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Morphological study on abdominal organs of healthy cats using omnidirectional radiography and fluoroscopy

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다각도 방사선촬영 및 투시법을 이용한 정상 고양이 장기의 형태학적 연구

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초 록 : 형태학적으로 가장 효과적인 X-선 촬영 및 투시각도를 연구하기 위해서 전방향 방호X-선기와 소동물용 360° 회전형 보정장치를 이용하여 고양이의 복부장기를 대상으로 방사선 투시와 촬영을 병행하여 조사하였다. 조사한 장기는 횡격막, 간, 위, 결장, 비장, 신장이였다. 본 연구에서 얻어진 결과는 다음과 같다.

1. 횡격막은 30°에서 90° 각도 사이에서 가장 선명한 결과를 얻을 수 있었다.

2. 간의 좌엽과 중간엽은 수평면의 60° 각도에서 관찰된 반면, 우엽은 수직면의 60° 각도에서 관찰되었다.

3. 위는 우측 30° 각도 복-좌배사면과 좌측 60° 각도 배-우복사면에서 가스가 존재할 때 특히 잘 관찰되었다.

4. 결장은 수평면의 30° 각도 이상에서는 자세히 관찰되었다.

5. 비장은 복배면과 우측 60° 복-좌배사면사이와 배복면과 좌-우외측면 사이의 각도에서 잘 관찰되었다.

6. 신장의 배쪽면과 등쪽면의 경우 수평면의 30°각도에서 가장 잘 관찰되었다.

7. 이상의 결과를 종합해 볼 때 본 연구의 결과는 고양이 각 장기의 이상유무 분석에 유용하게 사용될 것으로 판단되었다.

Key words : abdominal organs, cat, radiography, fluoroscopy.

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Introduction

X-ray diagnosis has already established its indispensable position in the veterinary clinical field, specially for small animals, same as that in the human medical field. However, in the small clinic, although radiography in two orthogonal directions has been employed in general, X-ray fluoroscopy and radiography in oblique have been avoided as far as possible considering safety of persons who retain animals being exposed to X-ray beams.

Recently, Nakagawa *et al*[1]. developed an apparatus for omnidirectional protective fluoroscopy and radiography, as well as a 360° rotational retaining unit for small animals[2], thus, matters related to retention and exposure to X-ray beams have markedly been improved, in the same way as in the human field, fluoroscopy and radiography in oblique projection shall widely be applied for detailed examinations to various diseases of small animals.

However, as far as the authors aware, although usefulness of the oblique projection is described frequently[3,4,5], any report of the systemic study, namely, which organ can be detected by fluoroscopy and radiography with X-ray irradiation in what angle to the abdomen of cats, and so on, has not been found. Thus, in this study, the authors performed a basic morphological study referring to findings obtained by the omnidirectional fluoroscopy and radiography using clinically healthy cats.

Materials and Methods

Animals : Three hybrid adult cats raised in the Obihiro university of agriculture and veterinary medicine were used in the present study.

Retention of Animals : Animals were fasted from the previous day of the experiment test, and kept out of water on the day. They were anesthetized for 30 minutes before starting the test with 0.05 mg/kg atropine sulfate (atropine sulfate injection, Tanabe Ssiyaku Co., Ltd., Osaka) and 2.0 mg/kg of xylazine (2 % Celactal injection, Bayer Japan Ltd, Tokyo) by intramuscular injection, respectively, and after sedation, with 12.5 mg/kg of pentobarbital sodium (Nembutal injection, Dainippon Pharmaceutical Co., Ltd., Osaka) injected intravenously.

After anesthesia, an animal was fixed in the 360° rotational retainer for small animals[2] (hereinafter referred to as the retainer), and under the fluoroscope dorsoventral and ventrodorsal image were observed. After checking straight duplication of the vertebrae and sternum to confirm that the body is not twisted the animal was rotated for the left-right projection, and confirmation of the spine of scarpular being at the right angle with the corpus humeri, fluoroscopy and radiography were started.

Fluoroscopy : For fluoroscopy, a unit of omnidirectional protective fluoroscope and radiograph for small animals[1] (MMS-105, Hitachi Medical Corporation, Tokyo, hereinafter referred to as the X-ray apparatus) was used. Fluoroscopy was started under automatically set conditions (0-100 KV, 0-320 mA) in the state that the cat is retained in the right lateral recumbent position in the retainer, together with radiography in anticlockwise rotations of the animal viewing from the head side.

Pictures were recorded during the test using a video tape recorder (S-VHS Video Cassette Recorder, NV-FS 850, Matsushita Electric Industrial Co., Ltd., Tokyo) into the video tape ((S-VHS Video Tape, XA 120, TDK Corporation, Tokyo) for later studies.

Radiography : For radiography the same apparatus used for fluoroscopy was used. Since either cat had the similar configuration, it was performed under definite conditions at 58 kV in tube voltage, and 20 mAs in current-time product. For radiography, the cassette (Fuji Medical System Co., Ltd., Tokyo) with the rare earth intensifying screen (Grenex HR-3, Medical System Co., Ltd., Tokyo), and the grid at a grid ratio 5:1 (Anti-scatter grid mitaya, Tokyo), as well as the orthotype X-ray film of 25.4 x 30.5 cm (Fuji medical X-ray film super HR-S, Fuji Photo Film Co., Ltd., Tokyo), were used. X-ray films were developed both in high contrast using the automatic developer (Tanaka mini auto-178, Tanaka Roentogen Seisakusho, Tokyo) and in ultrasoft contrast as reported by Sato et al[6].

X-ray film were made every 30° rotation having the left-right lateral projection in the right lateral recumbent position as the 0° the image. E. Positioning under Radiography and Description of Regions in Findings obtained from Fluoroscopy and Radiography. In this study positioning at each angle was indicated according to the report of Nakama[7].

Further, having the left-right lateral projection as the 0° image and the right-left lateral projection as the 180° ,the vertebral side was described as dorsal and the abdominal wall side on the bottom as ventral ,on monitoring pictures and X-ray films of the fluoroscopy and radiography within the range of 30°.

Further, as to 0° and 180° image within the range from 30° upto 90°, the vertebral side was described as vertebral. In addition, referring to pictures having that in ventrodorsal projection as the 90° image and in dorsoventral projection as the 270° image, the left side of the cat was described as left and the right side as right , accordingly.

Results

Finding incommon obtained from 3 cats used in this study by abdominal fluoroscopy and radiography are explained referring to respective organs.

Diaphragm : In the left-right lateral projection (hereinafter referred to as the 0° image; Fig 1), the diaphragm was noted in double lines dorsally, and the origin on both sides, i. e., the lumbar portions of the diaphragm were observed in the range from the 13th thoracic vertebra (hereinafter referred to as T13, the thoracic vertebrae as T in the same way) to the 1st lumbar vertebra (hereinafter referred to as L1, the lumbar vertebrae as L in the same way). Further, these dorsal lines of the diaphragm extended ventralward in the thoracic cavity inflating as a dome and joined at the position of postcava (5; hereinafter the number refers to that shown in figures) and ended at the xyphoid process of the sternum. The double diaphragm lines noted at the lumbar portion indicate the left and right crura. It was easily distinguished that the line on the head side is the left crus and that on the caudal side is the right crus, because gas in the fundus was found on the head side over one of the double diaphragm lines.

Further, at the position where at the left and right crura joined, the foramen of vena cava was observed. The diaphragm line anterior to the postcava formed a single line, but the central tendon was hardly distinguishable from the sternum. However, the origin and terminus of the diaphragm were noted moving within the range of about one thoracic vertebra according to respiration under fluoroscopy.

In the left 30° ventral-right dorsal oblique projection (hereinafter referred to as the 30° image; Fig 2), due to presence of gas in the fundus and shadow of the lung, the left crus was located cranialward and the right crus caudalward compared with the 0° image, which made both crura clearly distinguishable.

The line of left crus extended from the ventral side dorsalward within the range of T11 and T13 and its origin reached the lumbar vertebra one after that. Origin of the right crus was on the far ventral side of the psoas major and minor positioned on the ventral side of vertebrae, from T13 to L11. At the joint whereat the lines of left and right crus meet, there was the dorsal margin of postcava as if it continued to the right crus, and the spot whereat the line of postcava was not seen being covered by the highly X-ray absorbable liver, the vena caval foramen was observed.

In the left 60° ventral-right dorsal oblique projection (hereinafter referred to as the 60° image; Fig 3), the right crus made a line continued to the dorsal margin of postcava, while the left crus made a line crossing T11 and T12 in contact with the fundus. The diaphragm line inflating like a dome in the thoracic cavity was observed as a single line extending counter-dorsalward, but it was hard to distinguish the left and right crura. In the 60° image, the vena caval foramen was noted so as that in the 30° image.

In the dorsoventral projection (hereinafter referred to as the 90° image; Fig 4), the diaphragm was looked as a dome having the range from T9 to T11 as apex. This line of diaphragm mainly consisted anatomically of bilateral ribs and the central tendon. Postcava was located on the right side of cat, but the foramen of vena cava could not be seen clearly.

In the right 30° ventral-left dorsal oblique projection (hereinafter referred to as the 120° image; Fig 5), the line of right crus crossed over T10 to T13, and reached the right somatic wall. The left crus was on the caudal side of the right crus, having its origin located on the ventral side of the psoas major and minor positioned anterior to the lumbar vertebrae, T12 and T13. Postcava was crossing with the right crus on the countervertebral side of the thoracic aorta running parallel adjacent to the vertebrae, which however was unclear, and foramen of vena cava was undistinguishable either.

In the right 60° ventral-left dorsal oblique projection (hereinafter referred to as the 150° image; Fig 6), origins of the left and right crura were noted within the range from T 13 to L1, but positional relationship between the left and right crura, i. e., which one can be found on the head side, was indefinite. However, origin of the diaphragm line on the head side was arriving at its body of vertebra, and that of the diaphragm line on the caudal side was on the ventral side of the psoas major and minor located anterior to the body of vertebra.

Dorsal line of the postcava was in continuation with the right crus, enabling to distinguish the vena caval foramen. In the right-left projection (hereinafter referred to as the 180° image; Fig 7), same as in the 0 image, the line of diaphragm was noted double dorsally, and their origins, i. e., lumbar portions of the diaphragm were noted both within the range from T13 to L1. There lines of diaphragm were both inflated in dome-shape in the thoracic cavity extending ventrally, joined at the position of postcava, and terminated at the xiphoid process of sternum. At the position whereat the postcava crossed with the diaphragm, the foramen of vena cava was observed.

The diaphragm line anterior to the postcava was noted as a single line while the central tendon and the sternum were hardly distinguishable. In the right 30° dorsal-left ventral oblique projection (hereinafter referred to as the 210° image; Fig 8), too, origins of left and right crura were noted within the range from T12 to L1, but their positional relation was indefinite. Origin of the line positioned on the head side reached its body of vertebra, while that of the line positioned on the caudal side was on the ventral side of the psoas major and minor located anterior to its body of vertebra. Further, the dorsal line of the postcava was clearly noted being connected with the right crus, while the foramen of vena cava was easily distinguished.

In the right 60° dorsal-left ventral oblique projection (hereinafter referred to as the 240° image; Fig 9), nearly same as in the 60 image, the left crus was seen as a line crossing T12 to reach the left somatic wall, but the right crus was seen as a line continued to the vertebral margin of the postcava. The diaphragm line was inflated like a dome in the thoracic cavity extended countervertebralward as a single line, but the left and right crura were hardly distinguished. Further, the foramen of vena cava was observable.

In the dorsoventral projection (hereinafter referred to as the 270° image; Fig 10), nearly same as in the 90° image, the diaphragm was shaped liked dome having the range from T10 to T11 as apex. This diaphragm line apparently consisted of the central tendon and ribs on both sides anatomically. Postcava was on the right side of the animal, but the foramen of vena cava was noted clearly.

In the left 60° dorsal-right ventral oblique projection (hereinafter referred to as the 300° image; Fig 11), nearly same as that in the 120° image, line of the right crus crossed the range from T12 to T13 and arrived at the right somatic wall. The left crus was on the caudal side of the right crus, the origin of which being the ventral side of the psoas major and minor positioned anterior to T13 and L1. The postcava crossed the right crus on the countervertebral side of the thoracic aorta running adjacent to the vertebrae, but it was unclear and the foramen of vena cava was hardly distinguishable.

In the left 30° dorsal-right ventral oblique projection (hereinafter referred to as the 330° image; Fig 12), the right crus line reached a spot between T13 and L1. And the left crus line was on the caudal side of the right crus, being noted on the far ventral side of the psoas major and minor located anterior between T13 to L1. However, the dorsal line of the postcava was noted clearly in connection with the right crus, which the foramen of vena cava being easily distinguishable. Under the fluoroscope, according to rotations, the left crus moved headward over the right crus, which was noted clearer due to the presence of gas in the stomach.

Liver : In the 0° image (Fig 1), the liver was noted as a crescent region located between the diaphragm and the stomach, being settled in the costal arch. On the ventral side, the contour was noted clearly by the falciform ligament of the liver, but details of each lobe were hardly distinguishable. An acute angle region on the caudal side of the liver was anatomically the exterior left lobe. When a region with the clear border is noted on the far ventral side of the exterior left lobe, it was anatomically the interior right lobe. A region noted between the fundus of the stomach and the kidney was the posterior part of the exterior right lobe, but if the renal impression is not observed, it was hard to distinguish from the duplicated dorsal side of the spleen.

In the 30 ° image (Fig 2), the ventral contour of the liver was clearly noted by the falciform ligament of the liver, making it notable as the margin of the interior right lobe from the findings of the continuous fluoroscopy. Further, the contour of acute angle region noted on the dorsal side of the interior right lobe was identified to be the margin of the exterior left lobe from the findings upon fluoroscopy. In this angle the posterior part of the exterior right lobe was not was not noted clearly as it moved ventralward. In the 60° image (Fig 3), a somewhat unclear contour observed adjacent to the abdominal wall was the margin of the interior right lobe, without showing falciform ligament of the liver. Further, a margin of the acute angle region observed on the dorsal side of the interior right lobe was known to be the margin of exterior left lobe from the findings under fluoroscopy.

However, occasionally no contour to distinguish the interior right lobe from the exterior left lobe was noted in this acute angle region.

In the 90° image (Fig 4), there were the margin of left lobe on the left side of the animal adjacent to the diaphragm, and the margin of right lobe on the right side. Further, on the caudal side of the right lobe, the margin of renal impression on the posterior part of the exterior right lobe was observed in contact with the right kidney.

In the 120° image (Fig 5), the margin of renal impression on the posterior part of the exterior right lobe was observed as a contour in contact with the cranial end of the right kidney, but others such as margin of the liver and falciform ligament of the liver were hardly distinguishable.

In the 150° image (Fig 6), margin of the exterior left lobe was noted clearly as an acute angle region on the caudal side, and as the falciform ligament of the liver on the ventral side. Further, a contour of the renal impression was noted on the posterior part of the exterior right lobe in contact with the anterior end of the right kidney on the ventral side of L2, it means, the cranial end of the right kidney.

In the 180° image (Fig 7), findings similar to that of the 0° image were obtained, but in the 180 image the interior right lobe was noted always on the ventral side of the acute angle region on the caudal side. The renal impression on the posterior part of the exterior right lobe was hardly distinguishable in many cases in the 180° image.

In the 210° image (Fig 8), the anterior margin in the acute angle region on the ventral side of liver was the margin of the liver, and the posterior right lobe clearly distinguish by the falciform ligament of the liver, and the posterior margin was that of the exterior left lobe. There findings were confirmed by the continuous fluoroscopy. Renal impression on the posterior part of the exterior right lobe was noted unclear.

In the 240° image (Fig 9), similar to that of the 60° image, the falciform ligament of the liver was not observed. Further, the margin adjacent to the abdominal wall in the acute angle region of the caudal side was unclear but the margin on the vertebral side was that of the interior right lobe. In the 270° image (Fig 10), same as that in the 90° image, the left lobe margin was observed in contact with the diaphragm at left of the animal, while the right lobe margin was noted at right. Further, on the caudal side of the right lobe, the margin of renal impression on the posterior part of the exterior right lobe was noted adjacent to the right kidney.

In the 300° image (Fig 11), same as that in the 120° image, the margin of renal impression on the posterior part of the exterior right lobe was observed as the margin in contact with the cranial end of the right kidney, but others such as margin of the liver and falciform ligament of the liver were hardly distinguishable.

In the 330° image (Fig 12), same as that in the 150° image, the margin in the acute angle region on the caudal side was the margin of exterior left lobe. Further, the margin of renal impression in the posterior part of the exterior right lobe was also noted in contact with the cranial end of the right kidney.

Stomach : Either of 3 cats used in this study had gas in the stomach, but one of them showed that only slightly in the fundus. Detailed morphological observation of the stomach was feasible due to the presence of gas therein, therefore, findings obtained from other two animals showing gas nearly in the whole region of the stomach are explained below.

In the 0° image (Fig 1), it was located in the costal arch adjacent to the exterior left lobe of the liver on the cranial side, and a line linking the fundus and the corpus as well as the pylorus (hereinafter referred to as the gastric axis) was noted parallel to the ribs. Since gas retains in the fundus and the corpus, the mucous membrane was observed in a clear shape. Further, the pylorus was noted adjacent to the acute angle region on the ventrocaudal side of the liver.

In the 30° image (Fig 2), the gastric axis was noted parallel to the ribs, the fundus in contact with T12 to L1, and the pylorus mearly duplicated with the corpus adjacent to the caudal region of the liver. Gas in the stomach increased more in the corpus compared with that in the 0° image. Under the fluoroscope gas in the fundus and the corpus gradually was nated moving to the pylorus according to rotations.

In the 60° image (Fig 3), the gastric axis was parallel to the right ribs, and the fundus overlapped from T12 to L1, which made the face of mucous membrane somewhat unclear. The pylorus was distinguished by the presence of gas in a little amount, without overlapping the corpus. Further, it was noted that the esophagus crossed the wall of fundus. Under the fluoroscope, images of gas in the corpus were noted moving toward the pylorus according to rotations.

In the 90° image (Fig 4), the gastric axis was parallel to the vertebrae, showing gas nearly in the whole area of the stomach, revealing almost clearly the mucosal membrane and walls in the whole area of the stomach. The fundus was located at left in the costal arch, and the pyloric side of the corpus was duplicated with L1 to L3 as well as the transverse colon. The pylorus was noted adjacent to L2 and L3.

In the 120° image (Fig 5), the gastric axis was parallel to the vertebrae, and on the caudal side in the costal arch the fundus and cardiac side of the corpus were observed, while out of the costal arch the pyloric side of the corpus as well as the pylorus were noted. Much of gas was noted in the pylorus, specially at the transitional area from the corpus to the pyloric antrum showing it as a radiolucent region. Under the fluoroscope, up to the 120° image, gas was noted nearly in the whole area of the stomach, but gas in the fundus decreased exceeding 120°.

In the 150° image (Fig 6), the gastric axis was parallel to the costal arch, and the corpus and the pylorus were observed in duplication. Gas in the fundus reduced, specially at the transitional area from the corpus to the pyloric antrum, same as that in the 120° image, it was noted as the radiolucent region.

In the 180° image (Fig 7), nearly same as that of the 150° image, the gastric axis was parallel to the costal arch, showing the corpus and the pylorus duplicated. The region specially with high radiolucency among those gas images was noted at the transitional area from the corpus to the pyloric antrum. Further, gas in the fundus observed in the 0 image moved apparently to the pylorus.

In the 210° image (Fig 8), being different from the 30° image, gas was observed in the pylorus due to its movement in the stomach, and it was also noted in the fundus unlike that in the 180° image without showing its presence. Gastric axis was parallel to the costal arch, and the corpus overlapped the pylorus.

Under the fluoroscope, reduction of gas in the corpus was observed in according with rotations. In the 240° image (Fig 9), the gastric axis was parallel to the right ribs, and being nearly same as that in the 60 image, the fundus overlapped T13 and L1, but gas in the corpus was reduced. The radiolucent region not noted in the 210° image was observed in conformity with the transitional area area from the corpus to the pyloric antrum. Further, the esophagus was crossing the wall of fundus.

In the 270° image(Fig 10), same as that in the 90° image, the gastric axis was parallel to the right ribs, and the fundus only was observed in the costal arch. However, reduced gas in the corpus was less than that noted in the 90° image, showing no duplication with the transverse colon any more.

In the 300° image(Fig 11), same as that in the 120° image, the gastric axis was parallel to the vertebrae, and the fundus was noted within the costal arch. However, compared with the 120° image, gas remained in the corpus was a little, while gas in the fundus increased. Under the fluoroscope, upon further rotations upon 330° image, gas in the corpus moved to the fundus, disappearing from the corpus.

In the 330° image(Fig 12), same as that in the 150° image, the gastricaxis was parallel to the costal arch, but in the corpus gas was not noted, being shown as a uniform radiopaque region. In the fundus and the pylorus, gas was noted, specially, it was not found in the 150° image, but in the 330 image. Under the fluoroscope, gas was observed counterflowing from the pylorus to the fundus. The corpus was noted as a uniform, highly X-ray absorptive region.

Large intestine : In the 0° image(Fig 1), running of the colon was noted clearly due to gas retained therein, but as curvatures, they were individuals showing both transitional areas from the ascending colon to the transverse colon as well as that from the transverse colon to the descending colon(hereinafter referred to as the one with 2 transitional areas observable), and those showing the transitional area from the transverse colon to the descending colon only (hereinafter referred to as the one with 1 transitional area observable). In either case, the ascending colon and the descending colon ran close each other, and the part of reversed running was located closest to the anterior. Such reversed part differed by running of the transverse colon individually, and in case of the one with 1 transitional area observable, it was the transitional area from the transverse colon to the descending colon. In the region of L4 and L5 on the caudal side of the ascending colon, there was an area with a small amount of gas in irregular form, which was considered to be anileocolic junction. The rectus was hardly observable when gas and feces were not present, as it was running in the pelvic cavity.

In the 30° image(Fig 2), compared with the 0° image, a distance on the film the ascending colon to the descending colon was extended, and that noted most anterior among those colons was transitional area from the ascending colon to the transverse colon(2 transitional areas observable) or the transitional area from the transverse colon to the descending colon(1 transitional region observable).

In the 60° image(Fig 3), the ascending colon was noted adjacent to the right abdominal wall, and most part of the descending colon was duplicated with L3 and further.

In the 90° image(Fig 4), the transitional area from the transverse colon to the descending colon was crossing L3.

In the 120° image(Fig 5), the ascending colon crossing the lumbar vertebrae toward the left cranial side from the ileocolic junction of the cat was noted, and the transverse colon (2 transitional areas observable) or the descending colon reversed at the transitional area from the transverse colon to the descending colon(1 transitional area observable) were running nearly parallel to the vertebrae.

In the 150° image(Fig 6), it was indefinite whether the ascending colon was observed anterior or posterior to the descending colon. Under the fluoroscope, according to rotations, gradually the ascending colon begin to be seen anterior to the descending colon.

In the 180° image(Fig 7), same as that in the 0° image, the transverse colon(2 transitional area observable) or the transitional area from the transverse colon to the descending colon(1 transitional area observable) was noted most anterior.

In the 210° image(Fig 8), the ascending colon was observed most anterior.

In the 240° image(Fig 9), same as that in the 60° image, the ascending colon was adjacent to the right abdominal wall, and most part of the descending colon was duplicated with the vertebrae from L3 rearward.

In the 270° image(Fig 10), same as that in the 90° image, the transitional area from the transverse colon to the descending colon was noted across the range from L2 to L3.

In the 300° image(Fig 11), same as that of the 120° image, the ileocolic junction was unclear due to duplication in the range from L4 to L5, and the ascending colon was crossing the lumbar vertebra toward the left cranial side of the cat. The descending colon reversed at the transverse colon(2 transitional areas observable), or the transitional area from the transverse colon to the descending colon (1 transitional area observable) were running parallel to the vertebrae, too.

In the 330° image (Fig 12), same as that in the 150° image, it was indefinite whether the ascending colon was observable anterior or posterior to the descending colon. Under the fluoroscope, according to rotations, gradually the ascending colon began to be seen anterior to the descending colon.

Spleen : In the 0° image(Fig 1), on the ventral side of the psoas major and minor in the region from T13 to L2 a dorsal part of the spleen triangie-shaped was noted being duplicated with the posterior part of the exterior right lobe of the liver.

Under the fluoroscope, according to further rotations, a state of separating form the posterior part of the exterior right lobe was noted clearly.

In the 30° image(Fig 2), the dorsal part in triangle shape, where in the dorsal side was duplicated with T13 to L2 and the cranial side was adjacent to the gas image in the fundus, was noted.

In the 60° image(Fig 3), the dorsal part in triangle shape, duplicated with L1 and L2 and adjacent to the left 12th or 13th rib, the left kidney, and gas images in the left kidney and the fundus, was noted.

In the 90° image(Fig 4), the dorsal part was observed as a triangle region encircled by gas images of the fundus and the corpus, as well as the left abdominal wall and the left kidney. Under the fluoroscope, according to rotations, the dorsal part adjacent to the left abdominal wall was noted moving gradually toward the center. Simultaneously, the region got between the dorsal and ventral parts continued from the dorsal part began to be clear gradually in contact with the left abdominal wall, and in addition, the region got between the dorsal and ventral parts as well as the ventral part became clearer gradually increasing its thickness from the region adjacent to the left abdominal wall.

However, in the individual, where in already in the 90° image the region got between the dorsal and ventral parts continued form the dorsal part and the ventral adjacent to the left abdominal wall, its thickness decreased by rotations.

In the 120° image(Fig 5), the dorsal side was noted as a triangle region adjacent to the fundus, while the region got between the dorsal and ventral parts crossing gas images in the fundus and the corpus, was running aside the left abdominal wall. Further, along the left abdominal wall up to the L7 region a uniform X-ray absorptive region was noted as the ventral part.

Under the fluoroscope, according to rotations the region got between the dorsal and ventral parts and the ventral part reduced its thickness gradually in the state in contact with the abdominal wall, from the side opposite to the abdominal wall.

In the 150° image(Fig 6), the dorsal part was unclear, and the region got between the dorsal and ventral parts and the ventral part were already subsided, or sometimes the ventral part was a little not able.

In the 180° image(Fig 7), different from the 0° image, the borders adjacent to the cranial end of the kidney, were the posterior part of the exterior right lobe, and the dorsal part of the spleen, but since the renal impression at the posterior part of the exterior right lobe was unclear, it was hard to distinguish the dorsal part, Under the fluoroscope, according to rotations the dorsal part was separated from the posterior part of the exterior right lobe. In the 210° image(Fig 8), the 240° image(Fig 9), and the 270° image(Fig 10), same as that of the 30°, 60°, and 90° images respectively on the opposite side, the dorsal part in triangle shape, was noted. Under the fluoroscope, too, according to rotations further than 270° in the same manner, the dorsal part adjacent to the left abdominal wall moved gradually to the center, and region got between got between the dorsal and ventral parts continued to the dorsal part was noted clearer gradually in contact with the left abdominal wall. Further, the region got between the dorsal and ventral parts and the ventral part become clearer gradually in creasing its thickness from the region in contact with the left abdominal wall.

In the 300° image (Fig 11), same as that in the 120° image, the whole of spleen was observed. Under the fluoroscope, in the same manner according to rotations, the region got between the dorsal and ventral parts and ventral part reduced its thickness gradually in the state adjacent to the abdominal wall, from the side opposite to the abdominal wall.

In the 330° image (Fig 12), different from the 150° image, the dorsal part was clearly observed as a triangle region in contact with the cranial end of the left kidney. Further, in the dorsal and ventral parts, the ventral part was noted reducing its thickness compared with that in the 330° image in duplication with the intestines, up to the L7 region adjacent to the abdominal wall, being unclear though. Under the fluoroscope, according to rotations the ventral part gradually reduced its thickness being adjacent to the abdominal wall from the side opposite to the abdominal wall, and disappeared before arriving at the position in the 0° image.

Kidney : In the 0° image (Fig 1), kidneys on both sides were positioned anterior to the psoas major and minor in the region from L2 to L4. When the renal impression of the liver was distinguished, both kidneys were distinguishable, as a bean-shaped shadow of the right kidney in conformity with the renal impression and a shadow of the left kidney in an elliptic shape unlike the right kidney. In the right kidney, a depressed part considered as hilum of the kidney and a radiolucent region considered as sinus of the kidney were observed clearly.

In the 30° image (Fig 2), the left kidney was noted as anelliptic shadow duplicated with vertebrae from L2 to L4, while the right kidney was observed as a bean-like shadow duplicated partly with the left kidney on the ventral side of the left kidney. In the right kidney sinus of the kidney was also noted.

In the 60° image (Fig 3), the left kidney was noted as a bean-shapes shadow duplicated with vertebrae from L2 to L 4, while the right kidney was noted without overlapping the left kidney, as a bean-shaped shadow duplicated with gas image of the transverse colon, together with sinus of the kidney. In the left kidney sinus off the kidney was noted on the spinal side but that in the right kidney was unclear.

In the 120° image (Fig 5), the right kidney was noted as a bean-shaped shadow duplicated with vertebrae from L2 to L 4, while the left kidney without overlapping the right kidney was noted as a bean-shaped shadow duplicated with the gas image of the transverse colon, together with hilum of the kidney.

In the 150° image(Fig 6), findings reversed in left and right compared with the 30° image were obtained. The right kidney was noted as an elliptic shadow adjacent to the ventral side of vertebrae from L2 to L4, while the left kidney was noted as a bean-shaped shadow partly duplicated with the right kidney on the ventral side of the right kidney.

In the 180° image (Fig 7), kidney on both sides were observed as bean-shaped shadows. The right kidney was located anterior to the psoas major and minor in the region from L2 to L4, and the left kidney was located on the ventral or caudal side duplicated with the right. In the right kidney hilumand sinus of the kidney were distinguishable, which was not feasible in the left kidney.

In the 210° image (Fig 8), same as that in the 30° image, the left kidney was noted as an elliptic shadow duplicated with vertebrae from L2 to L4, while the right kidney was noted as a nearly bean-shadow duplicated partly with the right was noted as a nearly bean-shaped shadow duplicated with vertebrae from L2 to L4, while the right kidney was noted as a nearly bean-shaped shadow duplicated partly with the left kidney on the ventral side of the left kidney.

In the 240° image (Fig 9), same as that in the 60° image, the left kidney was observed as a bean-shaped shadow duplicated with vertebrae from L2 to L3, while the right kidney without overlapping the left kidney, noted as a bean-shaped shadow duplicated with gas image of the transverse colon. However, outlines of both kidneys were not clearly noted.

In the 270° image (Fig 10), same as that in the 90° image, the kidneys on both sides were observed within the range from L2 to L4 in the symmetrical position having the vertebrae in between, as the bean-shaved shadows. In the left kidney hilum and sinus of the kidney were noted on the vertebral side, but they were not clear in the right kidney.

In the 300° image (Fig 11), same as that in the 120° image, the right kidney was noted as a bean-shaped shadow duplicated with vertebrae from L2 to L3 while the left kidney without overlapping the right kidney, was observed as a bean-shaped shadow duplicated with gas image of the transverse colon.

In the 330° image (Fig 12), same as that in the 150° image, the right kidney was noted as an elliptic shadow in contact with the ventral side of vertebrae from L2 to L4, while the left kidney was noted as a bean-shaped shadow duplicated slightly with the right kidney on the ventral side of the right kidney.

Discussion

As pathology causing positional changes of the diaphragm in cats, there are ascites, swelling of the liver, tumor in the abdominal cavity, gastric dilation, pneumothorax, hyperinflation of the lung, pneumatosis, asthma and so on.

In addition, the positional changes of animal organ can be made by physiological situation such as prenanccy, etc[8~10]. Further, by respiration, origin of the lumbar portion of the diaphragm is said to move as much as about one vertebra of the spine[8~10].

Anatomically, the diaphragm can be divided into lumbar portion, central tendon, costal portion and sternal portion[11~15], but in this study, too, it was difficult to see whole portions of the diaphragm from the conventional routine 4-directional radiograms (bilateral, ventrodorsal, and dorsoventral projections) and only by observation of the oblique image, firstly details of the whole portions can be grasped. It means that when the left and right crura in the lumbar portion are distinguished in the lateral projection, the crus on the film side is noted on the head side[9], which however was not always definite in this study, and that on the head side cannot be determined as the crus on the film side.

In this study the result was obtained using a retainer to keep the vertebrae of cat horizontally in a position straightly crossing the X-ray beams, thus, during the experiment in case of changing a direction of X-ray irradiation posture of the cat was not moved at all, and after rotating the retainer by 360° reproducible fluorograms and radiograms were obtained, which makes it confirmed.

It is frequently misunderstood that in the ventrodorsal and dorsoventral projections the left and right crura are clearly observed[9], but as known from the result of this study, these diaphragm shadows were not in conformity with the anatomical left and right crura but left and right costal portions of the diaphragm, thus, it was clarified in this study that the left and right crura are hardly observed under such directions of X-ray irradiation. Besides, in oblique images within the range of angle from 30° up to 90°, regardless of gas present in the fundus, easily the left and right crura were distinguished enabling to observe their shapes.

In the liver, numbers and degrees of signs appeared are said to be correlated with numbers of the lobe invaded or retracted and degrees of the liver inflated[5], therefore, in X-ray diagnosis for the liver, it is important to observe as many borders of the lobe as possible to see their shapes.

The exterior left lobe only, or the exterior left lobe and the interior right lobe, were noted in the left- right lateral projection (0° image), the conventional routine radiogram; the exterior left lobe and interior right lobe were noted in the right-left lateral projection (180° image); and the renal impression on the posterior part of the exterior right lobe was noted by the ventrodorsal projection (90° image) and the dorsoventral projection (180° image). However as the result of omnidirectional X-ray irradiation employed in this study, the exterior left lobe and the interior right lobe were noted in angles of 30° to 90° as well as 150° to 240°, wherein it was clarified that contour adjacent to the pylorus of stomach anatomically was the exterior left lobe and what anterior to that was the interior right lobe. Further, it was also clarified that the exterior right lobe can be seen in angles from 90° to 150°, and 270° to 330°.

In addition, swelling of the liver in many cases is evaluated by observing the border of the acute angle region on the anterior caudal side[3~5], but in case when both the exterior left lobe and the interior right lobe are observed simultaneously, the border is looked round as if the liver itself is swelling[4] for which sufficient care must be taken.

Simple X-ray diagnosis of the stomach is only feasible with the presence of gas therein acting as a negative contrast[3~5].

In this study, too, since the morphological observation was firstly feasible with a cat showing retention of gas in the stomach to a certain extent, it is necessary to use the retainer and to inject a certain amount of gas into the stomach before starting the test, when the result of this study obtained by the simple fluoroscopy and radiography on the stomach of healthy cats is applied clinically to the X-ray diagnosis.

Further, by rotations of the retainer always gas in the stomach moves upward, which makes it feasible to see the shape of moving area clearly.

The first purpose of this study is not an observation of the stomach morphology, but a part of morphological studies related to the organs in the abdominal cavity of the cat, thus movement of gas in the stomach was not taken into consideration from the beginning. Accordingly, the result obtained in this study is, as described under methods, a series of observations starting from the right lateral recumbent position, and shapes of the stomach was observed rotation the animal anticlockwise viewing from the head side. The way of such observation should have to be studied further. By this method, findings similar to those in the reports[3~5] stating that the corpus is duplicated with the pylorus in the lateral projection, and gas can be seen only at the fundus in the left-right lateral projection, or only at the pylorus in the right-left lateral projection.

Further, in the ventrodorsal and dorsoventral images gas was noted in the whole area of stomach, but being duplicated with the vertebrae, the transitional area from the corpus to the sinus of stomach and the pylorus are also duplicated usually with the vertebrae[16,4], which is important in cats smaller in angle of the incisura angularis[15] than that in dogs.

On the contrary in the 30° ventral-left dorsal oblique projection (120° image) and the left 60° dorsal-right ventral oblique projection (300° image), the stomach was not duplicated with the vertebrae. Further, every part of the stomach was not duplicated with each other showing gas both at the fundus and pylorus, which suggested that such oblique images are very useful to study the stomach.

Esophagus is said to be hardly confirmable with simple X-ray films, being pressed to closure except when meals are swallowed, and having the same concentrations as that of the adjacent tissues in the neck and mediastinal septum[3~5]. However, in this study, running of the esophagus was noted even by the left 60° ventral-right dorsal oblique projection (60° image) and the reversed right 60° dorsal-left ventral oblique projection (240° image), in addition to approximate position of the cardia. For the diagnosis of occlusion at the transitional area from the esophagus to the stomach as one of the primary disease in esophageal palsy, for instance, occlusion of the transitional area from the esophagus to the stomach, gastroesophageal invagination, and hiatal hernia[3~5], such oblique projections are considered to be useful.

In cats, the transitional area from the ascending colon to the transverse colon dose not exist anatomically as a curvature[13]. In this study, too, there were some animals showing that running of the colons can be noted only as a curvature simply connecting the ascending and descending colons. Since gas exists generally in the colon[4], and the transverse colon is noted most anterior in the lateral projection[13], occasionally the reversed part is misunderstood as the transverse colon. In this study the area noted most anterior was confirmed to be the descending colon by continuous fluoroscopic observations. Further, in an individual wherein the transitional area from the ascending colon to the transverse colon as well as that from the transverse colon to the descending colon were apparently noted as curvatures, running of the transverse colon being nearly in confirmity with the direction of X-ray beams within the range of ±30° from the lateral projection, the transverse colon was noted as a radiolucent round region.

As to the spleen there reports available stating that in lateral projections the anterior part of the spleen in a semicircular shape is found on the bottom of abdomen on the caudal side off the liver[3,5], and that such is not observable[4]. In either cat used in this study the spleen was not noted on the bottom of abdomen, and under lateral projection in the region between the fundus and the kidney, dorsal part of the spleen duplicated with posterior part of the exterior right lobe was noted. On the contrary, in the ventrodorsal and dorsoventral images as reported so far[3~5], the dorsolateral part was observed clearly. One of the reasons is considered to be difference in the mode of retention. It means that according to the conventional manipulation when the ventrodorsal and dorsoventral radiations are employed, the anterior and posterior limbs of the test animal are somewhat stretched to the front and rear to have his spine observed straightly on the film, which makes its posture nearly same as that retained in the apparatus used in this study. However, generally in case of manipulation for lateral projections the extremities are not drawn forward and rearward but suspended perpendicularly from the body in a retaining position similar to that far ECG. On the contrary, when the retainer is used, animals are retained in the completely same position as that for the ventrodorsal and dorsoventral projections. It cannot be determined with the result of this study only, but it is the known fact that for radiography it should be filmed at least in 2 directions, and be diagnosed with a knowledge on conformation of the organ tissues. However, if findings obtained from such 2 directional radiography of an animal retained in different postures, the diagnostic value is markedly spoiled, on which the result of this study is considered to suggest many useful findings.

In this study, the spleen was observed as a whole by the 90° image to the right 60° ventral-left dorsal oblique projection (150° image) as well as by the 270° to 0° image, specially in the 120° and 300° images it was noted clearly in either animal. Accordingly when the spleen is X-ray diagnosed making use of this retention method, its special usefulness in observation of these oblique images is suggested.

As to the kidneys, their normal capacity has been evaluated by means of measuring kidney diameters in the ventrodorsal image, wherein the craniocaudal diameter of the kidney is compared with the 2nd lumbar vertebra, being 2.5-3.0 times greater than L2 in the normal kidney of cats[3-5].

However, since size of the normal kidney ranges widely, it is infeasible to evaluate courses of all renal diseases based on changes on size of kidney[3-5]. Morphological changes of the kidney can be used as the more useful pathological index compared with changes in size of the kidney. Because the change of normal bean-shaped kidney is important, it is necessary to watch carefully whether such change of formation gives effects on a small part of the kidney (locally), or invades the whole organ (diffusively)[3-5]. Accordingly, the kidney should be studied in all aspects. In this study it was suggested that the kidney is moving around in the abdominal cavity, as shadows of the kidneys radiographed in two directions being orthogonal each other are those formed by irradiation in nearly the same angle. By rotations firstly different shadows, namely, the conventional bean-shaped one and the elliptic one, were noted. It means that both hilum and sinus of the kidney are observed with the bean-shaped shadow in many cases, but they are noted unclearly or unobservable with the elliptic shadow. Such findings are noted in the left 30° ventral-right dorsal oblique projection (30° image) and the 150° image as well as the right 30° dorsal-left ventral oblique projection (210° image) and the left 30° dorsal-right ventral oblique projection (330° image) on the opposite side, which suggests that observation of these oblique images is useful in X-ray diagnoses of the kidney.

Summary

To establish the method for the most effective radiography and fluoroscopy, the abdominal organs of cats were investigeted using omnidirectional angles with the center of the body as the axis using an omnidirectional protective shielding X-ray system and a 360° rotary restraint unit for use in small animals. The organs examined were the diaphragm, liver, stomach, colon, spleen and kidney. The results obtained in the present study were as follows:

1. Regardless of gas in the stomach present or not, it was feasible to distinguish the left and right crura in the lumbar portion of diaphragm in the oblique projection inclined over 30° and under 90° from the lateral projection.

2. Outlines of the exterior left lobe and the interior right lobe of the liver were observed in the oblique image inclined up to 60° from the lateral image, while that of the exterior right lobe was noted in the oblique image inclined up to 60° from the ventrodorsal-dorsoventral images.

3. It was necessary to have gas present in the stomach for detailed morphological observations of the stomach. It was most clearly observed in the right 30° ventral-left dorsal oblique projection(120° image) and the left 60° dorsal-right ventral oblique projection(300° image).

4. Morphology of the colon was observable in detail by

the oblique projection inclined over 30° from the lateral projection.

5. To observe the whole spleen it was required to have images from the ventrodorsal projection (90° image) to the right 60° ventral-left dorsal oblique projection (150° image) as well as those from the dorsoventral projection (270° image) to the left-right lateral projection 0° image).

6. Dorsal and ventral sides of the kidney were observable in the oblique images inclined 30° from the lateral image.

7. Considering above findings collectively, it was thought that the results of present study might be useful for the analysis of abnormalies in each organ of cat.

Legends for figures

Fig 1. Left-right lateral projection (0° image). The diaphragm was noted in double line dorsally, and the origin on both sides.

Fig 2. Left 30° ventral-right dorsal oblique projection (30° image). Presence of gas in the fundus and shadow of the lung, the vena caval foramen was observed.

Fig 3. Left 60° ventral-right dorsal oblique prejection (60° image). The right crus made a line continued to the dorsal margin of postcava.

Fig 4. Dorsoventral projection (90° image). The diaphragm looked like a dome having the range from T9 to T11 as apex.

Fis 5. Right 30° ventral-left dorsal oblique projection (120° image). The line of right crus crossed over T10 to T13, and reached the right stomatic wall.

Fig 6. Right 60° ventral-left dorsal oblique projection (150° image). Origin of the left and right crura were noted within the range from T13 to L1.

Fig 7. Right-left projection (180° image); Same as in the 0° image. Same as in the 0° image.

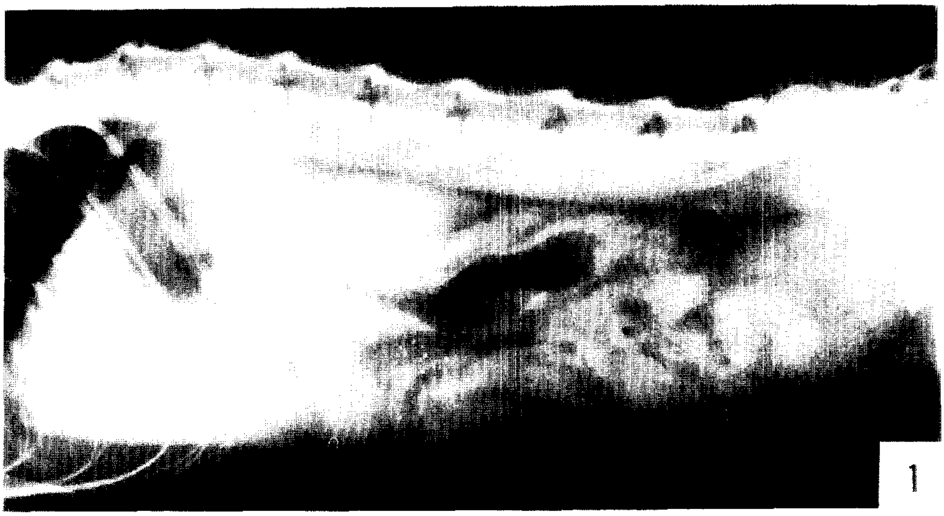
Fig 8. Right 30° dorsal-left ventral oblique projection (210° image). The dorsal line of the postcava was clearly noted being connected with the right crus, while the foramen of vena cava was easily distinguished.

Fig 9. Right 60° dorsal-left ventral oblique projection (240° image). Nearly same as in the 60° image.

Fig 10. Dorsoventral projection (270° image). Nearly same as in the 90° image.

Fig 11. Left 60° dorsal-right ventral oblique projection (300° image). Nearly same as that in the 120° image.

Fig 12. Left 30° dorsal-right ventral oblique projection (330° image). The right crus line reached a spot between T13 and L1.



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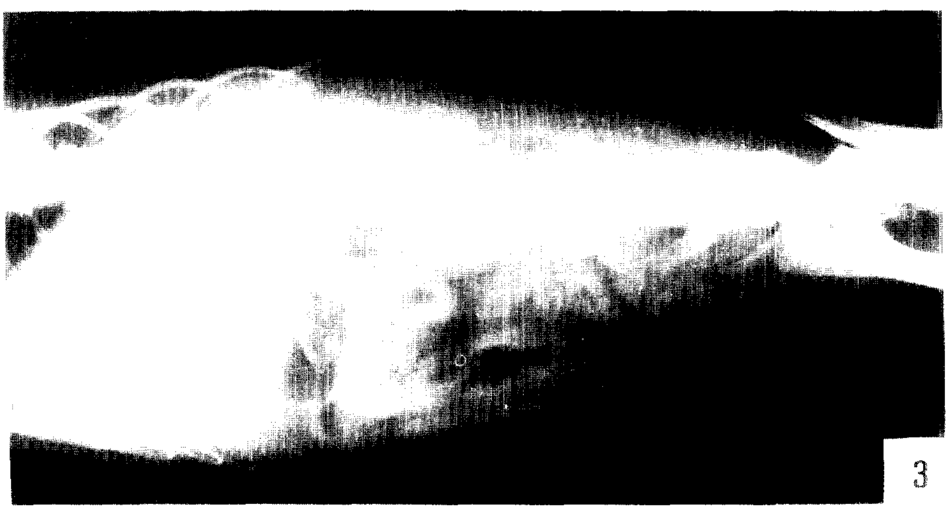

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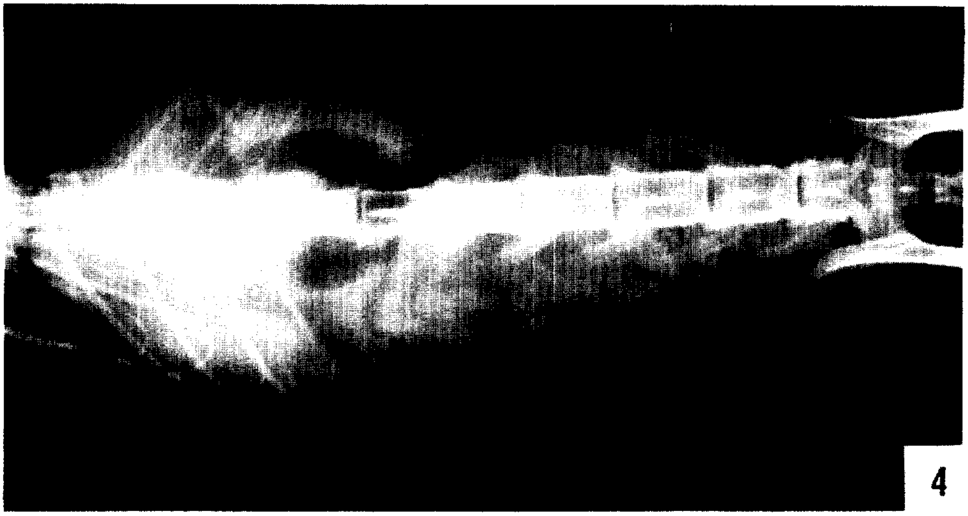

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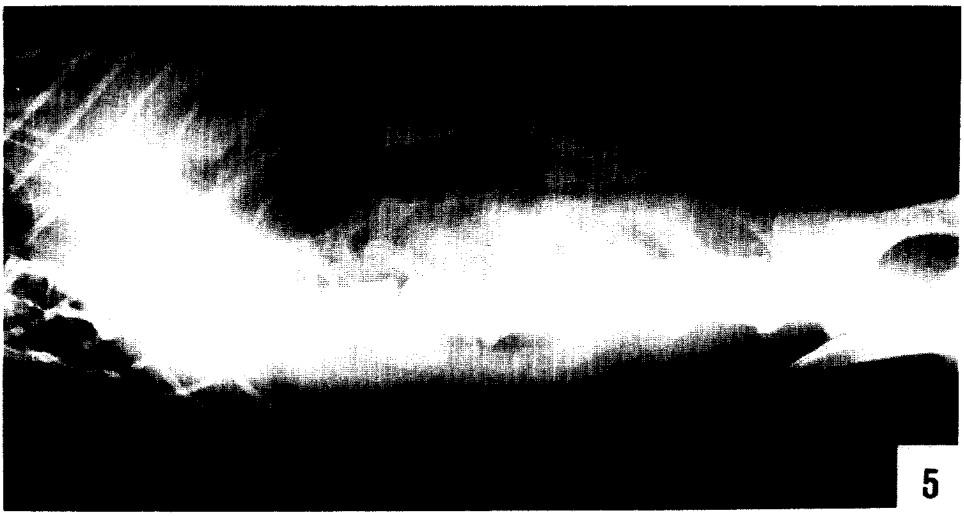

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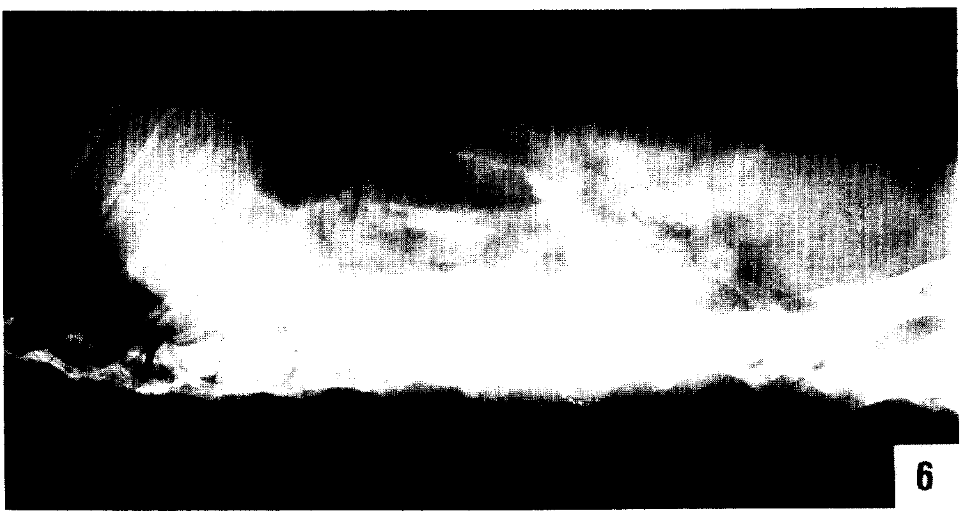

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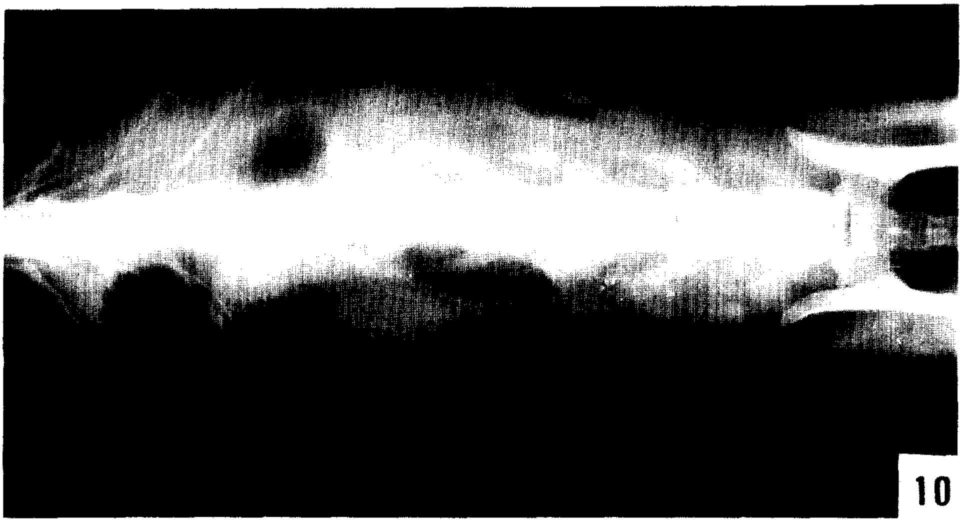
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