheres for hepatocellular carcinoma in our institution. 16 (89%) of them are males of an average age of 64 ± 9 years (range: 46–80 years), and the remaining 2 (11%) them are females of an average age of 75 years (range: 44–83 years). The average administered radioactivity for $^{90}$Y glass microspheres (18 patients, 18 administrations) was 2.54 ± 0.87 GBq (range: 1.65–4.75 GBq).

A lead-lined blanket of size 60 × 64 cm, weight about 4 kg and lead equivalence of 0.5 mm has been used in the study. The blanket was wrapped in a sterilized plastic bag and was placed on the patient abdominal region immediately after the $^{90}$Y microsphere radioembolization procedure. All patients were tolerated to the size and weight of the blanket.

Figure 1 shows the interventional radiologist performing puncture site pressing for haemostasis with the use of the rod-type compressor and the lead-lined blanket placed on the abdomen of the patient radioembolized. At each patient administration session, radiation dose rates at the chest position (approximately 0.5 m from the patient abdomen) and at the hand position (approximately 10 cm above the puncture site) of the interventional radiologist were measured with a calibrated radiation survey meter (model 451; Fluke, Cleveland, OH) with and without the blanket in place. These measured dose rates were then normalized by the patient-administered $^{90}$Y microsphere radioactivity. After performing the same normalization for a number of patient administrations, normalized average dose rates, expressed as average dose rate per unit radioactivity of the $^{90}$Y microsphere administered, were obtained at the interventional radiologist hand and body chest. The normalized average body dose rate was then used to estimate the occupational dose of nurse and porter colleagues who provided patent care to the patient radioembolized during patient transfer from the X-ray table to the patient stretcher and during patient transport from the interventional suite back to the patient ward, respectively, by knowing their average time spent with the patient radioembolized and the patient-administered $^{90}$Y microsphere radioactivity. From the experience of our nurse and porter colleagues working in the interventional suite, it takes not more than 5 min for our nurse colleagues to transfer the patient radioembolized from the X-ray table to the patient stretcher. Similarly, it takes not more than 15 min for our porter colleagues to transport the patient radioembolized from the interventional suite back to the patient ward in our institution.

Figure 1. After the radioembolization procedure, a lead-lined blanket is covered over the patient abdomen. The interventional radiologist uses a rod-type compressor for puncture site compression for haemostasis. The radiologist wears a lead apron of the same lead equivalence of 0.5 mm as the blanket.

The same normalization method was also used to estimate the radiation dose received by patients who are adjacent in a common ward with the abdomen of the patient radioembolized covered with the lead-lined blanket during hospitalization.

### Statistical method

The *t*-test for paired samples was used to compare the difference in the measured dose rates between using the lead-lined blanket or not. The software used was SAS (v. 9.4, Cary, NC). Values of $p \leq 0.05$ were considered to be statistically significant.

## RESULTS

Table 1 shows the dose rates, normalized by the patient-administered $^{90}Y$ microsphere radioactivity, measured at the chest position of the interventional radiologist and at the hand position during puncture site pressing with and without the lead-lined blanket covering the patient abdominal region. Without the use of the blanket, the normalized average dose rate at the radiologist body position was measured as 1.43 ± 0.31 μSv/(h GBq). With the use of the blanket, the normalized average dose rate at the radiologist body position was measured as 0.71 ± 0.16 μSv/(h GBq). Therefore, an average dose rate reduction factor of 0.50 at the radiologist body position was obtained with the use of the blanket. Similarly, an average dose rate reduction factor of 0.38 at the radiologist hand position was obtained with the use of the blanket (Table 1). Dose rate reductions to the radiologist body and hand were statistically significant when the lead-lined blanket was used ($p < 0.01$). At the radiologist hand position during puncture site pressing, the normalized average dose rate was measured as 2.30 μSv/(h GBq). The average infused $^{90}Y$ radioactivity among our patients was 2.54 GBq. The radiologist thus received 1.95 μSv at his hands during puncture site pressing for an average of 20 min of pressing time for each $^{90}Y$ radioembolization administration. Similarly, the normalized dose rate at the radiologist body position was measured as 0.71 μSv/(h GBq), corresponding to an average dose of 0.60 μSv.

Since the radiologist also wears a lead apron of the same lead equivalence of 0.5 mm of the lead-lined blanket, he would actually receive a body dose of 0.30 μSv (by the same dose reduction factor of 0.50 with the use of the blanket) under his own lead apron. This average 0.30 μSv occupational dose is comparable with the 1 hour background radiation level at our institution area.

The radiation dose measurement at the radiologist chest position of 0.71 μSv/(h GBq) at 0.5 m from the patient radioembolized using $^{90}Y$ can be used to estimate the occupational dose of nurse and porter colleagues who perform patient transfer from the X-ray table to the patient stretcher and patient transport from the interventional suite back to the patient ward, respectively, after the $^{90}Y$ radioembolization procedure. The distance of 0.5 m between the patient radioembolized and nurse and porter colleagues has been considered in the occupational dose calculation for these colleagues to take into account possible close contact with the patient during their patient care. The calculated occupational exposures to the supporting team colleagues, 0.15 μSv for the nurse and 0.45 μSv for the porter, are therefore regarded as an upper bound and are indeed very minimal during the course of the care of the patient radioembolized (Table 2). In comparison, the daily background radiation level is about 6 μSv in our institution area.

Our patient service in using $^{90}Y$ microsphere radioembolization has been about 10 cases per year. With this workload, the radiologist would receive an annual dose of 3 μSv as a whole-body dose and 19.50 μSv as a hand dose with the use of the lead-lined blanket during puncture site pressing after each radioembolization procedure. The annual dose limits for an occupational radiation worker, as recommended by the International Commission on Radiological Protection (ICRP), are 20 mSv for the whole body and 500 mSv for the skin averaged over any 1 $cm^2$ area of an extremity.[9] Therefore, the occupational doses received by the radiologist and other supporting team colleagues, as discussed in the present study, are far below the dose limits as recommended by ICRP.[9]

## DISCUSSION

Radiation safety considerations in $^{90}Y$ radioembolization have been described in detail for patient dosimetry accuracy,[5,6] interventional radiology suite radiation contamination prevention and scenarios for patients radioembolized who come in contact with their family.[10,11] In our present work using a lead-lined blanket of 0.5 mm lead equivalence with size and weight tolerable to patient comfort, it has been shown that bremsstrahlung radiation emitted from the patient treated using $^{90}Y$ can be significantly shielded, resulting in less exposure to the interventional suite personnel. This dose reduction is useful in maintaining a low occupational dose to personnel according to the "as low as reasonably achievable" principle and to cope with the trend of administering higher $^{90}Y$ radioactivity in radiation protection and safety.[7]

Table 1. Normalized average dose rates (mean ± standard deviation) of the interventional radiologist performing puncture site pressing with and without the use of blanket

| Use of lead-lined blanket | Normalized average dose rate [μSv/(h GBq)] | |
|---|---|---|
| | Radiologist body dose | Radiologist hand dose |
| No ($n = 18$) | 1.43 ± 0.31 (range: 1.09–2.21) | 6.05 ± 2.84 (range: 2.41–14.55) |
| Yes ($n = 18$) | 0.71 ± 0.16 (range: 0.43–1.10) | 2.30 ± 0.99 (range: 0.97–4.55) |
| *p*-value | <0.01 | <0.01 |

There were 18 patient measurements ($n = 18$).

Table 2. Occupational dose estimation per procedure with and without the use of the blanket covered on patient abdomen after $^{90}$Y microsphere radioembolization

| Staff | Procedure | Estimated time spent (min) | Occupational dose (μSv) | |
|---|---|---|---|---|
| | | | Without blanket | With blanket |
| Radiologist | Puncture site pressing | 20 | 5.13 on hands<br>0.60 on body | 1.95 on hands<br>0.30 on body |
| Nurse | Patient transfer | 5 | 0.30 on body | 0.15 on body |
| Porter | Patient transport | 15 | 0.90 on body | 0.45 on body |

The average patient-administered $^{90}$Y microsphere radioactivity of 2.54 GBq was used in the calculation. The estimated time spent with the patient radioembolized was based on the experience and workflow of our supporting team. The radiologist body dose included a further reduction owing to wearing of a lead apron of the same lead equivalence of 0.5 mm as the blanket.

Generally, there are local recommendations and regulations regarding the safe use of unsealed radioactive substance to patients during hospitalization and to patient release. Our institutional radiation safety regulation requires that patients treated using $^{90}$Y of >1.5 GBq radioactivity be accommodated in a single room ideally with private toilet facility.[12] Sometimes, this cannot be achieved owing to insufficient isolation ward availability or non-availability of such a facility in some hospitals; but, $^{90}$Y radioembolization has to be performed. We suggest that the patient treated using $^{90}$Y be accommodated at a corner bed in a common ward with the use of the lead-lined blanket. The normalized average dose rate at 0.5 m from the patient radioembolized has been measured as 0.71 μSv/(h GBq), corresponding to 1.80 μSv/h for an average 2.54 GBq $^{90}$Y microsphere radioactivity. The distance maintained between patients who are adjacent in a common ward is normally about 2 m. The radiation dose rate at the patient who is adjacent is calculated as 0.11 μSv/h using the inverse square law. The patient radioembolized is suggested to stay at the corner bed for the next 49 h until the $^{90}$Y radioactivity has physically decayed from 2.54 to 1.5 GBq before release from hospitalization. Since the initial dose rate at the patient who is adjacent is 0.11 μSv/h, the patient would receive a total dose of 4.20 μSv during the 49-h hospitalization period of the patient radioembolized. The dose limit for the general public is 1 mSv per year, as recommended by ICRP.[9] Therefore, a radiation dose of 4.20 μSv received by the patient who is adjacent corresponds to 0.42% of the annual dose limit for the general public and is considered as negligible. On the other hand, if the patient treated using $^{90}$Y stays at the corner bed without the use of the lead-lined blanket, the patient adjacent would receive a dose of 8.4 μSv (the dose reduction factor of the blanket being 0.5 for body dose) for the same scenario just discussed. A radiation dose of 8.4 μSv is slightly higher than the daily background radiation level in our institution area (about 6 μSv). In other words, radiation exposure to the patient adjacent due to the patient treated using $^{90}$Y is low and can be further reduced to a negligible level if the use of a lead-lined blanket and a distance of 2 m between patients who are adjacent are followed.

Therefore, with the use of the lead-lined blanket for the patient radioembolized, hospital resource in isolation room facility and radiation exposure to other patients who are adjacent and non-radioactive may no longer be of concern while performing $^{90}$Y radioembolization.

## CONCLUSION

A practical measure of using a lead-lined blanket not only reduces the occupational dose of the interventional suite personnel to the background level, but also solves the problem of limited isolation room availability. A rod-type puncture site compressor for haemostasis is used by the interventional radiologist to avoid direct contact with possible residual radioactivity at the puncture site. The present work is applicable to both types of $^{90}$Y microspheres of resin and glass.[3,4]

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