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CALCULATION OF EFFECTIVENESS OF THE VETERINARY X-RAY SYSTEMS PROTECTIVE CABIN

Introduction. *The transition from the use of X-ray film to digital radiography (DR) has made X-ray diagnostics in veterinary clinics simple and efficient. The number of examinations is small compared to medical use, but a significant part of them is performed without anesthesia of the animals by manual fixation of the animals. Such fixation of the animals is usually performed by veterinary clinic staff.*

Methods. *In this work, we measured the dose loads and calculated the protection efficiency of a new cabin for a veterinary X-ray system. Cabins provide protection in space in three coordinates. Accordingly, the calculations of the attenuation coefficients must also be performed in volume.*

Results. *The experimentally found values of the three-dimensional distribution of the attenuation coefficients on the surface of the cabin make it possible to calculate the necessary thickness of lead protection, which guarantee compliance with the relevant sanitary standards. In the experiment, a decrease in the protection factor of the screen with a lead equivalent of 0.6 mm was registered up to 2 times, which corresponds to an increase in the effective anode voltage. Thus, the well-known in X-ray tomography effect of increasing the hardening of radiation appeared.*

Conclusions. *In veterinary medicine, compared to human medicine, the presence of personnel who fix the animal with their hands is fundamentally different. This workplace is located in close proximity to both the direct X-ray beam and the maximum scattered radiation. It requires special attention during calculating X-ray protection. The small size of the cabin, where the X-ray examination is performed, reduces the area and the price of structural protection. That determines the economic attractiveness of the concept.*

Keywords: *digital radiography, protection, veterinary medicine, cabin, computed tomography, Compton effect.*

Introduction

The transition from the use of X-ray film to digital radiography (DR) has made X-ray diagnostics in veterinary clinics simple and efficient. This led to an increase in the number of X-ray studies for small veterinary clinics from 20...30

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to 200...300 per month. Such a number of examinations is small, compared to medical use, but a significant part of them is performed without anesthesia of animals with the help of fixing animals with hands. Such fixation of animals is usually performed by the staff of veterinary clinics. As a result, the radiation load on clinic staff also increased tenfold. In addition, cone beam X-ray tomography scanners (CBCT) are starting to be used in small veterinary clinics, which also creates X-ray dose loads. These features necessitate the development of more effective means of protection for the personnel of veterinary clinics (IAEA, 2024, p. 7).

Methods

The existing concept of protection was developed in the middle of the last century for film technology. Protection measures include individual means: aprons, gloves, collars, caps and glasses, as well as structural means: lead sheets, barite platei and protective curtains (Ministry of Health of Ukraine, 2007, p. 17). Individual means are put on people, and the X-ray room is equipped with structural means. Individual protective equipment has a considerable weight – 6...10 kg, which is inconvenient for clinic staff. Structural means do not protect personnel in the X-ray room. They cover a large area of walls and ceilings and, as a result, are expensive (Fig. 1a).

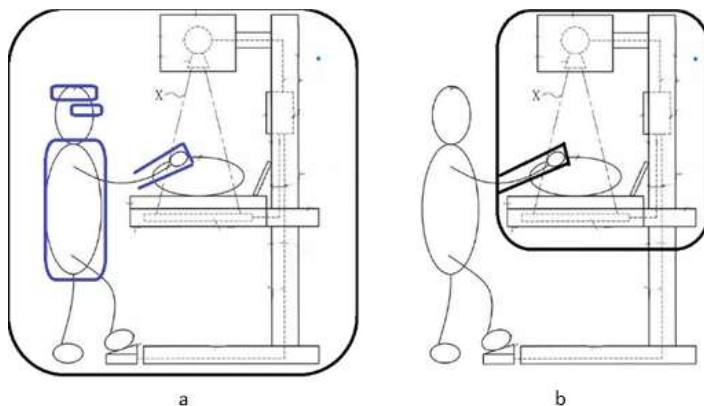


Fig. 1. Protection of the clinic staff in the X-ray room with individual protective equipment 0,25...0,5 mm Pb and structural means – outside the X-ray room 0,5...1,5 mm Pb (a).

Protection of the clinics staff in and outside the X-ray room with the help of a cabin 0,6...2,0 mm Pb (b)

Places of installation and the lead equivalent of structural protection means are calculated in advance, which turns the cabinet into a stationary system and excludes mobility. A detailed description of the X-ray room of the veterinary complex is given in the US patent N 10,045,751B2 (Okusu, Ohashi, & Okabe, 2018, p. 17), issued in the name of the Fuji film company.

The concept proposed by us (Miroshnychenko, O., Miroshnychenko, S., & Nevhasymyi, 2024, p. 14) is new for veterinary implementation, but is commonly used in population lung screening and non-destructive control systems, based on the use of

a mobile protective cabin. A fundamentally new feature is the presence of workplace of staff that fix the animal by the hands (Fig. 1b). This workplace is in close proximity to both the direct X-ray beam and the scattered radiation maximum. It requires special attention when calculating X-ray protection. In this work, we offer a combination of individual and structural means of protection. Structural protection is placed on cabins tripod, which makes it possible to significantly decrease the dose load and ensure the convenience of human work. At the same time, the small dimensions of the cabin, where the X-ray examination is performed, reduces the area and the price of structural protection. That determines the economic attractiveness of the concept.

The cabin provides protection in space in three coordinates (abbreviated – in 3D, Fig 2). Accordingly, the calculations of the attenuation coefficients have also to be performed in 3D. The values of the three-dimensional function $K(x,y,z)$ found experimentally on the surface of the cabin make it possible to calculate the required thickness of lead protection $Pb(x, y, z)$ according to the tables (Ministry of Health of Ukraine, 2007, p. 54), which guarantee compliance with the relevant sanitary standards.



**Fig. 2. Exterior view of the closed (a) and open (b) DR cabin.
Exterior view of the closed CBCT cabin (c)**

Results

In this concept of X-ray protection all radiation divided into two parts: direct one (zone A, Fig. 3a) – includes direct irradiation not in the way to the receiver, and scattered (by Compton effect) – includes radiation scattered by an animal (zone B, Fig. 3a). In both DR and CBCT systems, the direct radiation of the X-ray tube matches on the X-ray sensitive field of the receiver. This makes it possible to reduce intensity the direct beam with separate screens behind the receiver and on the back surface of the emitter.

The basis for the calculation of radiation protection (Ministry of Health of Ukraine, 2007, p. 42) is the determination of the attenuation factor – K of the dose rate of X-ray radiation at a given point in the absence of protection P_D to the value of the protected dose rate P_{Dp} , in units of the absorbed or exposure dose:

$$K = P_D / P_{Dp} . \quad (1)$$

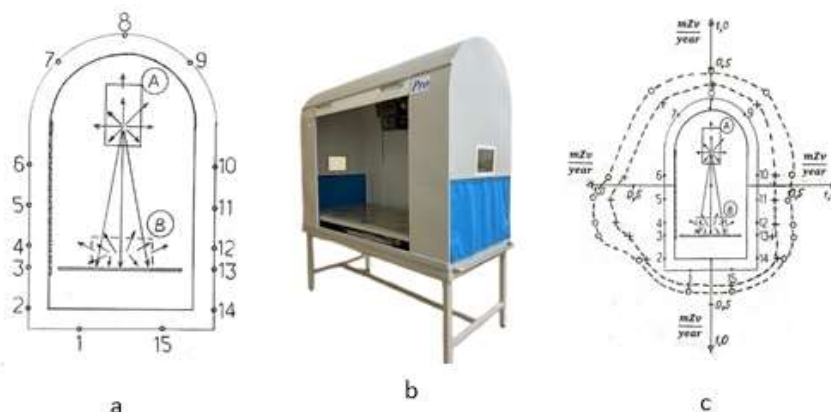


Fig. 3. Zones of direct (A) and scattered (B) radiation (a). External view of the cabin (b). Graphs of the annual dose load without (+) and with the presence (o) of a water phantom

For conducting research, a cabin with protective screens and fabric curtains was made to reduce direct radiation. In addition, the entire inner surface of the cabin was covered with a screen with the equivalent of 0.6 mm of lead. The place of the worker who fixes the animal is located on the side of the fabric curtains and transparent window (Fig. 3b). During the experiment, the radiation components were measured separately at points 1–15 (Fig. 3a) in the absence and presence of a water phantom. The research was carried out in two stages with dosimeter GS-01.

At the first stage, direct radiation was studied by measuring the power of the radiation dose P_D without the protection. Then the protection was installed: 1.0 mm of lead on the frontal and back side of emitter and 0.5...0.6 mm of lead on the side walls and the radiation dose with protection P_{Dp} were measured. The attenuation factor K of individual screen on the back side of the emitter, P_{Dey} equivalent annual dose with and P_{Dpey} without protection were calculated (Table 1).

At the second stage, the presence of the animal was simulated using an equivalent water phantom (zone B Fig. 3a). P_{DF} and P_{DpF} – the dose rate of X-ray radiation at a given point in the absence and with protection, K_F – attenuation factor, P_{DpeyF} and P_{DeyF} – equivalent annual dose with and without protection in presence of phantom respectively.

During the experiment with a water phantom, a decrease in the protection factor of the screen with a lead equivalent of 0.6 mm was registered up to 2 times; σ – relative reduction of the protection factor – $\sigma = K_F/K$. That is, the effect known in computer tomography of increasing the hardness of radiation in the presence of a biological object in the field of study appeared. Physically, this is due to the fact that during the formation of scattered radiation by a water phantom, low-energy photons are absorbed by the phantom itself, and radiation with a more "hard" energy distribution is emitted the outside of the phantom.

Table 1

Results of measurement of short-term dose rate and attenuation factor

Point No	2	3	4	5	6	7	8	9	10	11	12	13	14
P_D , mSv/h	18,3	24	50	52	51	50	50	50	51	52	53	24	18,3
P_{Dp} , mSv/h	0,79	1,3	1,8	1,9	2,0	0,91	0,71	0,73	0,78	0,80	0,83	0,43	0,46
K	23,2	18,5	27,8	27,4	25,5	54,9	70,4	68,2	65,5	62,4	63,8	55,8	39,8
P_{Dey} , mSv/y	5,3	6,7	13,9	14,5	14,3	14,3	14,1	14,3	13,8	13,4	14,7	6,7	5,6
P_{Dpey} , mSv/y	0,23	0,36	0,50	0,53	0,56	0,26	0,20	0,21	0,21	0,23	0,23	0,12	0,14
P_{DF} , mSv/h	18,2	57	55	57	53	52	52	52	53	57	55	57	18,2
P_{DpF} , mSv/h	0,9	3,2	3,5	3,5	2,6	1,7	1,49	1,49	1,61	1,59	1,62	1,78	0,48
K_F	20,2	14,3	15,6	16,3	20,4	30,6	34,9	34,9	32,9	35,8	33,9	32	37,9
P_{DeyF} , mSv/y	5,3	12,9	15,3	15,9	14,7	14,7	14,7	14,7	14,8	16,11	15,3	16,0	5,7
P_{DpeyF} , mSv/y	0,26	0,9	0,98	0,98	0,72	0,48	0,42	0,42	0,45	0,45	0,45	0,50	0,15
σ	0,87	0,77	0,56	0,6	0,8	0,56	0,5	0,5	0,5	0,57	0,53	0,57	0,95

As a result, the additional protection of the cabin surface with 0.5...0.6 mm of lead on the border satisfied the condition of the permissible annual dose of less than 5 mSv/year (the graph is marked – ooo, Fig. 3c).

Discussion and conclusions

The combination of individual and structural means of protection makes it possible to significantly increase the degree of protection and the convenience of a person's work. At the same time, the small size of the cabin, where the X-ray examination is performed, reduces the area and the price of structural protection. That determines the economic attractiveness of the concept.

Authors' contribution: Sergii Miroshnychenko – conceptualization, formal analysis, writing – original draft; Oleksandra Miroshnychenko – formal analysis, writing – review&editing; Yurii Khobta – investigation.

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РОЗРАХУНОК ЕФЕКТИВНОСТІ ЗАХИСНОЇ КАБІНИ ДЛЯ ВЕТЕРИНАРНОЇ РЕНТГЕНІВСЬКОЇ СИСТЕМИ

Вступ. Перехід від використання рентгенівської плівки до цифрової рентгенографії (ДР) зробив рентгенодіагностику у ветеринарних клініках простою й ефективною. Кількість обстежень порівняно з медичним використанням невелика, але значна їх частина проводиться без анестезії тварин шляхом ручної фіксації тварин. Таку фіксацію тварин зазвичай проводять працівники ветеринарної клініки.

Методи. Проведено вимірювання дозових навантажень та розраховано ефективність захисту нової кабінки для ветеринарної рентгенівської системи. Кабіни забезпечують захист у просторі за трьома координатами, відповідно й обчислення коефіцієнтів ослаблення необхідно виконувати, використовуючи просторові координати.

Результати. Знайдені експериментально значення тривимірного розподілу коефіцієнта ослаблення рентгенівського випромінювання на поверхні кабінки дають можливість по таблицях розрахувати необхідні товщини свинцевого захисту, які гарантують виконання відповідних санітарних норм. В експерименті було зареєстровано зниження коефіцієнта захисту екрана майже у два рази при вимірюваннях з водним фантомом, порівняно з вимірюваннями без нього. Це відповідає підвищенню ефективної анодної напруги. У процесі дослідження проявився відомий у рентгенівській томографії ефект збільшення жорсткості випромінювання, коли фотони з низькою енергією поглинаються фантомом, а з високою проходять крізь нього.

Висновки. *Принципово новим є наявність місця персоналу, який фіксує тварину руками. Це місце розташоване у безпосередній близькості як до прямого рентгенівського променя, так і до максимуму розсіяного випромінювання. Робоче місце потребує особливої уваги в розрахунках рентгенівського захисту. До того ж, за рахунок малого розміру кабінки, де виконується рентгенівське обстеження, зменшується площа і ціна конструкційних засобів захисту. Це зумовлює економічну привабливість концепції.*

Ключові слова: *цифрова рентгенографія, захист, ветеринарія, медицина, кабінка, комп'ютерна томографія, ефект Комптона.*

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