Abstract:
The implementation of the Council directive 96/29 EURATOM and the corresponding national Radiation Protection Ordinance and the X-ray Protection Ordinance coming subsequently into effect led to a changed situation regarding the occupational radiation protection in the medical sector. To reduce the occupational exposure of veterinarians and assisting staff in veterinary radiography is particularly challenging as, in opposite to human radiological examination, the presence of staff is indispensable to restrain the patient. Beyond that the relevant literature reports about too high and/or about unnecessary radiation exposures (e.g. [1, 2]).

To gain a comprehensive knowledge upon the possible exposure of involved staff, the variety of typical examination methods in veterinary clinics and at practitioners had been investigated during the daily routine. Dose measurements were performed for different employees during the examinations taking into account several places of exposure (lens, thyroid, chest, hand, gonad, and feet). Veterinary X-ray diagnostic examinations for pets as well as in equine radiography had been accounted for this study. In total, 101 examination methods, 4,484 accompanied examinations and 53,892 single dose readings resulted in a reliable statistical base to set up a “Job-Exposure-Matrix” allowing the dose assessment for a variable number and kind of examinations.

The “Job-Exposure-Matrix” is believed to be a useful tool for optimization of occupational radiation exposure of veterinarians by appraising the height of a possible dose, forcing a review of the status quo and triggering the improvement of personal protection by establishing adequate measures.

1 INTRODUCTION

Subject of the project was to analyse the radiation exposure of the medical staff due to diagnostic X-ray examinations in veterinary medicine. In detail the radiation exposure of the medical staff was first measured and next analysed and transformed into a data structure (called “Job-Exposure-Matrix”), which allows an easy estimation of the radiation exposure of the veterinary staff due to diagnostic X-ray examinations. Between March 2006 and January 2007 data from 1374 investigations in the involved large animal hospital of the FU Berlin and 2739 investigations in the involved small animal hospital of the FU Berlin were collected. Thus the desired statistics of 1000 investigations with large animals and 1000 investigations of small domestic animals could be achieved. 42 large animal X-ray-diagnostic examination methods and 59 small animal X-ray-diagnostic examination methods were considered. In addition the data from 1450 investigations of 64 different X-ray-diagnostic examination methods were collected during the measuring campaign at four veterinary surgeons.

After evaluation of the collected data the “Job-Exposure-Matrix” was constructed out of altogether 53892 measured values from 4489 investigations.

The measurement and the related analysis show, that the exposure of the medical staff during a single X-ray examination is low. However, a high frequency of examinations during a year may result in exposures which might exceed the relevant dose limits. Thus, the
measurements also highlight the importance of radiation shielding even in case of low exposure due to a single X-ray examination.

The compilation of the measured data in the data structure allows an easy estimate of the radiation exposure due to a single X-ray examination. Information is available for different members of the medical staff during the examination and for different positions. When estimating the dose care has to be taken, that the data do only take into account exposure due to scattered Roentgen radiation. Thus, contribution due to the direct X-ray beam, e.g. to a hand, are not taken into account due to the high dose rates and the technical limitations of the EPD systems used. These contributions to the exposure need to be avoided by appropriate X-ray protective clothing and proper behaviour of the medical staff.

2 CONCEPT AND MEASUREMENTS

The measurements for the “Job-Exposure-Matrix” are taken during routine examinations primarily performed at two veterinary clinics of the “Freie Universität Berlin (FU Berlin)” but also at four other veterinary clinics in Germany. In addition some examinations measurements are performed using animal phantoms. Due to the shielding of the X-ray aprons and the resulting very low values the doses are measured in front of the X-ray aprons. Generally, electronic personal dosimeters (EPD) are used, complemented by thermo luminescence dosimeters and an ionisation radiation chamber (Fig. 1).

**Fig 1:** Pictures of the used Dosimeter systems
(top left: ComDos EDM-III; top right: Thermo EPD MK2; bottom left: Ionisation chamber STEP RGD 27091; bottom right: TLD XD-700)

Two EPD systems from different manufacturers were used:

ComDos EDM-III from Dosilab (former Comet AG, Swiss),
- 12 units with two rack-chargers APD-Light;
EPD MK2 from Thermo Fisher Scientific (former Siemens AG, Germany), 21 units.

**ComDos EDM-III [3, 4, 5]**
The dosimeter measurement energy range is from 20 keV to 1.5 MeV for photons (Gamma and X-ray) and from 60 keV to 6 MeV for the Beta radiations, in accordance with the IEC-61526:2005-02 standard. On the APD display the current values are shown in alternation for
deep dose (Hp10), shallow dose (Hp0.07), deep dose rate (Hp10/h), shallow dose rate (Hp0.07/h) and person ID. Furthermore, the LEDs show alarm situations such as low battery or that an exposure over the set alarm level occurred. The dose range is from 1 μSv to 10 Sv with an resolution of 1 μSv. The dosimeter is able to store up to 50 exposures with at least one minute between two exposures. If two exposures come within one minute they are counted as one and the doses are added. The accordance to the IEC standard guaranties that the dosimeter is working at dose rates up to 1 Sv/h but according the manufacturer they are working at dose rates up to 8 Sv/h.

**EPD Mk2 [6]**
The energy range of the EPD Mk2 system is from 15 keV to 6 MeV for gamma and X-ray radiation. The dose range is from 1 μSv to 10 Sv with an resolution of 1 μSv. The dosimeter is able to store between 250 and 348000 exposures with at least two seconds between two exposures. The dosimeter is working at dose rates up to 4 Sv/h according to the manufacturer.

To qualify the EPD systems for the very short exposure pulses during X-ray examinations water phantom measurements were made comparing the dose measured by the EPD systems with the dose measured with an ionisation chamber and thermo luminescence dosimeters (TLD).

**TLD XD-700**
The thermo luminescence dosimeter from the LPS Berlin has an energy range from 15 keV to 3 MeV and an dose range from 50 μSv to 10 Sv.

**Ionisation chamber STEP RGD 27091**
The energy range of the ionisation chamber is from 6 keV to 7.5 MeV and the dose range is from 0.01 μSv to 2 Sv.

The comparison showed that the ComDos EDM-III dosimeters are working without any correcting factors in very good correlation to the TLD and the ionisation chamber up to dose rates of 4 Sv/h. The EPD Mk2 dosimeters needed correcting factor of 1.1 for X-ray tube voltage below 70 kV and the correlation was good only up to 1 Sv/h dose rate.
One of the major goals was the measurement of realistic exposures during normal clinical investigations of pets (mainly dogs and cats) and bigger animals like horses. The undisturbed use of dosimeters during the X-ray investigation for the veterinary staff had to be assured. All persons present during the X-ray examination had to be prepared with EPD at representative positions (Fig. 2). Possible wearing positions were head, thyroid gland, thorax, gonads, hands (or cassette mounting) and feet.

For some positions during certain examination methods it was not possible to use the EPD, either because of the too high dose rate or because the EPD was disturbing the workflow. In those cases we had to perform measurements with dead animal phantoms and TLD dosimeters (Fig. 3).

For all X-ray examination methods separated by the type of animal (pet or horse) the methods were described including the positions of the staff (example see Fig. 4).
Altogether 42 large animal (mainly horses) X-ray examination methods and 59 small animal (pets) X-ray examination methods were considered. In addition the data of 64 different X-ray examination methods was collected during the measuring campaign at four veterinary surgeons (mainly horses, some pets). For the large animal X-ray examinations the staff had three different jobs. The animal keeper holds animal, the cassette holder holds the X-ray cassette with a support and the X-ray shooter who activates the X-ray beam (Fig. 4).

For the pet X-ray examinations only two persons are involved. The main person holds and fixes the animal on the X-ray examination table and sometimes also the helping person (Fig. 5).

**Fig 3:** Example of dead animal phantom. Shown are also different dosimeters at different wearing positions with the measured dose.

**Fig 4:** Example of X-ray examination method of horses showing the positions of staff and there distances to the backscattering animal part.
3 DATA ANALYSIS AND CONSTRUCTION OF THE „JOB-EXPOSURE-MATRIX“

Between March 2006 and January 2007 altogether data from 1374 investigations in the involved large animal hospital of the FU Berlin (Fig. 6) and 2739 investigations in the involved small animal hospital of the FU Berlin were collected. Thus the desired statistics of 1000 investigations with large animals and 1000 investigations of small domestic animals could be achieved.

![Case numbers of examination methods at the veterinary clinic for horses, general surgery and radiology at the FU Berlin (GTK)](image)

Fig 6: Case numbers of X-ray examinations at the large animal hospital of the FU Berlin
All the results were collected in two Microsoft Excel documents, one for the large animals (horses) and one for the pets (mainly dogs and cats). Both Excel documents have several tables with one called the “Job-Exposure-Matrix”. The “Job-Exposure-Matrix” (JEM) shows for each X-ray examination method in one row (Fig. 7) the minimum, maximum and mean value of the X-ray tube parameters (high voltage [kV], milliampere-seconds [mAs], exposure time [ms]) for all staff members and dosimeter wearing positions the number of acquisitions, the minimum, maximum and mean value of measured doses $H_p(10)$ or $H_p(0.07)$ in [$\mu$Sv]).

By default the matrix is showing all results but it is possible to choose certain X-ray examination methods or certain dosimeters, animal sizes and considered veterinary hospitals.

All the specified doses in the JEM are personal deep dose equivalents $H_p(10)$ in [$\mu$Sv], measured with EPD’s worn above the lead apron.

![Fig 7: Part of the “Job-Exposure-Matrix” for large animals (horses).](image)

With the help of the JEM it is now possible to estimate the average dose per year (or for other time periods) for a person who is working in the field of veterinary X-ray diagnostics. Because of the large data base of more than 50,000 measured doses the representativeness of the results is high and the estimated dose is reliable.

The JEM is a powerful tool to support radiation protection purpose in the field of veterinary X-ray diagnostics. The veterinary X-ray diagnostics represents a special range where beside the technical personnel also the auxiliary personnel falls under the radiation protection.
regulations. Differently than in the human medicine in the veterinary medicine for most X-ray-diagnostic methods staff has to be present during the X-ray examination to hold the animal patient.

The good estimation of the dose during veterinary X-ray diagnostics might help to protect the X-ray staff from exceeding dose limits and to point out that the use of radiation protection equipment is obligatory in all cases.

4 REFERENCES

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