Radiation exposure dose of medical workers during radioguided sentinel lymph node biopsy

Original Article

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ABSTRACT

Introduction: Radiation monitoring of professionally exposed workers is obligatory in nuclear medicine departments. The purpose of our study was to evaluate the radiation exposure dose received by medical workers during radioguided sentinel lymph node biopsy in breast cancer and endometrial cancer patients.

Methods: Radiation exposure dose of medical staff was prospectively recorded during 35 radioguided sentinel lymph node biopsy procedures in a 6-month period. All patients received 4 mCi [^{99m}Tc]Tc-SENTI-SCINT on the day of surgery. Thermoluminescent dosimeters in the shape of a bracelet, ring and badge were used for recordings and data was compared to dose limits imposed by the regulations.

Results: Mean time interval between activity administration and surgery was 223.63 min and mean duration of surgery was 142.5 min. The recorded 6-month cumulative dose was 0.33 mSv for the senior surgeon, 0.25 mSv for the surgeon's first assistant, 0.24 mSv for the anesthesiologist and 0.54 for both nuclear medicine physician and resident. The approximately equivalent dose for the surgical staff in each procedure was 9.7 µSv, 7.3 µSv and 7.05 µSv respectively, which means that the senior surgeon could perform 106 and 2127 sentinel lymph node biopsy procedures per year in order to reach the annual dose limit for a public member and a radiation worker.

Conclusion: Occupational radiation exposure dose of medical staff during radioguided sentinel lymph node biopsy is low and under annual dose limits, requiring no routinely personal dosimetry for surgical staff performing the procedure.

Key words: Radiation exposure dose; Dosimeter; Medical staff; Sentinel lymph node

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INTRODUCTION

Radiation protection management of professionally exposed workers is mandatory in nuclear medicine departments. Personal radiation monitoring is usually performed by a thermoluminescent dosimeter (TLD), which consists of a crystal that accumulates and stores radiation energy. The intensity of radiation the crystal is exposed to is proportional to the intensity of visible light released from the crystal when put in a specific heater. The high sensitivity lithium fluoride (LiF) material in TLDs enables extended monitoring for up to 6 months [1]. The use of radioactive agents for lymphoscintigraphy demands optimization of radiation safety issues, regarding both patients and medical staff. Surgical staff is still concerned about the possible health issues, related to the use of radio labeled colloids.

Intraoperative lymphatic mapping and sentinel lymph node (SLN) identification are an important part of the standard care protocols for early-stage cancer patients. Identifying the regional lymph node status is essential for surgeons to determine the type of operative treatment (radical or selective lymphadenectomy). In patients with early-stage breast cancer, if the SLN biopsy is negative, axillary lymphadenectomy is not performed [2, 3]. This technique has become a gold standard for breast cancer patients who are clinically node-negative.

In low, intermediate and high risk patients with endometrial cancer, SLN biopsy seems to be a reasonable solution to systemic lymphadenectomy, decreasing lymphatic complications and duration of surgery [4, 5].

Although various agents are available for SLN mapping, in accordance with the current guidelines for lymphoscintigraphy, ^{99m}Tc-labelled nanocolloids are the radiotracers of choice. The activity for total injection dose varies from 0.1mCi to 10mCi [6].

The aim of our study was to identify and quantify the occupational radiation exposure dose (RED) received by medical workers in the operating room during SLN biopsy in breast cancer and endometrial cancer patients.

METHODS

The study was carried out at the Medical faculty in Skopje, including the Institute of Pathophysiology and Nuclear Medicine, University Clinic for Thoracic and Vascular Surgery and University Clinic for Gynecology and Obstetrics. RED of 35 radioguided sentinel lymph node biopsy (RSLNB) procedures in the period between July and December 2018 was conducted.

Dosimetry was performed on surgical staff members and nuclear medicine staff, as well as measurements of the ambient dose of the facilities with gamma cameras used in the research. The personal dosimeters were attached to the senior surgeon, the surgeon’s first assistant and the anesthesiologist, for each RSLNB. The senior surgeon wore a personal dosimeter ring on the index finger of the right hand. The surgeon’s assistant had a dosimeter bracelet worn on the wrist on the right hand. The anesthesiologist wore a dosimeter badge over the left chest. RED was registered during the intervention. All recordings in the operating room were assessed without any lead protection. Personal dose measurements of the nuclear medicine physician and resident involved in the study were recorded by a dosimeter badge worn over the left chest. Ambient dose measurements in the rooms with gamma cameras where patients were imaged, were also analyzed.

For radiation dose measurements, TLDs were used. TLDs used in the research were Harshaw’s crystal elements assembled into rigid aluminum cards and mounted within shielded filter-holders with energy filters. Each crystal according to tissue equivalence had different thickness and was covered with specific filter material. The TLD-100 model of EXT-RAD dosimeter consists of LiF:Mg TL chips 3mm^2 square, encapsulated between two sheets of Teflon. The TLD of this model was worn as a badge on the upper abdominal position and was used for whole body measurements. Same crystal material in a single chip was used for extremity measurements in the shape of a bracelet. The carrier of the crystal was plastic and allowed multiple readouts while providing protection and filtration for the TL crystal. Another type of extremity dosimeter within the system was Harshaw’s DXT-RAD measuring the fingers' doses in the shape of an adjustable low-density plastic ring. A TLD pellet was bonded to a Kapton film. A plastic cap was pressed into the recess to provide hermetic sealing and 2x magnification of the readouts.

Dose measurements were quantified at the Institute for public health, Department for dosimetry, in consecutive intervals of 3 months for surgical staff and one-month interval for nuclear medicine staff within a 6 months period. Quantification of data collected by TLDs was performed by automated TLD reader Harshaw TLD Model 6600 Plus. Specific calibrations were periodically done assuring heating up to precise temperatures for each crystal material and proper reading of the emitted light spectrum. Additionally, preparation of the dosimeters for new usage through annealing the residual information was performed as final action in the reader.

Lymphoscintigraphy procedure

Preoperative lymphoscintigraphy for SLN visualization was performed on the day of surgery. [^{99m}Tc]Tc-SENTI-SCINT (Human Serum Albumin millimicroagregate colloidal particles with a diameter of 100-600nm) was injected subcutaneous and periareolar, clockwise at four sites (3, 6, 9 and 12) by nuclear medicine physician in breast cancer patients, while the gynecological operator injected four intra-cervical injections in endometrial cancer patients. The total activity of the tracer was 4 mCi (148 MBq) divided in four doses per injection (1mCi (37 MBq) per injection) for all patients. Dynamic scintigraphy in AP position (30 minutes; 60 seconds per frame) and subsequent planar images in AP and AO positions (300 seconds per position for breast cancer patients and 600 seconds per position for endometrial cancer patients) at 30 min, 1h, 2h followed by SPECT/CT at 2.5 h post injection were performed. Additionally, the location of the SLN was marked on the skin with a permanent marker in breast cancer patients. The patients were taken to the operating room approximately 3.5 h after radiocolloid injection. All patients underwent RSLNB using the dual-tracer method (blue dye and [^{99m}Tc]Tc-SENTI-SCINT). Intraoperative hand-held gamma probe was used for guiding the surgeon and identifying "hot" nodes during surgery. If SLNs were positive for metastasis, axillary lymph node dissection was performed along with mastectomy or quadrantectomy as indicated. In patients with endometrial cancer, after RSLNB, hysterectomy with bilateral salpingo-oophorectomy was done.

Statistical analysis

Descriptive statistics was used for data analysis. RED data was evaluated for surgical staff, nuclear medicine staff and was compared to dose limits imposed by the regulations.

RESULTS

A total of 35 patients were included in this study. Thirty patients, aged 52.8 ± 10.3 years, were with early-stage breast cancer and five patients, aged 55.6 ± 2.7 years, were with low-risk endometrial cancer. In the breast cancer group, 10 patients underwent RSLNB and mastectomy, 16 patients underwent RSLNB and quadrantectomy, 2 patients underwent RSLNB, mastectomy and axillary lymphadenectomy and 2 patients underwent RSLNB, quadrantectomy and axillary lymphadenectomy. All patients with endometrial cancer underwent RSLNB and hysterectomy with bilateral salpingo-oophorectomy. The mean time interval between injection application and surgery was 223.63 ±31.39 minutes and mean duration of surgical procedure was 142.5±16.58 minutes.

The analysis of RED for surgical staff is shown in Table 1.

The 6-month cumulative dose was 0.33 mSv for the senior surgeon, 0.25 mSv for surgeon's first assistant and 0.24mSv for the anesthesiologist resulting in an average equivalent dose of 9.7 µSv, 7.3 µSv and 7.05 µSv per each surgical procedure, respectively.

Table 1: Radiation dose values of the senior surgeon, first assistant and the anesthesiologist.

Surgical staff	**July-September**	**October-December**	**mSv/total**
Senior surgeon	0.20	0.13	0.33
Surgeon's first assistant	0.16	0.09	0.25
Anesthesiologist	0.15	0.09	0.24

Table 2: Radiation dose values of nuclear medicine staff.

Personal dose measurements (mSv)	**July**	**August**	**September**	**October**	**November**	**December**	**mSv/total**
Nuclear medicine physician	0.09	0.09	0.09	0.09	0.09	0.09	0.54
Nuclear medicine resident	0.09	0.09	0.09	0.09	0.09	0.09	0.54

Note: TLDs read personal dose equivalent Hp (10) in mSv and 0.09mSv is the lowest value that can be entered into results.

Table 3: Ambient dose measurements.

Ambient dose measurements	July	August	September	October	November	December	mSv/total
MEDISO camera	0.22	0.29	0.27	0.2	0.18	0.19	1.35
GE SPECT/CT camera	0.12	0.24	0.16	0.21	0.13	0.27	1.13

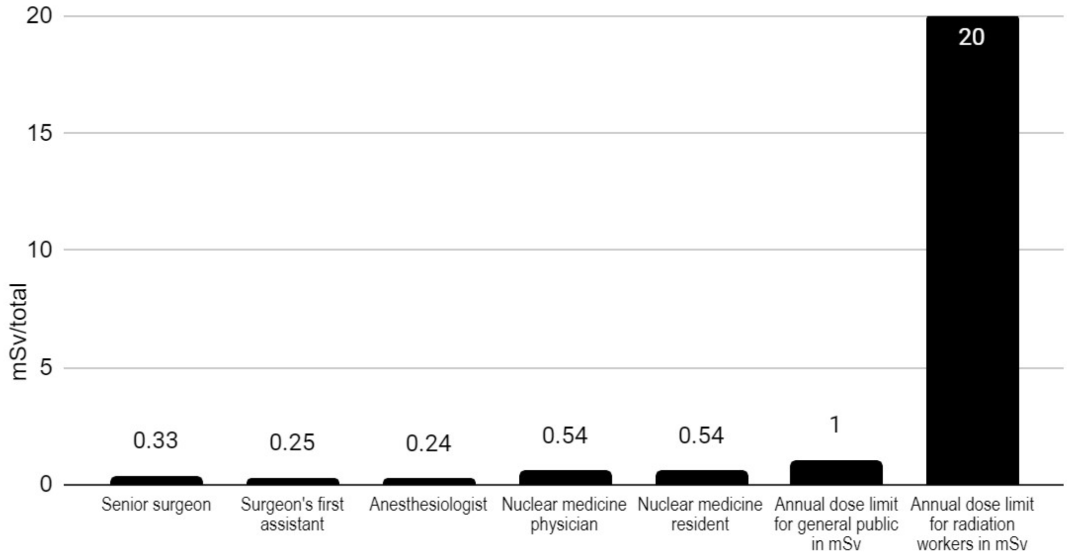

Fig 1. Dosimeter values of medical staff.

The analysis of RED for nuclear medicine staff is shown in Table 2. RED was 0.9 mSv per month, with 6-months cumulative dose of 0.54 mSv for both the physician and resident.

RED of both surgical and nuclear medicine staff during SLN mapping and annual dose limit for public and radiation workers are presented in Figure 1.

The analysis of ambient dose measurements in the rooms with gamma cameras used in SLN imaging is shown in Table 3.

DISCUSSION

Radiation protection of professionally exposed individuals to ionizing radiation, as well as the general public, is crucial because of potential radiation exposure effects. Changes in biological tissues might appear resulting from interaction between primary or secondary radiation and biological matter. Occupational exposure refers to professional exposure in medicine or industry, where sources of ionizing radiation are used. Occupationally exposed workers are under permanent personal dosimetry surveillance and exposed areas are under constant radiation control, known as controlled and supervised areas. According to the purpose and type of ionizing radiation used, different measuring devices are applied [7].

At Conventional Nuclear Medicine Departments mostly used radionuclide is metastable technetium (^{99m}Tc, $T_{1/2}$=6h, E=140keV). ^{99m}Tc as an emitter of gamma radiation produces photons that may interact one or more times when passing through matter, or never. Even though the collective ionization behavior may be predicted, an individual interaction through Compton or photoelectric events is very random.

Radiation impact on medical personnel contributes to locally absorbed dose (quantity that describes the amount of energy deposited on the unit mass of the matter). Detrimental effects resulting from the radiation exposure may be classified as stochastic or deterministic in nature. In stochastic effects, the probability of the resultant condition is dose related, but its severity does not depend on the dose received, while deterministic effects are proportional with absorbed radiation dose [8].

Quantity Effective dose is generally used when radiation influence is described considering both the type of radiation and type of tissue (organ) irradiated. Tissue weighting factors are used to represent the relative contribution of an organ or tissue to the total detriment due to the stochastic effects resulting from uniform irradiation of the whole body. Values of the weighting factors are not applicable to occupational radiation exposed individuals (despite dependence of age and sex), according to International Committee for Radiation Protection (ICRP) [9].

When exposure to radiation occurs, three important principles must be considered. The first one is the principle of justification: radiation exposure must be justified by sufficient medical benefit. The second one is the principle of optimization of protection: the justified radiation exposure should be kept as low as reasonably achievable (ALARA), considering economical and societal factors. The third one is the principle of limitation of doses: the total individual radiation dose should be kept below the limits recommended by the ICRP. This means that an individual dose needs to be defined and it should be reduced as low as reasonably achievable [10].

Personal dose equivalent H_p(d), the operational quantity for individual monitoring, is commonly denoted as H_p(10) and H_p(0.07) depending on reference depth. H_p(10) represents the effective dose and is used for assessment of deep organs, while H_p(0.07) is used to estimate the equivalent dose to small areas of skin and extremities. Depth of 3mm is recommended for monitoring of the lens of the eye and the operational quantity to be used is H_p(3). Dosimeters calibrated for previously mentioned equivalents might properly estimate the equivalent dose to eye lens [11].

Limits of doses applied to professionally exposed people differ from those to the public. The effective dose to the body overall is limited to 1 mSv/year for a public member and equivalent dose limits for the eye lens and skin are set to 15 mSv and 50 mSv per year, respectively. For occupational exposed staff, the effective dose received should be less than 20 mSv per year, while the annual equivalent dose for lens of the eye and skin should not exceed 20 mSv and 500 mSV, respectively [1].

The use of radiolabeled colloids for RSLNB requires radiation exposure to the involved patients and medical staff. Consequently, it has led to safety concerns referring to the potential radiation risk associated with this method. In our study, RED for the senior surgeon, the surgeon's first assistant and the anesthesiologist was 0.33mSv, 0.25 and 0.24 over a six months period, respectively. Our data has shown that RED of the surgical staff was well within relevant limits specified in ICRP 2007. Considering the median exposure reading of the senior surgeon in our study, he could perform 106 RSLNB in order to reach the annual dose limit of 1mSv for a public member and 2127 RSLNB per year in order to reach the dose limit of a radiation worker.

Measurements of RED for the surgical team performing RSLNB have been previously investigated by several authors. Highly sensitive TLDs were used for radiation dose recordings [12-17].

Najafi et al. assessed RED of the surgeon's hands, abdomen and thyroid area. Because of using non-dominant hand for handling the radioactive specimen and dominant hand for working with surgical instruments, the highest mean equivalent radiation dose was measured in the second finger of the non-dominant surgeon's hand (53.49±24.60) [12]. Whole-body dose for the surgeon was recorded to be less than 2 µSv per procedure in all investigated cases by Waddington et al. [13]. Peştean et al. analyzed the exposure of the surgeon's non-dominant index during 196 SLN removal procedures. The cumulative dose for the surgeon's hands was 1.31 mSv/year at 39.55 ± 1.96 MBq administered activity of [^{99m}Tc]Tc-albumin nanocolloid per procedure [14]. Burrah et al. conducted a retrospective study including radiation exposures during 183 RSLNB. Authors used low dose activity given on the day before the surgery, so exposure measurements in their study were very low. They identified higher RED in the assistant (range 0.01–0.13 mSv) rather than the surgeon (range 0.01–0.03 mSv) as a result of his closer position to the injection site during the operation [15].The obtained values from measurement of absorbed dose to the surgeon's dominant hand of third or fourth finger (79 cases) and abdominal wall (67 cases) during RSLNB in breast cancer after average injected activity of 88 ± 28 MBq and single day protocol in the study of Klausen et al. were 0.04 ± 0.04 mSv, 0.01 ± 0.02 mSv, respectively. The authors also analyzed pathologist's hand exposure during frozen section examination (17 cases) which was at the detection limit (0.01 mSv) indicating an average pathologist hand dose per procedure of <1 µSv [17].

Bekis et al. measured RED at distances of 50 cm, 100 cm, 150 cm, and 200 cm from the side of the patient's head, right and left chest prior to the operation in 3 randomly selected cases. They used a mathematical formula to calculate dose rates at each distance for five surgical team members. The highest RED was calculated for the senior surgeon (2.00-4.70µSv) and the least exposed was the anesthetist (0.18-0.65µSv) [18].

We did not measure the RED of the involved pathologist and it could be considered as a limitation of our study. We also did not include any pregnant surgeons. RED of the lower abdominal region received by a pregnant surgeon, first and second assistants, anesthesiologist, and scrub nurse were evaluated by Kimura et al. The highest median exposure dose per procedure was of the surgeon (3 µSv) and the least exposed was the anesthesiologists with less than 1 µSv in all surgeries [19].

Factors, which are relevant to the radiation exposure, are exposure time, distance from the source and shielding [20]. Protective clothes reduced radiation exposure in the study of Kimura et al. [19]. Further, a closer position to the injection site can increase exposure rate [13, 15, 19]. However, the injection activity, time interval between injection and surgery, type of breast surgery and duration of procedure did not affect the levels of RED in several above-mentioned studies [16, 18-19].

The administered activities vary significantly between the above-mentioned studies with doses of 0.1 mCi to 10 mCi for lymphoscintigraphy being reported [6]. All radiation doses to patients should be kept as low as reasonably achievable [21]. We have performed lymphoscintigraphy using a single day protocol and a dose of 37MBq [^{99m}Tc]Tc-SENTI-SCINT applied in 4 injections (total dose of 4mCi) which has given the best image resolution, higher SLN detection rate and also is in accordance with ALARA principle. This slightly high activity compared with other literature reports enables switching from one to a two-day protocol if a SLN is not visualized 3 hours after tracer application without the need for tracer reinjection. Furthermore, the dose of 4 mCi is still very low compared with doses used in the other diagnostic nuclear medicine procedures. This also means minimal radioactivity at the injection site and consequently minimal exposure of the surgical staff.

CONCLUSION

The implementation of RSLNB into interclinical surgical protocols requires an initial monitoring of radiation exposure of the surgical staff members for optimization of radiation safety issues. The recorded values indicated that the used tracer dose was optimal for minimal radiation exposure of the medical stuff included in the procedure. Our results showed that occupational RED of medical workers in the operating room during SLN procedures is far below the annual dose limits, according to ICRP recommendations. Furthermore, SLN biopsy is standard of care for nodal staging in breast cancer treatment. In the last decade, it has become a promising technique in endometrial cancer patients also. In contrast with conventional lymphadenectomy, selective lymphadenectomy is less invasive, decreasing postoperative complications and duration of surgery. Moreover, the method offers pathological assessment of occult metastasis, improving patient staging and finally offering better quality of life. In accordance with our results, as well as the so far published literature reports, personal dosimetry for surgical teams performing RSLNB is not routinely required and we reaffirm the radiation safety of the procedure.

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