A Survey of X-Radiation Exposure *in the* Practice of Veterinary Medicine

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THE occasional appearance among veterinarians of cases of radiation exposure resulting in permanent disability of the hands has given rise to considerable speculation concerning the role of radiation as an occupational hazard of that profession. Nowhere have we seen this conjecture supported by a systematic study of actual radiation exposure conditions encountered in the practice of veterinary medicine. In keeping with the established program and policies of the radiological health program of the New Jersey State Department of Health this study has been developed to meet this need.

We did not construct our sample of New Jersey's veterinary population with an objectivity that would warm the heart of a rigorous biostatistician. We simply wrote to the approximately 350 licensed veterinarians in the State, described the field survey we wished to make, and invited their participation. We received favorable replies from 61 animal hospitals. We have no way of knowing the exact number of veterinary X-ray installations in New Jersey, but we have fair reason to believe that 61 represents about one-half. If the 61 typify the profession with respect to X-ray usage, then our survey findings will be representative of prevalent conditions. It is necessary to express a word of caution in this respect. It is quite possible that those who replied may be the ones who are most apprehensive of the harmful effects of radiation; they consequently may use radiation equipment less frequently and with more caution than the veterinary population as a whole. To the extent that this is true our estimates of radiation exposure will be in error and, unfortunately, not in a conservative direction.

One advantage of this invitation approach to the survey was that all of the participants were happy to see us and were cooperative and hospitable. Many were amazed that the New Jersey State Department of Health offered such a service. All inquiries were answered frankly, even such questions as, "I see you have leaded aprons and gloves, Doctor, but do you wear them?"

In all, we visited 54 animal hospitals out of the 61 replying. The facilities are used by about 90 veterinarians. Our survey personnel made joint visits to the first six hospitals to assure the use of standard procedures in later surveys. We sought in these visits information on the type of X-ray facilities used, the

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frequency and manner of their use, protective devices and techniques, and the expected radiation exposure of the veterinarian and his assistants.

Facilities and Their Use

Of the 54 animal hospitals surveyed, 33 use radiographic X-ray alone, that is, no fluoroscopy. The majority of the veterinarians visited have fluoroscopic equipment also but never use it. The principal reason given for disuse was fear of excessive radiation exposure. Some men also asserted the value of having a permanent record of all radiographic examinations. Eight of the 54 hospitals use fluoroscopy only. Veterinarians at those hospitals praised the versatility of fluoroscopy and the saving of the time and expense required for taking and developing X-ray pictures. The remaining 13 hospitals employ both techniques.

Only two of the hospitals surveyed use the X-ray machine for therapy, but several other veterinarians expressed the intention of employing their equipment for this purpose in the near future.

About three-quarters of the X-ray units surveyed have a maximum current setting of 15 milliamperes and a peak voltage setting of 80 kilovolts. Three machines have unvariable settings. The remainder, consisting generally of newer machines, permit either 30 ma. or 50 ma. maximum current.

Only one hand fluoroscope was discovered. Happily that murderous device is retained by its owner for its antiquarian value only.

We have estimated from the data given us that the average frequency of use of the X-ray machine by veterinarians in this study is about 5 times a week. The average use of fluoroscopy is probably 2 to 3 times a week, with a weekly viewing time of perhaps 20 to 30 seconds. Far beyond all other factors, infrequent use of the equipment tends to keep veterinarians' exposure to radiation within accepted limits. Many of the techniques observed, if employed by a full-time radiologist or in a busy X-ray clinic, would create gross overexposure of personnel. If the X-ray usage by any veterinarian substantially exceeds the average found in this study, then, of course, he is more likely to receive greater exposure.

Protective Devices

All but two of the veterinarians visited have leaded aprons and gloves. About one-fourth, however, admitted that they seldom if ever wear them. Many times only one apron is available even though both the veterinarian and an assistant are simultaneously exposed. The gloves are worn less frequently than the apron. The veterinarians asserted that the bulkiness of leaded gloves makes positioning of a small animal, and palpation during fluoroscopic examination, difficult if not impossible.

In approximately one-fourth of the installations surveyed, a partially or completely lead-shielded cabinet is provided below the table to house the X-ray tube during fluoroscopy. The remaining three-fourths of the hospitals visited use an unshielded cabinet or, more frequently, an ordinary open table. In five study cases the veterinarian has provided himself with a lead shield behind which he stands when the machine is in operation. In only one instance is the X-ray remotely operated from a fully shielded control room.

One-fifth of the machines surveyed either have no external cone, or the cone used is so large that it is completely ineffectual from the point of view of protection. The principal reason for coning in most X-ray installations is to prevent avoidable scatter which tends to fog the X-ray film. However, under the conditions of use that prevail in most veterinarians' offices, coning is of considerable importance in minimizing radiation exposure to the operator. The difference in exposure with and without proper coning is described under the category "exposure estimate."

Somewhat the same point can be made concerning X-ray filters; they are useful in preventing unnecessary exposure to the operator although this is not usually their essential purpose. A filter removes from the useful beam X-rays of such low energies that they will not penetrate tissue to reach the film anyway. In X-raying humans, filtration is employed to limit useless exposure of the patient. In veterinary radiography, filtration reduces exposure of the operator since he is close to and occasionally within the direct beam. X-ray tubes possess some inherent filtration, a quantity we were unable to measure. For the great

majority of X-ray tubes inherent filtration is not adequate. We are inclined to recommend the addition of a least 1 mm. aluminum external filtration for all tubes.

In 2 of the 21 survey hospitals that use fluoroscopy, a leaded rubber curtain, suspended from the screen to the table top, shields the viewer from scatter radiation.

Techniques

The great majority of veterinarians anesthetize most of the animals before X-raying them. In many instances, however, anesthesia is omitted if a picture is to be made of an extremity of a docile, controllable animal. Neither is it used when the animal's health is considered too precarious to support the toxic effects of the anesthetic. In some of these latter instances the animal is narcotized. These practices simplify but do not eliminate the holding of the subject in the hand. Even if the animal is asleep or narcotized, in almost all cases someone holds it in the proper position for the desired picture. A small minority of the veterinarians use sandbags and other props for positioning the animal. Some men request the owner to hold the cat or dog, on the theory that one-time exposure for the owner is far less objectionable than repeated exposure for the veterinarian and his technician or handler. Of course, in many instances the animal is left at the doctor's office for diagnosis and treatment, and the owner is not present when the X-ray is taken. The majority of animals are manually positioned by the veterinarian or his employee.

One disturbing observation made in the field visits is the lack of standardization in the selection of various X-ray factors such as current, voltage, time, and distance. It is, of course, understood that some variation of these factors is possible without sacrificing picture quality but surely not to the extent encountered.

Among the veterinarians the distance from tube target to the film varies from 20 inches to 36 inches; in virtually all installations the dimension, once selected, is never varied. Differences in voltage, current, and time selections for comparable radiographs are considerable. Radiation dose delivered to animals for pictures of equivalent tissue depth may range from 100 to 500 milliroentgens. This disparity is reflected in such variation of picture quality that some operators are obviously not gaining the full advantage of X-ray as a diagnostic aid. The art of obtaining maximum picture definition and contrast is not in our province, and, generally, we scrupulously avoided offering recommendations in this connection. However, X-ray factor selection is in our field of interest when improper settings require two or more X-rays where one would suffice, and when the delivered X-ray dose is considerably larger than is required for good picture quality.

The procedure usually employed in changing the voltage and current to new settings for different tissue thicknesses makes our attempts to determine average equipment usage highly unrealistic in many cases. An X-ray machine may be operated to an extent equivalent to 4, 5, or more exposures in the process of adjusting the current and voltage to desired levels. In only three instances the operator was observed to push the X-ray tube down flush with the table surface of a completely shielded fluoroscope cabinet so as to contain radiation issued during test procedure. As mentioned earlier, many installations are not equipped with such a cabinet; in these cases testing simply adds to the weekly X-ray workload.

Exposure Estimate

In all of our regular field appraisals of radiation exposure, we are guided by the recommendations of the National Committee on Radiation Protection, published in handbooks of the National Bureau of Standards. For persons occupationally exposed, the committee has suggested a maximum permissible radiation dose of 300 mr. a week for irradiation of the whole body and 1,500 mr. a week for irradiation of the hands alone. These maximum levels are generally accepted in the field of radiological health.

On all our field visits in this study and elsewhere, we have insisted that no one should feel cheated if he does not get his allowable radiation dose for the week. All ionizing radiation produces tissue destruction; some of this destruction is irreversible. The concept sup-

porting a maximum permissible dose is that cumulative tissue damage is not likely to be appreciable in the course of a man's life if exposure is kept below this limit. However, the pathological effects of radiation are not precisely predictable. Nor can we know with any certainty in what manner or to what extent the genetic effect of radiation can or will transmute the progeny of exposed persons or, in turn, their offspring. These doubts support the contention that all unnecessary radiation exposure is excessive.

To corroborate the exposure determinations made by instrument survey, we distributed to all participating veterinarians and their technicians radiation-monitoring film badges to be worn when using the X-ray machine for, in most cases, two consecutive 1-month periods. It was our intention to obtain a measure of actual radiation dose received by veterinarians under typical operating conditions. For the time that the badges were worn, each veterinarian was requested to keep a complete record of the exposure time and factor settings on his machine. The results of the film badge project were provocative if not completely satisfactory. We feel that this useful procedure should be carried on for a longer survey period, personnel and equipment permitting.

Badges were lost. Some veterinarians neglected to wear their badges when using the X-ray machine. So much delay was encountered in getting the veterinarians to return the badges that many badge readings are considered unreliable. In all, 161 badges were processed by a commercial contractor. Allowance was made for the energy dependence of film in converting densities to radiation exposure. The following table gives the exposure in milliroentgens per month:

Milliroentgen/month range	*Number of badges*
0	64
1–100	62
100–200	14
200–500	11
500–1,000	3
1,000–2,500	3
Over 2,500	4
Total	161

The film data show that most of the veterinarians participating in this study at the time they were monitored did not receive, on the average, a weekly radiation dosage in excess of the generally accepted limit of 300 mr. Seven badges of the 161 showed a weekly exposure of more than a 300 mr. One man received a monthly dosage of 30, 1.7, and 2.5 roentgens for three consecutive months. Another man using the same machine received 2.6, 5.3, and 0.3 roentgens for the same monthly periods. Our inspection revealed that the machine had no cone and was employed to an extent considerably in excess of the average usage in this survey.

In general, we are reluctant to accept the preceding data as descriptive of exposure conditions in the practice of veterinary medicine. Since individuals often forgot to wear the badge, and in most cases when worn it was clipped near the left breast pocket, we feel that badge readings tended to indicate a minimum possible exposure. We consider the information obtained by instrument survey to be more reliable.

We made three types of radiation measurements in the instrument survey: direct beam radiation doses, scattered radiation dose in the operator's position, and radiation rate at selected sites in the vicinity of the machine. A Victoreen Condenser-R meter and a Tracerlab-SU-1F were used for these measurements.

If a man standing immediately adjacent to the X-ray table operates a properly coned X-ray tube at 70-kv. peak and 15 ma. in radiography, he will receive, on the average, scattered radiation amounting to 3–5 mr. per second. If the tube is not coned he is likely to receive 10 times this dose, or 30–50 mr. per second. If his hands are in the direct beam, they will receive approximately 250 mr. per second. If the table is not shielded and the operator stands next to it, as did the majority of the veterinarians observed, his feet are likely to be within the direct beam, receiving an exposure of approximately 50 mr. per second.

Using the X-ray without proper coning, employing an unshielded table, and holding the animal with the hands in the direct beam are the three conditions which cause the most severe exposure in veterinary radiography. If these practices were avoided, approximately

fifty 1-second exposures per week could be made before the operator's exposure reached the limit of 300 mr. It should be emphasized that these are typical values as measured in a number of veterinary radiographic installations and cannot be considered to apply to all radiographic installations, veterinary or otherwise.

In operating a fluoroscope at 60-kv. peak and 5 ma., scattered radiation in the position of the viewer is approximately 1 mr. per second. If the hands are introduced into the direct beam after subject absorption, to move or palpate the animal, they will receive a dose of about 250 mr. per second. Three veterinarians informed us that their hands had received a disabling dose of radiation. They attributed the exposure to work done in years past with bare hands under the fluoroscopic screen.

In 10 installations the inadequacy or lack of coning permitted the direct radiation beam to overlap the screen and strike the face of the viewer. In such a case approximately 2 seconds of viewing will cause radiation exposure in excess of the suggested limit for the week.

Radiation rate measurements made at the operator's knee level during fluoroscopy reveal scatter radiation of approximately 2,500 mr. per hour. For those installations with a shielded cabinet, this level is about 5 mr. per hour, indicative of a reduction by a factor of 500. Dose readings made on the operator's side of a leaded rubber curtain suspended from the fluoroscopic screen were virtually zero for 10 seconds of viewing time.

Although other radiation measurements were made for various types of machines and conditions of operation, the data gleaned are too detailed for suitable presentation in a summary report. Some mention should be made, however, of the relationship of exposure and the use of leaded aprons and gloves. It is difficult to state with any accuracy the degree of protection afforded by these garments. If they contain one-half millimeter of lead, they will reduce the high energy component of 75-kv. peak X-ray by a factor of 7 to 10. They will exclude the lowest energy component. Their net effect upon a radiation beam of mixed energies, such as is produced by an X-ray machine, is to provide a reduction in exposure by a factor of more than 100.

Any exposure an X-ray operator receives as a result of failing to wear a leaded apron is both avoidable and useless and is excessive in the purest sense of the word.

Summary Recommendations

For veterinarians employing X-ray and fluoroscopic equipment under average conditions of workload and use encountered in this survey (less than 10 milliampere-minutes per week), we have the following recommendations:

- Always wear a leaded apron when using the X-ray or fluoroscope.
- Wear leaded gloves when hands are in the vicinity of the direct beam.
- When possible, anesthetize subject animals and use props to position them for radiography.
- Restrict radiation dose to the lowest level consistent with good picture quality and screen image visibility. Dark-adaptation of the operator's eyes will aid the latter.
- House the X-ray tube in a shielded cabinet for fluoroscopy.
- Suspend a leaded rubber curtain from the fluoroscopic screen to the table top on the side where the viewer stands.
- Always use a cone or diaphragm that will restrict the useful beam to the film size used.
- Never hold the animal to be radiographed with hands in direct beam.
- Provide at least a 1-mm. aluminum external filter for all X-ray tubes.
- When testing for desired factor settings, push the X-ray tube down flush with the table surface of the shielded fluoroscope cabinet.
- Provide a cone or diaphragm for fluoroscopy that will give an unilluminated area at least one-quarter inch wide around the entire periphery of the screen. Fix the motion of the screen to the tube in order to prevent removal of the screen from the direct beam.