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Estimation of the Effective Dose in the Radiology Room: Case of Standard Chest and Abdomen Radiographs Without Preparation of the Dog

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1. Abstract

The objective of this study is to determine the effective doses from the doses at the entrance surface corresponding to the radiological practice in the radiology room of the EISMV. To do this, we worked on data collected with the MICADO software of the Institut de Radioprotection et de Sureté Nucléaire. On the one hand, the different radiological parameters (in particular Kv, mAs) are introduced in the MICADO software which generates the input doses (DE). The different parameters are the parameters used during the most common radiographic examinations in the radiology room. Then with the R software, the statistics were calculated. At the end of the study, for the two abdominal views together, the average effective dose was 0.05 mSv. For the two thoracic incidences, the average effective dose was 0.06 mSv.

2. Introduction

Medical applications of ionizing radiation are the main source of human exposure to ionizing radiation. Due to their increasing use, medical irradiation is nowadays the second most important cause of exposure to ionizing radiation in the population, after natural irradiation. Thus, diagnostic procedures represent more than 97% of the exposure of artificial origin and nearly 26% of the total exposure of the population. It is therefore important to regularly estimate this medical exposure and to analyze its evolution over time. In order to maintain this exposure at levels compatible with medical requirements, the European Commission (EC) has established a directive on radiation protection that recalls the importance of assessing and optimizing the doses received by patients during the various radiodiagnostic practices. In addition, the conditions under which X-rays are taken in veterinary medicine do not always allow the radiation field to be limited to the anatomical area being explored, due to the movements of the animal. The radiation protection of patients is therefore equal to that of operators [2]. The interaction of ionizing radiation with the human body results in damage at the cellular level of the tissues crossed by this radiation. This damage is induced by cellular DNA damage that depends on the amount of energy deposited in the cells, the nature of the radiation, the modalities of exposure and the organ affected. The main risk of irradiation is the appearance of cancer in the long term. The effective dose is the ideal element for assessing the effects of ionizing radiation on the living. It represents the impact of the absorbed dose in terms of risk for the whole organism. It therefore allows the risk of stochastic effects in humans to be assessed. It is for this reason that this study proposes to determine the effective doses received by the operators during the most common radiological examinations in the radiology room of the EISMV.

3. Materials and Methods

3.1 Area, Period of Study

The veterinary clinic of the EISMV of Dakar is located within the establishment at the University Cheikh Anta Diop (U.C.A.D) of Dakar in the Fann district. It is a referral clinic that is currently one of the most frequented veterinary clinics in the city of Dakar due to the quality of the services offered to patients. This study took place from June 2018 to August 2019.

3.2 Materials

3.2.1. Animal Material

To conduct this study, we used unanesthetized dogs, regardless of weight, age, and size. These were dogs presented in the radiology room for routine radiography, and whose owners had agreed to their participation in the study. Dogs were recruited as they arrived in the radiology room. We thus recruited a total of 30 patients. The animals were healthy animals, referred by clinicians at the EISMV University Hospital and also by clinical veterinarians in private practice for routine examinations, and brought by the animal owners.

3.2.2. X-ray Equipment

The Inter-State School of Veterinary Science and Medicine in Dakar has a radiology room in the clinic where the present study was conducted. The radiographic apparatus used is of the brand CAWOWAT. This device has the following characteristics:

- Maximum voltage (kV): 150 kV
- Maximum second milliamperage: 300 mAs

The adjustment of these parameters is done thanks to the control panel of the radiographic apparatus.

3.2.3. Measuring Equipment

It is a plastic tape measure of 4 meters length

3.3 Method

The determination of the effective doses received by the operators of the radiology room is based on the methodology of CHI FREJUS in 2012, which is based on the principle that the radiation protection of patients is equal to that of the operators [2].

3.3.1. Data Collection

Data were collected using the MICADO software of the Institut de Radioprotection et de Sureté Nucléaire (IRSN). We entered the exposure parameters, the type of examination performed, the applied voltage, the inherent and additional filtrations used, and the length and width of the field at the surface on the IRSN website. This operation gave us the following results: the air dose rate, the backscatter factor, the dose at the patient's entrance surface (DE) calculated. The different EDs were noted and used to calculate the effective dose.

3.3.2. Measurement of the Region to be Radiographed

For each examination, we measured the length and width of the regions to be radiographed and then calculated the averages in order to have the entry surface of the rays.

3.3.3. Calculation of the Effective Dose

The calculation of the Dose x Surface Product (DSP), for the most common radiological examinations, was done using the following formula:

PDS = ED x Se / FRD (REHEL, 2010)

Se = skin surface

FRD: Backscatter factor (it is 1.35 for Kv ranging from 60 kv to 80 Kv)

The SDPs then allowed us to calculate the effective doses, by multiplying the SDPs of the radiological examinations (Thorax, Abdomen) by the conversion factor related to the anatomical region (SIRINELLI, 2013). The conversion factor is 1/3 for the thorax and 1/5 for the abdomen.

3.3.4. Statistical Analyses

The collected data were entered on Sphinx Plus 5.0 and exported in Microsoft office 2016 Excel format. They were analyzed with R 2.13.0 software which was used to calculate the statistics.

4. Results

Based on the doses at the input surface obtained via the MICADO software, we proceeded to the calculation of the SDPs and then the effective doses for the most common radiological examinations. To do this, for each examination, we measured the length and width of the regions to be radiographed. The average length and width in centimeters of the 30 regions radiographed for the thorax and the 30 regions radiographed for the abdomen are shown in (Table III). These average measurements were used to calculate the entrance area, then the SDPs and finally the effective doses.

They allowed us to calculate the SDPs for the two regions of our study from the entry doses, which are shown in (Tables IV and V).

4.2.1. Calculation of the Dose x Area Product

4.2.1.1. Calculation of the Dose x Area Product of Thoracic Radiographic Examinations

The input doses (Table I) allowed us to calculate the Dose x Area Product (DAP), summarized in Table IV. Thus, the average DPS is 0.148 ± 0.022 Gy.cm2 and the 75th percentile is 0.21 Gy.cm2. The 75th percentile thus corresponds to the diagnostic reference level expressed in SDP.

4.2.1.2. Calculation of the Dose x Area Product for Radiographic Examinations of the Abdomen

The input doses (Table II) allowed us to calculate the Dose x Area Product (DAP), summarized in Table V. The mean DSP is 0.229 ± 0.063 Gy.cm2 and the 75th percentile is 0.26 Gy.cm2. The 75th percentile thus corresponds to the diagnostic reference level expressed in SDP.

Table I: Calculated entry doses for a thoracic radiographic examination (via MICADO software)

Examination numbers	DE (mGy)
1	0,37
2	0,22
3	0,25
4	0,27
5	0,34
6	0,42
7	0,47
8	0,78
9	0,72
10	0,52
11	0,76
12	0,66
13	0,61
14	0,3
15	0,39
16	0,2
17	0,18
18	0,36
19	0,54
20	0,92
21	0,33
22	0,16
23	0,92
24	0,41
25	0,54
26	0,15
27	0,69
28	0,8
29	0,25
30	0,19
Average	**0,4573 ± 0,2**

Table II: Calculated entry doses for radiographic examination of the abdomen using the MICADO software

Examination numbers	DE (mGy)
1	0,29
2	0,32
3	0,36
4	0,39
5	0,42
6	0,46
7	0,49
8	0,53
9	0,56
10	1,06
11	1,11
12	1,15
13	0,22
14	0,26
15	0,29
16	0,6
17	0,64
18	0,67
19	0,71
20	0,74
21	0,78
22	0,82
23	0,86
24	0,9
25	0,94
26	0,98
27	1,03
28	0,6
29	0,64
30	0,67
Average	**0,6497 ± 0,222**

Table III: Average measurements of the radiographed regions

	Thorax (cm)	Abdomen (cm)
Average length of the radiation field	21 ± 1,5	25 ± 2,3
Average width of the irradiation field	19 ± 2	16 ± 1,3

Table IV: PDS (Chest X-ray)

Dog numbers	DE (mGy)	PDS (Gy.cm2)
1	0,37	0,109
2	0,22	0,065
3	0,25	0,074
4	0,27	0,080
5	0,34	0,100
6	0,42	0,124
7	0,47	0,139
8	0,78	0,231
9	0,72	0,213
10	0,52	0,154
11	0,76	0,225
12	0,66	0,195
13	0,61	0,180
14	0,3	0,089
15	0,39	0,115
16	0,2	0,070
17	0,18	0,063
18	0,36	0,127
19	0,54	0,190
20	0,92	0,324
21	0,33	0,116
22	0,16	0,056
23	0,92	0,324
24	0,41	0,144
25	0,54	0,190
26	0,15	0,053
27	0,69	0,243
28	0,8	0,281
29	0,25	0,088
30	0,19	0,067
Average	0,4573 ± 0,199	0,148 ± 0,022

4.2.2. Calculation of Effective Doses

4.2.2.1. Calculation of Effective Doses for a Thoracic Examination

The SDPs then allowed us to calculate effective doses according to our methodology (SIRINELLI et al., 2013). Thus, for thoracic examinations, the SDP is divided by 3 to find the effective dose. The average effective dose is 0.06 ± 0.021 mSv (Table VI).

Table V: PDS (abdominal radiograph)

Dog numbers	DE (mGy)	PDS (Gy.cm2)
1	0,29	0,102
2	0,32	0,113
3	0,36	0,127
4	0,39	0,137
5	0,42	0,148
6	0,46	0,162
7	0,49	0,172
8	0,53	0,186
9	0,56	0,197
10	1,06	0,373
11	1,11	0,391
12	1,15	0,405
13	0,22	0,077
14	0,26	0,091
15	0,29	0,102
16	0,6	0,211
17	0,64	0,225
18	0,67	0,236
19	0,71	0,250
20	0,74	0,260
21	0,78	0,274
22	0,82	0,289
23	0,86	0,303
24	0,9	0,317
25	0,94	0,331
26	0,98	0,345
27	1,03	0,362
28	0,6	0,211
29	0,64	0,225
30	0,67	0,236
Average	0,6497 ± 0,222	0,229 ± 0,063

4.2.2.2. Calculation of Effective Doses for an Abdominal Examination

The SDPs then allowed us to calculate effective doses according to our methodology (Table VII). Thus, for radiographic examinations of the abdomen, the SDP is divided by 5 to find the effective dose. The average effective dose is 0.05 ± 0.0126 mSv.

Table VI: Effective Doses (Thorax Radiography)

Dog numbers	PDS (Gy.cm2)	Dose. Eff. (mSv)
1	0,109	0,036
2	0,065	0,022
3	0,074	0,025
4	0,080	0,027
5	0,100	0,033
6	0,124	0,041
7	0,139	0,046
8	0,231	0,077
9	0,213	0,071
10	0,154	0,051
11	0,225	0,075
12	0,195	0,065
13	0,180	0,060
14	0,089	0,030
15	0,115	0,038
16	0,070	0,023
17	0,063	0,021
18	0,127	0,042
19	0,190	0,063
20	0,324	0,108
21	0,116	0,039
22	0,056	0,019
23	0,324	0,108
24	0,144	0,048
25	0,190	0,063
26	0,053	0,018
27	0,243	0,081
28	0,281	0,094
29	0,088	0,029
30	0,236	0,047
Average	**0,148 ± 0,022**	**0,06 ± 0,021**

Table VII: Effective doses of a radiographic examination of the abdomen in left lateral incidence

Dog numbers	PDS (Gy.cm2)	Dose. Eff. (mSv)
1	0,102	0,020
2	0,113	0,023
3	0,127	0,025
4	0,137	0,027
5	0,148	0,030
6	0,162	0,032
7	0,172	0,034
8	0,186	0,037
9	0,197	0,039
10	0,373	0,075
11	0,391	0,078
12	0,405	0,081
13	0,077	0,015
14	0,091	0,018
15	0,102	0,020
16	0,211	0,042
17	0,225	0,045
18	0,236	0,047
19	0,250	0,050
20	0,260	0,052
21	0,274	0,055
22	0,289	0,058
23	0,303	0,061
24	0,317	0,063
25	0,331	0,066
26	0,345	0,069
27	0,362	0,072
28	0,211	0,042
29	0,225	0,045
30	0,236	0,047
Average	**0,229 ± 0,063**	**0,05 ± 0,0126**

5. Discussion

5.1. Method of Calculation of the Effective Dose

The calculation of the PDS can be done in several ways, in particular by mathematical calculation using software such as MICADO or by a measurement system integrated into the X-ray equipment. The MICADO radiology dose calculation tool as well as the deduction by mathematical formula are part of the elements entering the advice and the assistance to the radiology practitioners. As such, the MICADO tool is a more than reliable tool to evaluate the input doses, in the absence of an automatic measurement system [3, 8]. Indeed, the systems integrated into the device (detectors) use either ionization in air (ionization chambers) or ionization in solids (thermoluminescent dosimeters, semiconductor diodes, scintillation detectors) to determine the SDPs. Ionization chambers, for example, have the particularity of having a rather high uncertainty of the order of 20%. In addition, the main sources of error related to the use of these detectors are the position of the ionization chamber with respect to the table, the scattered radiation from the collimator, the patient or the table reaching the ionization chamber [3, 8].

On the other hand, to calculate the effective doses, there is a difference between the mathematical calculation method and other methods such as the Monte Carlo Method. Indeed, an American study compared effective doses from SDP calculation to those from Monte Carlo method calculation [7] and, the values from SDP tend to be lower than those obtained by Monte Carlo method (MC). As an example, regarding the child, effective doses calculated using the MC method tend to be higher than values calculated from conversion factors. For example, DEAK, 2010 found a 76% difference between the effective doses calculated by the 2 methods for a thoracic examination in a 5-year-old child [4].

5.2. Dose Area Product (DAP)

The DSPs that we measured allowed us to determine the DRL in DSP for thoracic and abdominal examinations. We did not find in the literature values that could be considered as diagnostic reference levels in veterinary medicine. Therefore, we used the radiography in human medicine as a reference.

The value of the DRL in PDS obtained for chest radiology by the 75th percentile method is 0.21 Gycm2 or 21 cGycm2. This value is higher than those cited by IRSN, in 2014 in countries such as the United Kingdom (10 cGycm2), Germany (16 cGycm2), and Switzerland (15 cGycm2) [6]. This high value of DRL in SDB in our study indicates that a large surface area of the dogs is unnecessarily exposed to X-rays in our X-ray room. Therefore, the aperture of the diaphragm should be adjusted to the anatomical limits of the thoracic region to be explored to further optimize the SDP. Indeed, a beam field that is too open unnecessarily exposes the dog. This may be due to the fact that the radiographic apparatus is mobile, requiring more manipulation to cover the dogs thorax.

The DRL value in SDB measured for abdominal radiology by the 75th percentile is 0.26 Gycm2 or 26 cGycm2. It is lower than the one proposed by IRSN, which is 30 cGycm2 [5]. These results corroborate the results we had with the dose at entry and respond to the same explanations related to the small thickness of the dog's abdomen compared to that of humans. Indeed, in view of the low abdominal contrast in humans, higher constants will be more used for abdominal radiographs.

5.3. Effective Doses

The effective dose represents the impact of the absorbed dose in terms of risk to the whole body. The interaction of ionizing radiation with living organisms results in damage at the cellular level of the tissues through which the radiation passes. This damage is induced by lesions of the cellular DNA which depend on the amount of energy deposited in the cells, the nature of the radiation, the modalities of exposure and the organ affected [3].

Since patient radiation protection is equal to operator radiation protection [2], patients and operators receive the same dose when taking radiological images. Our study obtained effective dose values of 0.06 mSv for the thorax and 0.05 mSv for the abdomen. Both values are slightly higher than the recommended doses for humans, which are 0.05 mSv for the thorax and 0.04 mSv for the abdomen without preparation, respectively [5]. This means that when taking radiographic images in dogs, the doses received by the operator are slightly higher than the doses recommended by the IRSN, 2012 dors of radiography in humans. The effective dose makes it possible to evaluate the occurrence of stochastic effects which are carcinogenic, genetic and hereditary effects. They are the consequence of alterations in the genetic material of the cells that induce cancer if they concern somatic cells, or of modifications in the phenotype of the offspring of the exposed individual if they concern germ cells. These effects are related to non-lethal mutations of the cells. As the threshold for these risks has not yet been determined, and in order not to underestimate them, it is considered that the increase in the probability of the appearance of cancer is proportional to the dose received. If the effect appears, it then evolves independently of the dose, its severity does not depend on the initial dose, but the frequency of appearance of these effects increases proportionally to the increase in the dose of ionizing radiation [1, 5, 9].

Radiation protection measures must thus be taken to protect personnel working in the EISMV radiology room.

6. Conclusion

The objective of this study was to determine the effective doses from the doses at the entrance surface corresponding to the radiological practice in the radiology room of the EISMV, to determine the Dose x Surface Products for which the value of the DRL in SDP obtained for abdominal radiology by the 75th percentile is 0.26 Gycm2 or 26 cGycm2 and the value of the DRL in SDP obtained for thoracic radiology by the 75th percentile is 0.21 Gycm2 or 21 cGycm2 On the other hand, for the two abdominal scans, the average effective dose is 0.05 mSv. For the two thoracic scans, the average effective dose is 0.06 mSv. These doses are higher than the doses resulting from the studies proposed by the Institut de Radioprotection et de Sureté Nucléaire and it is therefore imperative to reinforce the radiation protection measures in the room, in particular the wearing of aprons and thyroid covers and the wearing of dosimeters.

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