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Original Research Article

Medical Radiation Exposure of Various Personnel Categories at National Center of Rehabilitation and Neurosciences (NCRNS) of Rabat

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Abstract: The purpose of this study is to evaluate the medical radiation exposure for personnel categories in the radiology and Gamma knife radiosurgery unit at National Center of Rehabilitation and Neurosciences (NCRNS) of Rabat. Two types of detector (Inspector and RDS-31) have been used to estimate the annual doses to categories of staff upon their exercise around equipments that produce ionizing radiation (Gamma knife Perfexion, a Scanner and a monoplane angiography). To assess the reliability of the measurements made by the detector “Inspector” we confronted these measures with those given in the same positions by the RADOS RDS-31 survey meter. The error recorded during simultaneous measurements at the same positions between the two detectors varies from 0.3 to 9%, with an average value of 5%; which allowed us to trust the measurements obtained by the detector "Inspector" placed at our disposal throughout this study. According to the evaluation of the measured dose rates, the annual doses to personnel category A of the radiology and Gamma Knife radiosurgery unit, are between 1.3×10^{-3} and 0.368 millisivert (mSv) per year, and vary from 1.12×10^{-3} to 0.154 mSv per year for category B, while for category C, these values are from 1.74×10^{-3} to 0.162 mSv per year. The values for doses to personnel categories around the Gamma knife treatment room, the scan room and also around the angiography room do not exceed the annual dose thresholds established by the International Commission on Radiological Protection. Following these results the personnel categories practice in the best conditions for radiation protection.
Keywords: NCRNS, Personnel Category’s, Radiation Exposure, Annual Dose.

INTRODUCTION

With the discovery of radiation and radionuclide that can be used in medicine, doctors can offer their patients more varied and effective diagnosis, treatment methods and means of prevention for many diseases such as cancer that previously considered incurable and fatal. But on the other hand, medical practices for therapeutic or diagnostic purposes are the main source of exposure to ionizing radiation of artificial origin [1].

Through the emergence of new techniques, the medical use of ionizing radiation continues to intensify. The increase in medical imaging performance allows early diagnosis and guidance of therapeutic strategies. Diagnostic radiology is one of the oldest medical applications of ionizing radiation; it includes all the morphological exploration techniques of the human body using X-rays produced by electrical generators. Occupying an important place in the medical imaging field and comprises various specialties (conventional radiology, interventional radiology, computed tomography, angiography and mammography) and a wide variety of examinations (Chest radiography, Thoracic-Abdominal-Pelvic CT scan...) [2].

Radiotherapy uses ionizing radiation to destroy malignant cells (and sometimes non-malignant). Ionizing radiation, necessary for performing treatment, are produced by an X-ray generator or emitted by radionuclides of a sealed form. The Gamma Knife is revolutionary in the treatment of neurological disorders in that it, unlike conventional surgery, requires no incision or opening of the skull. Rather, it uses sources of radioactive Cobalt-60 for generating gamma-ray beams. The microscopic beams are digitally focused onto a specific pre-determined target within the brain, delivering a calculated amount of radiation. Targets are so precise that surrounding healthy tissue near the targeted area receives minimal radiation doses [3]. The Gamma Knife is backed by over 30 years of research, evaluation, and clinical use. The safe and effective procedure boasts results demonstrating minimum morbidity and no mortality related to the treatment [4].

Health professionals are chronically exposed to low rates of radiation doses. The effects of these exposures are more difficult to highlight. Cohort studies to radiologists or radiologist technicians conducted in the United States [5], United Kingdom [6] and China [7] showed an excess risk of certain cancers among those exposed, particularly those exposed in the early twentieth century. In France, 33 diseases have been recognized as occupational by the general regime of social security at 2003: 17 primary lung cancers, by inhalation, 1 bone sarcoma, 8 leukemia, 1 anemia, 5 cataracts and 1 radiodermatitis [8].

For purposes of monitoring of workers, the employer conducts an analysis of workstations that is renewed periodically and must include a dosimetry study of these positions. Based on these analyzes the employer proceeded to the radiological classification of workers. The worker may receive, in normal working conditions, an effective dose greater than 6 mSv per year or an equivalent dose higher than three-tenth of the annual exposure limit is classified as Category A; otherwise he is classified as Category B [9].

Periodic individual monitoring is required in the follow-up of the working conditions of all practitioners involved in procedures of medical radiology and radiotherapy in order to estimate the effective dose. The “effective dose” is the amount corresponding to the estimated total risk for induction of stochastic effects resulting from radiation exposure [10].

Morocco is considered among the first African countries experiencing a considerable development in this field and now it has several public and private centers fitted by technical means and the latest generation of devices. The National Centre of Rehabilitation and Neurosciences (NCRNS) is one of those facilities through its unit Gamma knife radiosurgery that is endowed with Gamma Knife Perfexion model [11], the first unit of this type installed in Africa [12].

The scarce studies on medical radiation exposure in Morocco [13, 14] and the lack of a previous study on the evaluation of dose rates around the various devices that produce ionizing radiation prompted us to undertake this study. The aim of this study is to monitor the exposure of the radiology and Gamma Knife radiosurgery unit personnel categories to these radiations.

MATERIALS AND METHODS:

To highlight the aspects of radiation protection in the radiology and Gamma Knife radiosurgery unit in NCRNS, we conducted measurements of dose rates mainly around the Gamma Knife device and the treatment room, around the scan room and also around the angiography room.

Personnel population:

Personnel working at the radiology and Gamma Knife radiosurgery unit in NCRNS are generally:

- Two neurosurgeons and radiotherapists:
- Medical physicist:
- Two Radiologists:
- Two medical imaging technologists:
- Anesthesiologist resuscitator:
- Nurses:

Gamma Knife, CT and Angiography machines:

a. Gamma Knife PerfeXion: equipment that uses Gamma rays from 192 radioactive sources of Cobalt-60 which are confined into the unit [4]. This model incorporates a high level of automation; the entire body can be mobilized in space with submillimeter accuracy for precise focusing of rays. This system allows a gain of considerable comfort to the patient. It mainly consists of two parts:
    1. The sources of radioactive Cobalt which are placed in a "metal ball" that provides shielding.
    2. A couch where the patient lies down during treatment; the couch moves to sources of radiation.

At the front of the couch is located the secondary collimator and the stereotaxic frame fixation system. The head is fixed so as to obtain the greatest possible precision during treatment. The secondary collimator used to direct gamma rays towards the target of irradiation.

b. The examination procedures were performed with the following X-ray equipment:

1- The scanner device, acquired by the NCRNS, is a General Electric (GE) product, Lights peed RT brand with a software system to produce high quality diagnosis. GE Light speed RT is a third generation 4-slice helical CT scanner with a gantry opening that is wider than those found on standard diagnostic CT systems [15].

2- The monoplane X-rays angiography acquired by the NCRNS has an efficient and reliable Allura Xper X-ray system thanks to its performance [16]:

- A revolutionary articulated arm equipped with anti-collision device.
- A plane sensor imaging chain for better images and dose reduction program (DOSEWISE).
- Software and connectivity program to interconnect the imaging network.

Detectors Measurements:

1. **Inspector Alert** is a health and safety instrument that is optimized to detect low levels of radiation. It measures alpha, beta, and gamma radiation [17], the numeric display shows the current radiation level in milliroentgens per hour or, when SI units are used, in microsieverts per hour. The Inspector Alert uses a Geiger-Mueller tube to detect radiation. The Geiger tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization. Each pulse is electronically detected and registers as a count. The Inspector alert displays the counts in the mode you choose.
2. RADOS RDS-31 survey meter is a compact GM tubed-based handheld gamma radiation detector. The RDS-31 is complemented by a full line of external probes to detect alpha and beta radiation. Its versatile functions and durability make it suited for a wide range of applications [18].

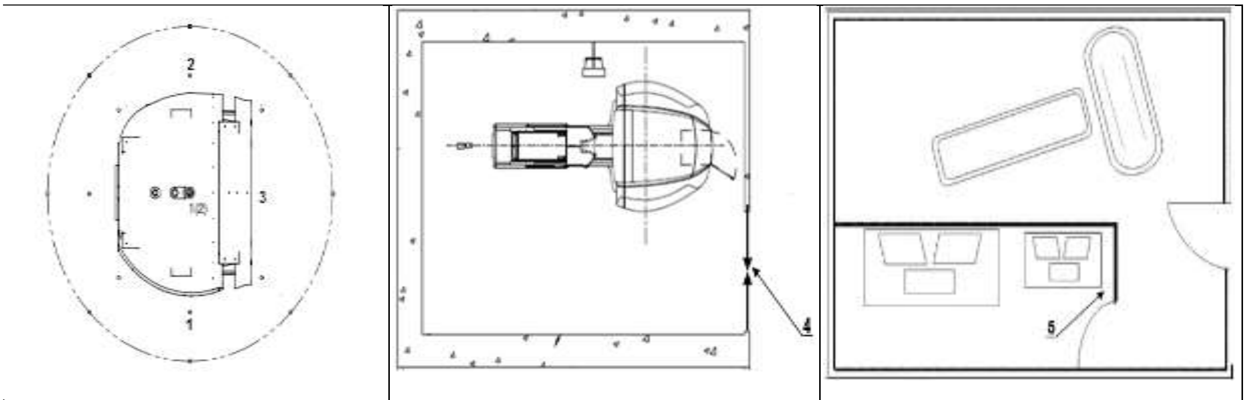
Annual Radiation Exposure Calculations:

The annual radiation exposure (**D_r**) of a category personnel around a diagnostic or a treatment room depends on the average of dose rates (**ADR**) at this site during treatments and the total duration (**T_e**) of all treatments in one year:

$$\mathbf{Dr = ADR * Te}.$$

RESULTS

To assess the reliability of the measurements made by the detector "Inspector" we confronted these measures with those given in the same positions by the RADOS RDS-31 survey meter. Figure 1 shows the five sites where measurements are conducted. The error recorded during simultaneous measurements at the same positions between the two detectors varies from 0.3 to 9 %, with an average value of 5 %. This comparison allows us to trust the measurements taken by the "Inspector" detector made available to us during this study to assess the dose. Results are exhibited in table I.



Head of the Gamma knife Perfexion | Gamma Knife traitement room | Scan room

Fig-1: Positions of measures taken by the Inspector detectors and RDS-31

Table-I: Results of measures taken in the same positions by the detectors.

Detector / Position of the measurement	Inspector D_1 (µSv/h)	RDS-31 D_2 (µSv/h)	Difference D_2-D_1 (µSv/h)	P= ($\frac{D2-D1}{D1}$×100) (%)
1	2.40	2.43	0.030	1,3
2	0.59	0.64	0.050	9
3	7.33	7.95	0.620	9
4	0.61	0.612	0.002	0,3
5	15.12	14.13	0.990	7

Table II shows the maximum dose rates measured, the dose rates at the beginning of the year 2015 and the estimated annual doses to staff categories in different sites around the Gamma Knife treatment room. These sites are shown in Figure 2

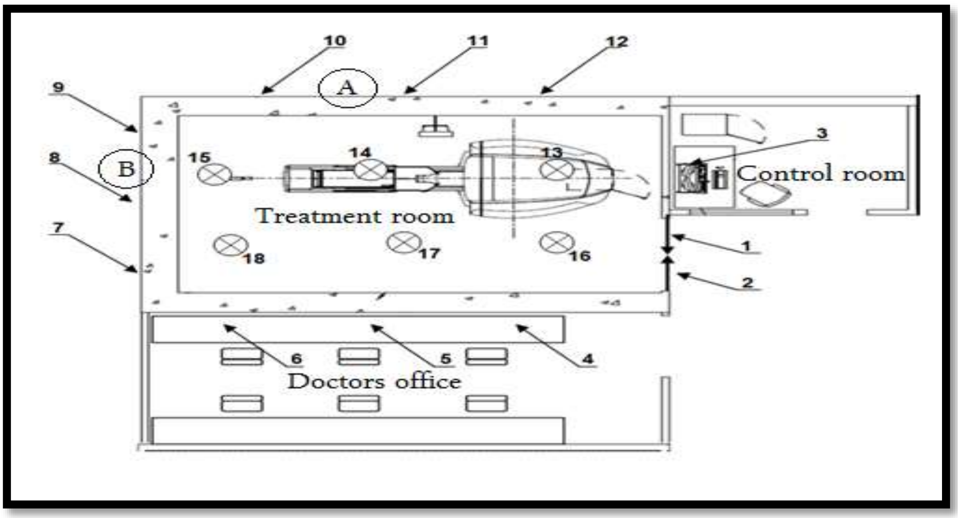


Fig-2: Positions of measures performed around the Gamma Knife treatment room

Table-II: Measured dose rates, dose rates at the beginning of the year 2015 and annual doses to staff categories around the Gamma Knife treatment room.

Site	Positions of Corresponding Measures	Category of personnel	Maximum dose rate measured MDR(μSv/h)	Dose rate at the beginning of the year DRB (μSv/h)	Estimated annual dose D_r (mSv/y)
Control Room	3	A	0.242	0.270	0.223
Doctors Office	4, 5 et 6	A	0.149	0.166	0.137
Dosimetry Room	1	A	0.101	0.112	0.093
Above the Treatment Room (an operating room)	13, 14, 15, 16, 17 et 18	B	0.167	0.186	0.154
Behind the Treatment Room : (A)	7, 8, et 9	C	0.161	0.180	0.149
Beside the Treatment Room : (B)	10, 11 et 12	C	0.176	0.196	0.162

The estimated annual dose to category A staff (neurosurgeons, radiotherapists, physician) around the Gamma knife treatment room varies between 0.093 and 0.223 millisivert per year, with an average value of 0.151 millisivert per year.

Category B personnel (Doctors Anesthesiologists, Nurse Anesthetists) practicing in the operating room located above the Gamma Knife treatment room are exposed to 0.154 millisivert per year.

The dose to category C related to the public members around the Gamma knife treatment room varies between 0.149 and 0.162 mSv/year, with an average value of 0,155 millisivert per year.

Table III exhibits maximum dose rates measured and estimated annual doses to staff categories in different sites around the scanner room. These sites are shown in Figure 3.

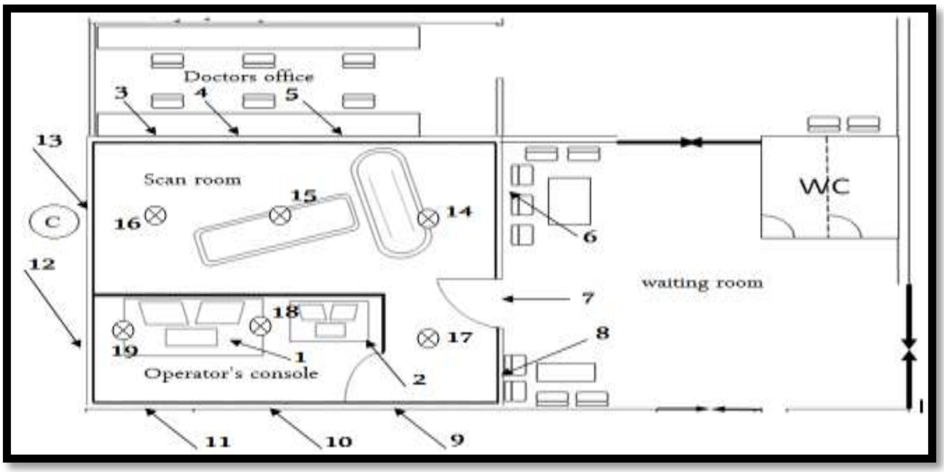


Fig-3: Positions of measures performed around the scan room.

Table-III: Measured dose rates and annual doses to different categories of staff around the scan room.

Site	Positions of corresponding measures	Category of personnel	Maximum dose rate measured MDR (μSv/h)	Estimated annual dose D_r (mSv/y)
Operator's console	1 et 2	A	15.12	0.368
Doctor's office (Beside the scan room)	3, 4 et 5	A	0.209	5.07×10^{-3}
Above the scan room (an operating room)	14, 15, 16, 17, 18 et 19	B	0.263	6.39×10^{-3}
Waiting room (In front of the scan room)	6, 7 et 8	C	4.520	0.110
Behind the scanner room (C)	12 et 13	C	0.149	3.62×10^{-3}

The estimated annual dose to category A staff (radiologists and the medical imaging technologists) around the scan room varies between 5.07×10^{-3} to 0.368 mSv per year with an average value of 0.187 mSv per year.

Category B personnel (Doctors Anesthesiologists and nurse Anesthetists) practicing in the operating room located above the scan room are exposed to 6.39×10^{-3} mSv per year.

The dose to category C related to the public members around the scan room varies between 3.62×10^{-3} and 0.110 mSv per year, with an average value of 0.057 mSv per year.

Table IV exhibits maximum dose rates measured and estimated annual doses to staff categories in different sites around the angiography room. These sites are shown in Figure 4.

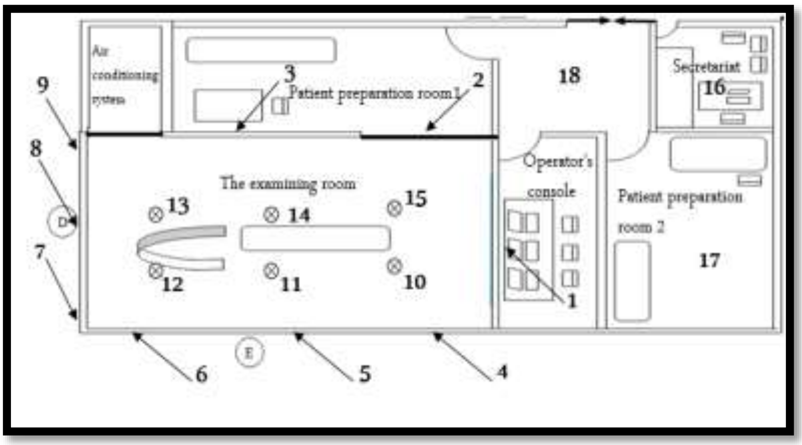


Fig-4: Positions of measures performed around the angiography room

Table-IV: Measured dose rates and annual doses to different categories of staff around the angiography room.

Site	Positions of corresponding measures	Category of personnel	Maximum dose rate measured MDR (µSv/h)	Estimated annual dose D_r (mSv/year)
Operator's console	1	A	0.125	1.3×10^{-3}
Above the angiography room (an operating room)	10, 11, 12, 13, 14 et 15	B	0.329	3.24×10^{-3}
Patient Preparation Room 1	2 et 3	B	0.203	2.1×10^{-3}
Secretariat	16	B	0.107	1.12×10^{-3}
Patient Preparation Room 2	17	B	0.113	1.18×10^{-3}
Beside the Angiography Room (D)	7, 8, et 9	C	0.167	1.74×10^{-3}
Behind the Angiography Room (E)	4, 5, et 6	C	0.179	1.86×10^{-3}

Category A personnel (radiologists and the medical imaging technologists) practicing around the angiography room are exposed to 1.3 µSv per year.

The estimated annual dose to category B staff (Doctors Anesthesiologists, nurse Anesthetists and nurses) around the angiography room varies from 1.12 to 3.24 µSv per year, with an average value of 1.91 µSv per year.

The dose to category C related to the public members around the angiography room varies between 1.74 and 1.86 µSv per year, with an average value of 1.8 µSv per year.

DISCUSSION

Figures 5 and 6 show a comparison between: the annual radiation exposure to staff in the radiology and Gamma knife radiosurgery unit at NCRNS, the occupational exposure of workers in medical field in 1995 supervised by OPRI [19], the external exposure in the field of medical and veterinary activities in 2014 [20], and also national and international regulatory standards [21,22]. These annual exposures are estimated to category A and B staffs during treatment and diagnostic operations.

Regarding category A staff, The maximum annual dose likely to be received during treatments by Gamma Knife, in the radiology and Gamma Knife radiosurgery unit, is 0.223 mSv per year. While during diagnostic examinations this dose is 0.368 mSv per year. These values are respectively lower than 2.21 and 2.39 mSv per year presented by OPRI through its appraisal on the occupational exposure of workers in medical field in France at 1995 [19]. These values are also respectively lower than 0.45 and 0.64 mSv per year, which were assessed by IRSN through its monitoring of external radiation exposure to workers of medical and veterinary fields in 2014 [20].

Moreover, these values are lower than 2 % of the annual dose threshold (20 mSv per year) recommended by the ICRP [21] and also recommended by the law No. 005-71 and the decree No. 2-97-30 on protection against ionizing radiation in Morocco [22]. So, the category A staff at the radiology and Gamma Knife radiosurgery unit, is far from being exposed to significant levels of radiation.

Concerning category B staff, the maximum annual dose likely to be received during treatments by Gamma Knife, in the radiology and Gamma Knife radiosurgery unit, is 0.154 mSv per year. This value is comparable to 0.19 and 0.14 mSv per year respectively found by OPRI and IRSN during their monitoring of personnel exposure in the medical field [17,18]. During the diagnostic examinations by scanner and angiography, the dose is 6.39×10^{-3} mSv per year. It is lower than 0.11 to 0.8 mSv per year respectively estimated by OPRI and IRSN during their monitoring of personnel exposure in the medical field [19,20].

These values do not exceed 0.7 % of the annual dose threshold (6 mSv per year) recommended by the ICRP [21] and also recommended by the law No. 005-71 and the decree No. 2-97-30 on protection against ionizing radiation in Morocco [22]. Thus, the category B staff, at the radiology and Gamma Knife radiosurgery unit, is far from being exposed to significant levels of radiation.

As for public members (category C), the annual dose to this category varies between 0.149 and 0.162 mSv per year around the Gamma Knife treatment room, between 3.62×10^{-3} and 0.110 mSv per year around the scan room, and between 1.74×10^{-3} and 1.86×10^{-3} mSv per year around the angiography room.

These values are lower than the annual dose threshold (1 mSv per year) recommended by the ICRP [21] and also recommended by the law No. 005-71 and the decree No. 2-97-30 on protection against ionizing radiation in Morocco [22]. So, the public members (category C) around the radiology and Gamma Knife radiosurgery unit are far from being exposed to significant levels of radiation.

According to these results, we conclude that the radiology and Gamma Knife radiosurgery unit provides its patients exploration techniques and advanced therapeutic methods in accordance with the regulatory standards. These standards are established by the law No.005-71 and decree No.2-97-30 on protection against ionizing radiation in Morocco [22] following the international recommendations of the ICRP [21].

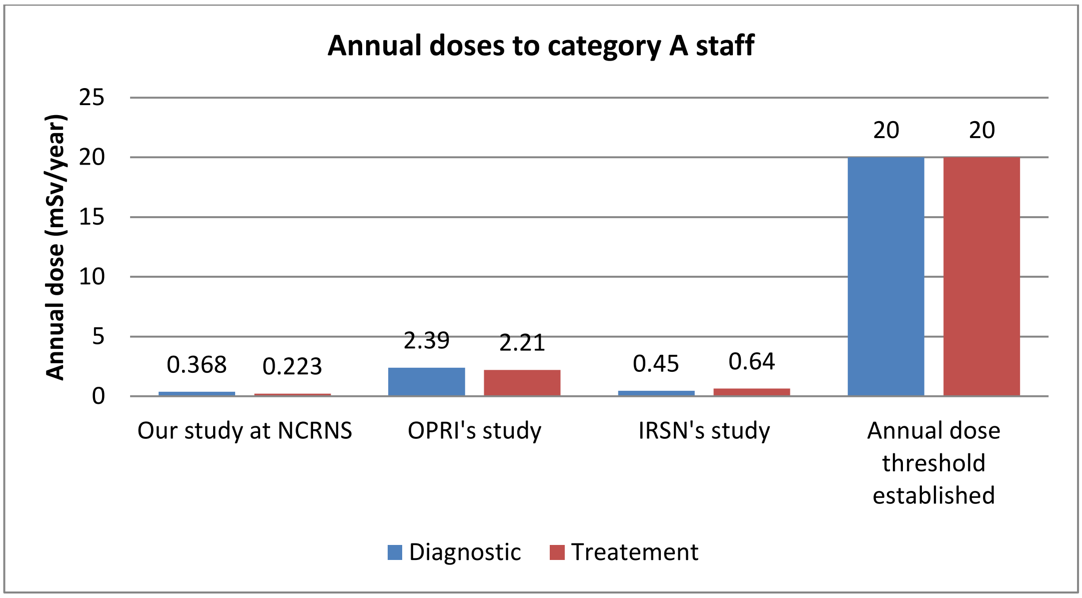


Fig-5: Annual doses to category A staff in radiology and radiotherapy estimated by different actors.

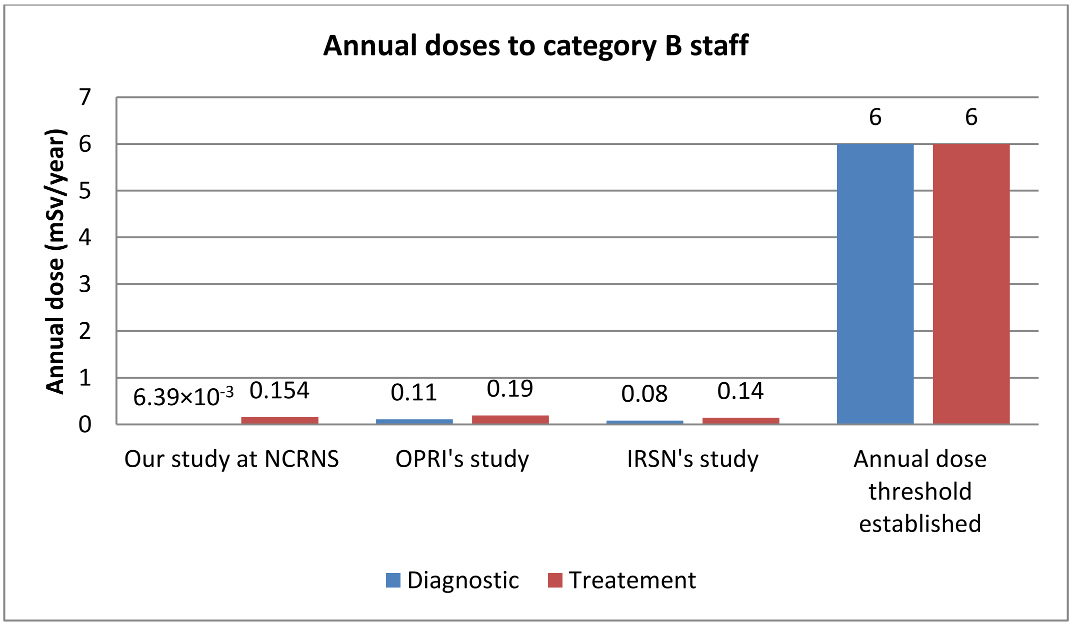


Fig-6: Annual doses to category B staff in radiology and radiotherapy estimated by different actors.

CONCLUSION

The Treatments and the examinations are not done continuously throughout the working time. Thus, to estimate the maximum annual doses received by category of staff upon their exercise around the Gamma knife treatment room, we used the total duration of all treatments by the device throughout the year and the average of dose rates during treatment. Around the scanner and angiography rooms, we considered the average exposure time during all examinations carried out in the year and the maximum measured dose rates. Then the results are discussed in relation to those obtained by OPRI and IRSN in French [17,18], and also in relation to national and international regulatory standards [19,20].

According to the evaluation of the measured dose rates, the annual doses received by the staff category A of the radiology and Gamma Knife radiosurgery unit, are between 1.3×10^{-3} and 0.368 mSv per year, and vary from 1.12×10^{-3} to 0.154 mSv per year for category B, while for category C, these rates are from 1.74×10^{-3} to 0.162 mSv per year.

The annual dose by staff categories around the Gamma knife treatment room, the scan room and also around the angiography room, do not exceed the annual dose threshold established for category A staff (20 mSv per year), for category B (6 mSv per year), and also for category C related to public members (1 mSv per year) [19,20].

The results show that the radiology and Gamma Knife radiosurgery unit provides patients exploration techniques and advanced therapeutic procedures using ionizing radiation in the best radiation protection requirements by establishing the principles of justification, optimization and limitation. Following this study, we recommend improving the practitioner's knowledge regarding radiation protection through the organization of periodic sessions of training and awareness campaigns.

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