Peritoneography and Herniography in Non-Human Primates

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INTRODUCTION

There have been infrequent reports of congenital and acquired hernias in the non-human primate (2, 4, 12, 13). Recently restraint systems have been designed for chronic studies and long-term experimentation. Many of these systems are of the type in which the animal is sitting upright in a chair or cart with cuff devices to limit the motion of the extremities (3, 7). We have noted that these methods of restraint have resulted in an increase of inguinal hernias in male primates utilized for chronic investigatory studies. Often the diagnosis of an inguinal hernia can be made by physical examination, but we have encountered small hernias that were not clinically detectable. In our experience, physical examination is often misleading when predicting whether or not an animal will develop a hernia on the opposite side. Because of this, many surgeons, in human practice, routinely explore the opposite groin at surgery because they, in past experience, found a patent processus vaginalis which was not apparent on pre-operative physical examination. In children, approximately 40% with clinical evidence of a unilateral inguinal hernia have a patent processus in the opposite groin. Of this group, about 20% will eventually develop a hernia into the contralateral open processus vaginalis (14). In 1967, it was suggested that positive contrast peritoneography (herniography) could be substituted for surgical exploration (1). This diagnostic procedure in our experience has proved to be an accurate method of recognizing the existence and configuration of patent vaginal processes, hydroceles, hernias, and also delineates a number of other intraperitoneal structures. For these reasons we utilized this diagnostic study in our non-human primate population, both to test its feasibility and to establish normal findings.

TECHNIC

The procedure is performed just after the animal has urinated or has been catheterized. Anesthesia is administered by intramuscular, intraperitoneal, or intravascular injection of an appropriate short acting pharmaceutical. We most commonly use an intramuscular injection of C1744[5], 2 mg/kg. Neither tracheal intubation nor supplementary inhalation anesthesia is necessary. The hair at the injection site is then shaved and the skin prepared with 1% tincture of iodine solution which is permitted to dry and removed with alcohol. A 3–5 cm 19 gauge needle is inserted slowly in the midline, about 2 to 3 cm below the umbilicus. The needle is gently aspirated (to check for air, urine, or blood, as these are the manifestations of inadvertent puncture of bowel, bladder, or

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[5] Parke, Davis & Co., Detroit, Mich. 48232.
[6] Hypaque 61% diluted 1 to 1 with sterile water. Winthrop Laboratories, Division of Sterling Drug, Inc., New York 18, N. Y.

A reprint from Volume XV, No. 2, 1974 of
JOURNAL OF THE AMERICAN VETERINARY RADIOLOGY SOCIETY

aorta.) The needle tip is carefully moved from side to side to be certain that a solid abdominal organ or retroperitoneal structure has not been entered. If the needle enters a solid organ or a retroperitoneal structure, it is removed and repositioned (11). Following this maneuver, the syringe is again aspirated.

If the needle enters the bowel, bladder, or a large vessel, it is removed and a different needle introduced either at a slightly higher or lower site. Sometimes we choose to inject laterally at the edge of the rectus muscle in larger animals because the linea alba below the umbilicus is fibrous and difficult to perforate (2).

Needles 3–5 cm long or longer were utilized by us initially, although we now believe that any needle of sufficient length to just enter the peritoneal space is preferred. In large primates even longer needles may be necessary. Although thinner needles (20 to 22 gauge) have been employed for some studies, injection, in our experience, is more difficult and the bowel is entered with greater frequency if the needle has a plastic sleeve.

Once the needle is in the peritoneal cavity, 30% meglumine diatrizoate is injected slowly.[6] The appropriate amount of contrast medium is based on the animal's weight (2 ml/kg). Following completion of contrast medium injection, the needle is removed.

When there is bowel in the animal's hernia sac, we reduce it manually prior to the study. The animal is turned prone on the radiographic table and rotated from side to side for approximately two minutes. This maneuver permits the contrast material to outline the lower anterior surface of the peritoneum. The head of the radiographic table is then raised 35° to preferentially cause the contrast medium to flow by gravity inferiorly over the internal inguinal rings. (An alternative technic which better accomplishes this in smaller primates is to hold the animal upright.) Five minutes after injection the animal is turned prone, and with the table or animal still tilted, a single posteroanterior radiograph of the pelvis and upper thighs is obtained. The animal remains prone until the radiographs are viewed for confirmation of proper contrast placement. If the inguinal area on one side is not satisfactorily delineated by contrast medium, we position the animal with that side dependent for several minutes. A second radiograph is obtained shortly after this maneuver.

Because of rapid peritoneal absorption of the water soluble contrast medium and excretion by the renal system, satisfactory delineation of the inguinal peritoneal margin with the contrast lasts only 10 to 15 minutes after injection (11). Once satisfactory projections for a diagnostic herniogram are made the study may be terminated. We sometimes obtain a delayed radiograph of the abdomen at 30–60 minutes. By this time, most of the contrast medium will be absorbed and there is satisfactory opacification of the renal collecting system to provide structural information sufficient to produce a modified intravenous urogram.

ANATOMICAL CONSIDERATIONS

The inguinal herniogram of primates is judged to be technically satisfactory when contrast medium sharply outlines the peritoneum both medial and lateral to the "epigastric notch" (formed by the inferior epigastric vessels) (Fig. 1). The rectovesical space and, in females, the rectovaginal space should also be delineated by the contrast medium. A hernia or patent processus vaginalis is excluded when a satisfactory herniogram shows no discontinuity in the peritoneum medial and lateral to the epigastric notch, and when there is no contrast medium below the peritoneal confines (11). In our human and nonhuman primate experience a number of different types of peritoneal sacs have been observed. However, all but two (direct inguinal hernias and femoral hernias) are variations of a patent processus vaginalis.

The processus vaginalis is a sleeve of peritoneum that originates lateral to the inferior epigastric vessels at the internal

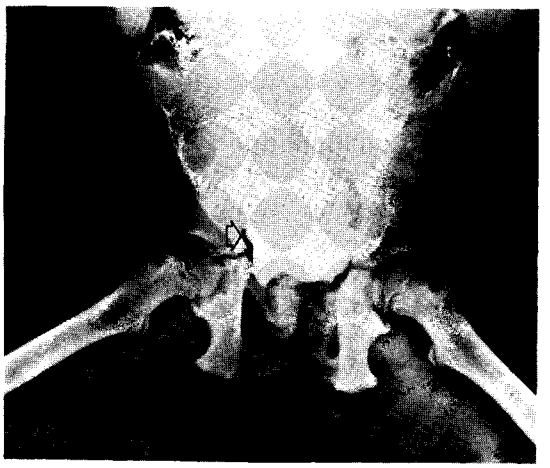

Fig. 1. The normal study in a male orangutan (*Panga pygmaeus*) shows a sharp outline of the margins of the peritoneal cavity. The "epigastric notch" is in the area of Y-cartilage on both sides (arrows). In this animal sufficient contrast medium is present intraperitoneally to outline the bowel content. If the animal is now appropriately positioned, retroperitoneal, intraperitoneal and subphrenic structures can be evaluated.

inguinal ring and passes obliquely and medially in the inguinal canal to the external inguinal ring (14, 15). From that point the processus vaginalis passes inferiorly and anteriorly to enter the scrotum. A processus vaginalis may remain partly or entirely patent in the adult (Fig. 2). In our experience this is especially true of the male rhesus monkey. If bowel enters a patent processus vaginalis, it may distend it to form a hernia sac in the scrotum and be detected on the preliminary radiograph prior to the study. When both contrast medium and bowel are contained in this sac, the diagnosis of an indirect inguinal hernia can be made with confidence (Fig. 3). If the hernia is reduced, an empty hernia sac will remain which is usually wider than a simple patent processus vaginalis. Occasionally this sac collapses sufficiently to prevent entry of contrast medium, making the differential diagnosis difficult.

When bowel fills the canal partially or completely and prevents contrast medium from entering the hernia sac, the internal inguinal ring just lateral to the epigastric notch will have an irregular outline. Changing the animal's position may facilitate entry of contrast medium in order to obtain a diagnostic study.

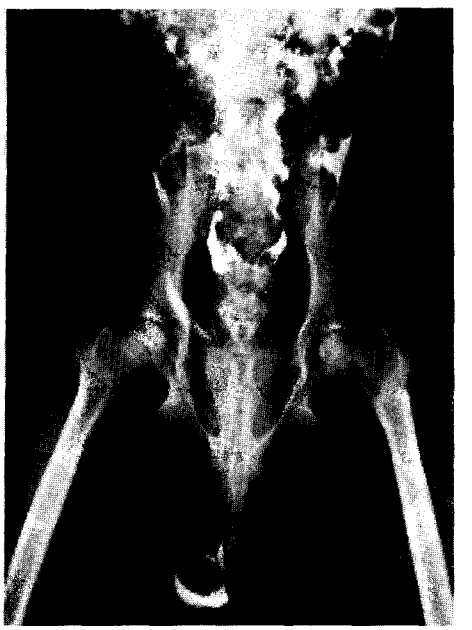

Fig. 2. Herniagram in a male sooty mangebey (*Cercacebus torquatatys*) shows a right-patent processus vaginalis. Contrast medium is seen in the scrotum and surrounds the right testis. In this particular radiograph the inguinal region on the right side is not optimally demonstrated. If this were the only radiograph obtained (and it was not) the delineation of the left inguinal area is not adequately visualized to permit exclusion of a left inguinal hernia.

Fig. 3. Herniagram in a male babaon (*Chuerapithecus papia*): This study shows small bowel in the scrotum, thereby demonstrating a right-inguinal hernia.

Fig. 4. Occosionally the controst medium is inodvertently injected into the bowel rother thon the peritoneol covity. This complicotion hos not been associoted with odverse reoctions. This male boboon (*Chueropithecus popio*) showed no clinicol or loborotory signs of bowel or peritoneol inflommotion.

A cystic collection of fluid which produces a hydrocele may occur at any point along the processus vaginalis. The processus above the hydrocele frequently remains patent and communicates with the peritoneal cavity. When the processus vaginalis is obliterated above and/or below the fluid collection, a noncommunicating hydrocele is formed. This cannot usually be demonstrated by herniography.

Although the inguinal herniogram is generally accurate, occasional errors of interpretation occur. The majority of these mistakes can be avoided by attention to technical details and careful analysis of the relative position of the anatomical structures. If a hernia is present, bowel filling the hernia sac may act as an obstruction and prevent the entry of contrast medium during herniography. As we have stated, the peritoneum lateral to the epigastric notch will not be outlined sharply by contrast medium but the contrast medium about the loop of bowel entering the internal inguinal ring will have an irregular, serrated appearance. If a unilateral hernia is obvious clinically, or the preliminary radiograph reveals air in the groin or scrotum, a herniogram is utilized to exclude the presence of bilateral hernias.

Injections into the bowel (Fig. 4) or bladder represent technical errors that can lead to interpretative mistakes. Certain anatomical structures may also lead to inaccurate interpretations by inexperienced observers. A slight out-pouching of the normal peritoneum just lateral to the epigastric notch may be misinterpreted as a positive herniogram. This occurs most frequently when the animal is slightly rotated or the peritoneum is outlined incompletely. In such instances, a properly aligned radiograph should be obtained immediately. Use of too small a volume of contrast medium to outline both groin areas is another common error as is failure to tilt the table or animal to facilitate contrast flow inferiorly. In our experience, careful analysis of the radiographs will almost always identify these mishaps.

DISCUSSION

The initial event that produces weakness of the abdominal wall in the male primate is movement of the testicle from behind the peritoneum to the scrotum. In its descent, the testicle pushes ahead of it various layers of the abdominal wall (10, 15). These structures contribute an attenuated covering to the testicle and spermatic cord. As the testicle descends it brings with it anteriorly a double layer of peritoneum (funicular process) forming a pouch. This pouch is, in humans, normally obliterated along the course of the spermatic cord. This closure is usually complete by the last month of uterine life which leaves behind a solid strand of connective tissue (10). If this obliteration fails to occur the persistent peritoneal sac predisposes to development of indirect inguinal hernias.

Congenital causes of indirect inguinal hernias include patency of the processus in the male, defects in abdominal wall musculature, failure of testicular descent, abnormal length of omentum and mesentery, and unusual patency of the internal inguinal ring. Acquired causes of inguinal hernias appear to be any mechanism which results in sudden or repeated increases in

abdominal or pelvic pressure. This is thought to be the pathophysiological mechanism that obtains with animal restraint chairs or carts, chronic constipation, and the association of obstructive lung disease (4).

Although the experience in non-human primates is limited, an initial double blind analysis of 100 human patients revealed that the accuracy of herniograms was 97%, compared to 59% by physical examination. Routine contralateral exploration demonstrated a hernia or a patent vaginal process on the opposite side in 44% of the infants and children which meant that surgical exploration of the opposite groin was unnecessary in 56% (16). It has usually been our practice to repair the hernia and to close a patent processus if it has been shown by herniography to be present on the contralateral side.

Positive contrast peritoneography has also proved valuable in the evaluation of diaphragmatic abnormalities in humans. We have not employed this study to date in the nonhuman primate (11). Abnormalities demonstrated by this technic include hernias and tumors of the diaphragm as well as characterization of intraperitoneal solid organs or masses (9).

Herniography is not difficult to perform and causes only mild discomfort to the animal. Intraperitoneal injection of the contrast medium appears to be no more painful than a venapuncture. Meglumine diatrizoate, the contrast medium we employ, is well-tolerated. The incidence of complications is probably low because the contrast medium is absorbed relatively slowly into the intravascular compartment of the primate after an intraperitoneal injection. In humans there are reports of vomiting after injection, but we have not encountered this in primates. No abdominal tenderness to palpation, temperature elevation, or diarrhea have occurred.

Occasional injections have been made into the anterior abdominal wall, the distended bladder, and bowel (Fig. 4) with no apparent adverse reactions. In primates the soft tissues usually tolerate meglumine diatrizoate well. Microscopic sections of 45 hernia sacs removed in humans the day following herniography showed no evidence of inflammation (1). Chemical inflammatory response to the contrast medium, if it occurs at all, probably subsides within 24 hours (8). Injection of a water-soluable contrast medium into the bowel is attended by a potential hazard in small primates. The hyperosmolar solution could cause fluid to move into the bowel lumen and result in dehydration (5). If the animal is maintained in good hydration and does not have intestinal obstruction, there should be no sequelae in this circumstance. Because of danger of puncturing the gallbladder, liver, or spleen, the upper abdomen is a poor site for the intraperitoneal injection of the contrast medium. In general, one must inject enough contrast medium and appropriately position the animal so that opportunity to enter the processus vaginalis is optimized. If a large hernia is present it may prevent the contrast medium from entering the scrotum and thus should be reduced manually prior to the radiographic procedure.

There have been several recent reports of successful repair of inguinal hernias in primates (4, 13). Complications of strangulation prior to repair have also been described (6). We have repaired those hernias diagnosed by herniography in primates. As more primates are placed in the type of restraint that confines them to a sitting position, an increased number of indirect inguinal hernias may be encountered. We believe that utilization of herniography will identify those primates which have an increased risk of developing hernias, will allow definitive diagnosis, and aid in delivery of appropriate care. Extension of the peritoneographic aspects of the study is anticipated and should prove to be a clinically useful procedure.

SUMMARY

In a number of different primate species, contrast medium was injected intraperitoneally to diagnose hernias as well as

evaluate the normal anatomical intraperitoneal relationships. The technical considerations of this diagnostic study are important because errors in the interpretation usually result from improper attention to correct technic. In general, one must inject enough contrast medium and appropriately position the animal so that opportunity to enter the processus vaginalis is optimized. If a large hernia is present it may prevent the contrast medium from entering the scrotum and thus should be reduced manually prior to the radiographic procedure. The potency of the processus vaginalis appears to be more common in the male primate than humans. Contrast herniography and peritoneography are useful under certain circumstances in primates such as evaluation of the inguinal region of the side opposite a clinically apparent inguinal hernia.

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ZUSAMMENFASSUNG

12 Primaten wurde Kontrastmittel intraperitoneal injiziert, um Hernia zu diagnostizieren, sowie die normalen anatomischen intraperitonealen Zusammenhänge auszuwerten. Die technischen Erwägungen dieser diagnostischen Studie sind wichtig, da Fehler in der Interpertation gewöhnlich aus ungenauem Achtgeben auf korrekte Techniken resultieren. Im allgemeinen, muman genug Kontrastmittel injizieren, und das Tier ungefähr in solche Position bringen, dass die Möglichkeit in den processus vaginalis einzudringen, am grössten ist. Falls eine grosse Hernia vorhanden ist, kann es das Kontrastmittel daran hindern, in den Hodensack einzudringen, und sollte deshalb mit der Hand vor dem röntgenologischen Prozess verkleinert werden. Die Potenz des processus vaginalis scheint im männlichen Primaten Häufiger zu sein, als beim Menschen. Kontrastherniographie und Peritoneographie sind unter gewissen Umständen bei Primaten nützlich, so zum Beispiel bie der Auswertung der inguinalen Region der Seite gegenüber einer klinisch offensichtlichen inguinalen Hernia.

RÉSUMÉ

Chez 12 primates, un véhicule de contraste a été injecté intrapéritonéalement pour diagnostiquer des hernies ainsi que pour évaluer les relations normales anatomiques intrapéritonéales. Les observations techniques de cette étude diagnostique sont importantes parce que des erreurs dan l'interprétation résultent habituellement d'une attention incorrecte pour corriger la technique. En général,

on doit injecter une quantité suffisante de véhicule de contraste dans le processus vaginalis en placant l'animal dans une position aussi favorable que possible. Si une grande hernie est présente, elle peut empêcher le véhicule de contraste d'entrer dans le scrotum et devrait donc être réduite a la main avant la radiographie. La puissance du processus vaginalis semble être plus ordinaire chez les primates mâles que chez les êtres humains. Le contraste herniographique et péritonéographique est utile chez les primates dans certaines circonstances telles que l'évaluation de la région inguinale du coté opposé d'une hernie inguinale apparente d'après la méthode clinique.