Evaluation of a Transvaginal Laparoscopic Natural Orifice Transluminal Endoscopic Surgery Approach to the Abdomen of Mares

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Objective: To report natural orifice transluminal endoscopic surgery (NOTES) using laparoscopic and endoscopic instrumentation transvaginally into the mare's abdomen and identify structures visible using this approach.
Design: Descriptive experimental study.
Animals: Mares (n = 8).
Methods: A standing, transvaginal approach was made in the cranial vaginal vault at either the 1 (right; 4 mares) or 11 (left; 4 mares) o'clock position relative to the cervix. The abdomen was visually explored and the viscera evaluated using a 2 m flexible endoscope followed by a 62 cm laparoscope. Incisional healing was monitored by vaginoscopy at days 3 and 7.
Results: Abdominal exploration was adequate through either a left or a right transvaginal approach. Endoscopically, the left kidney, spleen, nephrosplenic space, stomach, cecum, duodenum, left and right ovaries, diaphragm, and caudal peritoneal reflection were consistently observed and the liver inconsistently. Similar views of the caudal abdomen were obtained with the laparoscope; however, we were unable to view cranially beyond the nephrosplenic space or base of the cecum and lateral mobility of the laparoscope was limited. Incisional closure was evident at 3 days. Complications in 1 mare included mild colic behavior that resolved with conservative treatment.
Conclusions: The NOTES transvaginal approach is seemingly well tolerated and safe and provides adequate observation of most structures within the dorsal caudal region of the abdomen on the side of endoscope or laparoscope insertion.
Clinical Relevance: NOTES transvaginal approach may be a useful tool in the diagnosis of intraabdominal disorders in mares.

Equine abdominal laparoscopy has evolved since the original descriptions[1–3] and in selected cases, it is a minimally invasive technique for diagnosis of causes of chronic colic[4–8]; intraabdominal biopsy[9]; and confirmation of neoplasia, peritonitis, or even visceral rupture.[6,10,11]

Natural orifice transluminal endoscopic surgery (NOTES) was initially described in swine,[12] and has subsequently been used for evaluation and treatment in other animals and people.[13–15] Whereas NOTES is considered a new modality in human and veterinary medicine, the concept of a transvaginal approach to the equine abdomen is not novel. Transvaginal ovariectomy, by colpotomy, is well established in mares.[16–18]

NOTES techniques described in swine include transcolonic endoscopic cholecystectomy and transgastric ligation of the fallopian tubes.[19,20] These techniques, performed in swine for adaptation in human medicine,[15] are now being investigated for clinical application in animals rather than as a model for human research.[21] Current descriptions of NOTES in veterinary patients have been limited to dogs with reports on technique safety[22] and transgastric techniques to obtain tissue samples and perform oophorectomy.[21–23] Technique extrapolation and associated assumptions may not be appropriate in horses because of anatomic variation between species.

In people, the theoretical benefits of NOTES procedures over standard laparoscopic procedures include shorter recovery times, reduced pain, and no visible scarring. For mares, shorter recovery times means decreased hospitalization and aftercare, and would potentially allow earlier return to athletic use. Whereas most mares are unaffected by an incisional flank scar, a transvaginal approach may be preferred in show mares. Thus, there would be a cosmetic benefit in addition to other benefits associated with laparoscopy compared with laparotomy. Advances in NOTES

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technology and opportunities have accompanied advances in endoscope technology and capability.[15,24] Thus, it seemed to us that NOTES might be a feasible approach for abdominal exploration and ovariectomy in horses.

Our purpose was to evaluate the technical feasibility of exploring the mare's abdomen through a transvaginal approach and specifically to (1) compare access through right- and left-sided portal placement, (2) compare viewing fields obtained with a laparoscope and endoscope, and (3) evaluate intra- and postoperative tolerance of the procedure by healthy mares.

MATERIALS AND METHODS

Eight healthy adult stock horse type mares, aged 6–22 years, weighing 400–550 kg (mean, 464 kg) were used. Health status was determined by physical examination and preoperative hematologic profile. All mares were maintained in a teaching herd and their immediate history was well known.

Surgical Technique

To ensure optimal abdominal observation, food was withheld for 48 hours before laparoscopic evaluation. Procaine penicillin G (22,000 U/kg intramuscularly [IM]), gentamicin (6.6 mg/kg intravenously [IV]), and flunixin meglumine (1.1 mg/kg IV) were administered 30 minutes before surgery. Each mare was restrained in stocks and sedated with detomidine hydrochloride (0.01 mg/kg IV) and butorphanol tartrate (0.01 mg/kg IV). Redosing in increments (half the initial doses) was administered as needed to effect throughout the procedure.

Feces were evacuated and then the perineal region was prepared with povidone iodine scrub and a dilute povidone–iodine solution rinse of the vaginal vault. A 28 Fr Foley catheter (Bard Urological Division, C.R. Bard Inc., Covington, GA, USA) was placed into the bladder to help maintain a dry operating field and sterility if the mare urinated. Each mare had a single transvaginal abdominal approach lateral to the cervix (4 right [1 o'clock], 4 left [11 o'clock]). A lidocaine-soaked gauze sponge was placed on the vaginal mucosa at the intended surgical site for 5 minutes before perforation into the peritoneal cavity.

Right-Sided Approach. To minimize the risk of hemorrhage, sharp dissection was avoided. Instead, a curved mosquito hemostat was placed in the left hand of the surgeon, palmed to prevent inadvertent damage to the vaginal wall, and advanced so that the tip made contact with the vaginal wall ~3–4 cm lateral to the cervix between the 1 and 2 o'clock position. The hemostats were inserted bluntly through the vaginal wall and peritoneum, opened within the abdomen, then retracted into the vaginal vault while still open to create a ~2 cm incision into the abdomen. A single finger was then inserted into the opening to ensure that all layers had been penetrated.

Positive pressure insufflation was not used. A sterilized forward-looking 2 m flexible endoscope (Model: EC-450HL5, working length: 169 cm, diameter: 12.8 mm, Fujinon Inc., Wayne, NJ) was introduced through the incision by the surgeon with an assistant manipulating the controls. A systematic evaluation of the abdomen was performed and the endoscope removed and replaced by a 0° laparoscope (working length: 62 cm, diameter: 10 mm, Richard Wolf Medical Instruments Corp., Vernon Hills, IL). Systematic evaluation of the abdomen was performed with the laparoscope. After completion of laparoscopy, the incision was left to close by second intention.

Left-Sided Approach. The same technique was used with the mosquito forceps in the right hand of the surgeon and the tip ~3–4 cm lateral to the cervix between the 10 and 11 o'clock position. Systematic evaluation of the abdomen with the endoscope and then laparoscope was performed.

Postoperative Management

Physical examinations were performed daily for 7 days. Procaine penicillin G (22,000 U/kg IM every 12 hours), gentamicin (6.6 mg/kg IV once daily), and flunixin meglumine (1.1 mg/kg IV every 12 hours) were administered for 3 days. Incisions were examined by video endoscopic vaginoscopy on days 3 and 7.

RESULTS

All transvaginal approaches were performed without complication. No injury to internal organs was detected and no excessive bleeding or inadvertent puncture of the uterine branch of the urogenital artery occurred.

For the right approach, using the endoscope, the right ovary and uterine horn, base of the cecum, duodenum, caudal peritoneal reflection, and the caudal dorsal aspect of the diaphragm were consistently identified. In 2 mares, the caudal aspect of the right lobe of the liver located just cranial to the base of the cecum was also observed (Fig 1). The laparoscope provided similar views of the cecum, duodenum, right ovary, and caudal dorsal diaphragm; however, the right liver lobe was only identified in 1 mare (Fig 2). The right caudal peritoneal reflection could not be seen with a rigid laparoscope.

For the left approach, the endoscope was easily passed in 3 mares. In 1 mare, the incision was too dorsal (12 o'clock position) and was believed to have penetrated the medial fold of the fornix and thus directed the endoscope toward the right side of the abdomen. Where the approach was closer to 10 o'clock, the left ovary and uterine horn, caudal dorsal aspect of the diaphragm, spleen, left kidney, nephrosplenic ligament, caudal aspect of the left lateral lobe of the liver, left lateral aspect of the stomach, and the caudal peritoneal reflection on the left side (Fig 3) were consistently observed. In the mare with the dorsal approach, the endoscope was directed to the right side, so the right ovary, cecum, duodenum, and medial aspect of the left kidney were visible.

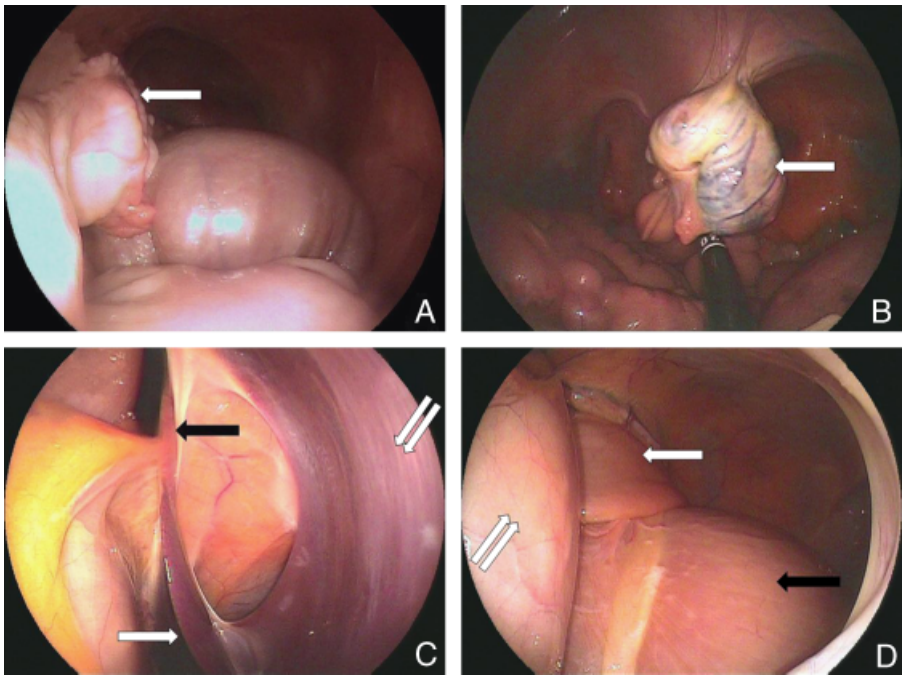

Figure 1 Endoscopic views from a right-sided transvaginal approach to the abdomen. (A) caudal-to-cranial view of the right ovary (white arrow) with segments of the ascending colon lying both ventral and cranial; (B) right caudal peritoneal reflection seen after retroflexing the endoscope. The right ovary (white arrow) and descending colon (ventrally) are visible; (C) caudal-to-cranial view of the caudal aspect of the right lobe of the liver (white arrow) suspended by the triangular ligament (black arrow). The diaphragm (double white arrows) is seen along the entire right aspect of the image; and (D) caudal-to-cranial view of the base of the cecum (black arrow) and the duodenum as it courses from a cranial-to-caudal direction. A section of ascending colon is seen on the left of the image (double white arrows).

The laparoscope provided similar views of the spleen, kidney, left ovary, and caudal dorsal diaphragm in all 4 mares (Fig 2). In the mare with the dorsal approach, the cecum and duodenum were also identified. The left lateral liver lobe and left caudal peritoneal reflection could not be clearly seen in any mare with a laparoscope.

For all mares, regardless of approach, identification of the ventral contents of the abdomen was variable. Segments of jejunum, ascending and descending colon were consistently visible with both the endoscope and laparoscope. The bladder was occasionally visible but not consistently because of its small size after evacuation. The viscera contralateral to the side of vaginal approach were not readily or consistently visible with either instrument.

Intraoperatively, 2 mares developed mild subcutaneous emphysema in the perineal region. This resolved spontaneously within 12 hours. All mares were stall confined for observation for 7 days. Appetite, attitude, and water intake remained normal for all but 1 mare that had signs of mild abdominal pain on Day 5, 48 hours after cessation of all medications. Flunixin meglumine (1.1 mg/kg IV), 4 L mineral oil, and 4 L water via a nasogastric tube were administered. Signs of colic persisted for 4 hours then subsided. No further signs of abdominal pain were observed.

By Day 3, all incisions were closed and appeared to be covered by mucosa with no communication remaining between the vaginal vault and the abdomen. The incision site was further contracted and less apparent by Day 7 (Fig 4).

DISCUSSION

Exploration and observation of the left and right compartments of the dorsal aspect of the abdomen was successfully performed in 8 mares; however, ventral exploration was limited as expected with a standing procedure. In 1 mare, a left-sided approach was intended; however, because of the dorsal location of the incision, the endoscope was directed into the right side of the abdomen. The abdomen is effectively divided into left and right sides because the mesentery of the descending colon and rectum limits medial movement of the endoscope or laparoscope after insertion. Using a hand for intravaginal manipulation, the rigid laparoscope could be guided under the rectum to view the opposite side; however, viscera on the side of approach were easier to view.

Laparoscope use through a transvaginal approach had some limitations. The length of the laparoscope did not allow passage beyond the nephrosplenic space or the base of the cecum, so viewing of the cranial dorsal aspect of the abdomen was limited. Medial to lateral movement was restricted by vaginal and vestibular dimensions, which limited lateral excursions of the laparoscope. Overall

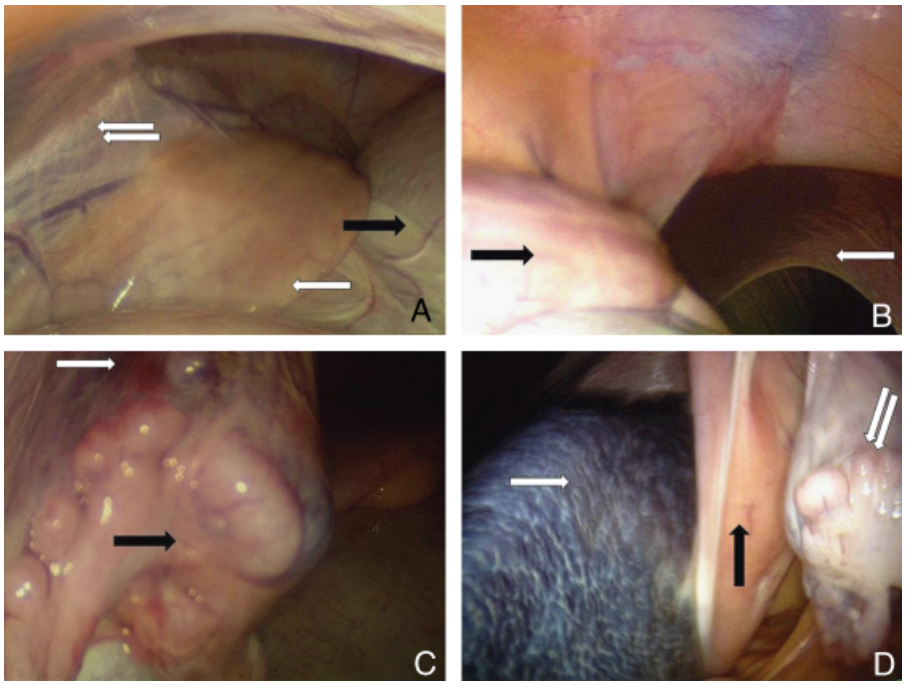

Figure 2 Laparoscope views of the abdomen from a right-sided (A–C) and left-sided approach (D). (A) caudal-to-cranial view of the duodenum (white arrow) as it courses over the base of the cecum (black arrow). Note the short mesenteric attachment of the duodenum at this level (double white arrows); (B) caudal-to-cranial view of the caudal aspect of the right lobe of the liver (white arrow). Duodenum (black arrow) is suspended from the dorsal body wall as it courses around the base of the cecum; (C) caudal-to-cranial view of the right ovary (black arrow) and mesovarium (white arrow); (D) caudal-to-cranial view of the spleen (white arrow), nephrosplenic space, caudal pole of the left kidney (black arrow), and left ovary (double white arrows).

laparoscope length limited passage beneath the descending colon to the opposite side for sufficient distance to prevent visual obstruction from the colon falling back over the laparoscope.

Compared with the laparoscope, the endoscope offered more mobility within the abdomen; however, this was also a limitation because the lack of rigid support resulted in the endoscope sagging ventrally within the abdomen when advanced cranially resulting in poor control over the distal end. This limitation could be partially counteracted by supporting the midsection of the endoscope on the viscera. A hand within the vagina could also be used to guide the endoscope dorsally through the caudal aspect of the abdomen. On the left side, the endoscope could be maneuvered into the nephrosplenic space to rest on the nephrosplenic ligament. This allowed the operator to maintain dorsal positioning of the endoscope into the cranial aspect of the abdomen providing consistent viewing of the stomach and left lateral lobe of the liver. To reach the more ventral aspects of the cranial abdomen, the endoscope could be passed along the body wall with some consistency; however, little control in a dorsal to ventral direction was possible.

When passing the endoscope under the descending colon to the contralateral side, the weight of the descending colon typically forced the endoscope ventrally resulting in inadequate viewing. It is possible that modification by use of a rigid guide sleeve or insertion of a stiffening wire in the biopsy channel would improve functionality. Also, a hand placed in the rectum may be able to elevate the descending colon dorsally to facilitate passage of the endoscope; however, it is likely that when the colon was no longer supported that the endoscope would be displaced ventrally. Rectal manipulation would likely need to be by the same person passing the endoscope because of space limitations and this might increase the risk of contamination and potentially septic peritonitis.

We used a single left or right vaginal approach in each mare and viewed the corresponding side of the abdomen. Observation of the left and right dorsal quadrants of the abdomen through a single incision would be a major advantage of this procedure; however, we were unable to consistently achieve this. Given the relative ease of the procedure and subsequent healing, we believe that left and right transvaginal approaches could be made concurrently to fully explore the abdomen; however, the feasibility and consequences of this need to be investigated. Whereas there is risk of trauma to the uterine branch of the urogenital artery and potentially fatal hemorrhage with transvaginal perforation, we believe this can be minimized by perforation of the vaginal vault and peritoneum by hemostats or closed scissors rather than sharp perforation with a blade.

Intraoperatively, 2 mares (1 left, 1 right) developed perineal emphysema that resolved within 12 hours without treatment. Air entry into the abdomen provided natural insufflation for adequate viewing and may have

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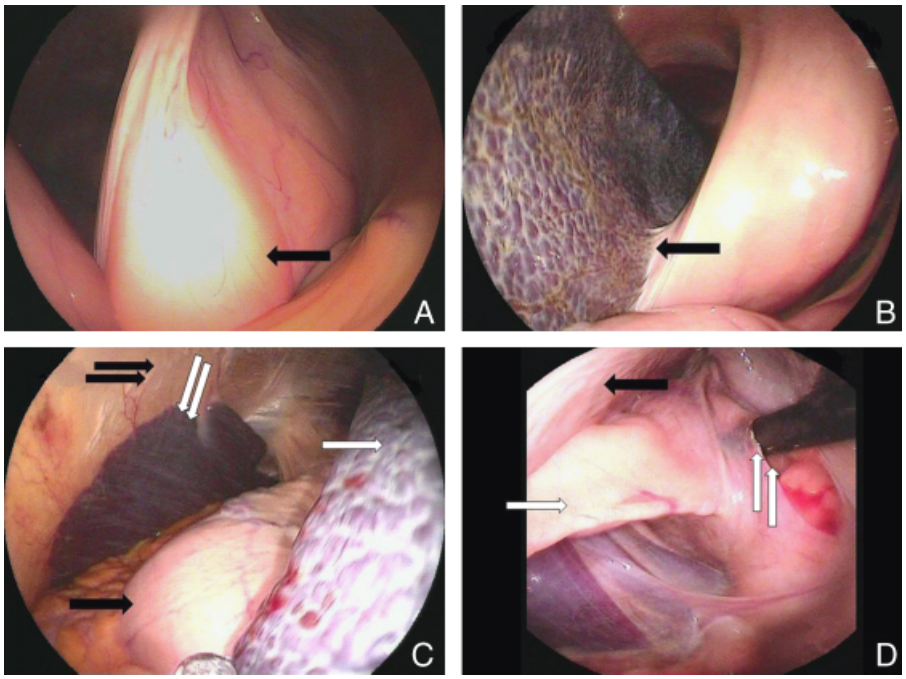

Figure 3 Endoscopic images of the abdomen from a left-sided transvaginal approach. (A) Caudal-to-cranial view of the caudal medial aspect of the left kidney (black arrow); (B) caudal-to-cranial view of the caudal aspect of the nephrosplenic space and nephrosplenic ligament (black arrow); (C) caudal-to-cranial view of the cranial (abaxial) border of the spleen (white arrow), greater curvature of the stomach (black arrow), caudal aspect of the left lateral liver lobe (double white arrows), and diaphragm (double black arrows); and (D) left caudal peritoneal reflection obtained by retroflexing the scope. The rectum (black arrow) and the left uterine horn (white arrow) are visible. The endoscope can be seen (double white arrows) as it passes through the peritoneal opening of the approach.

contributed to the development of perineal emphysema. We believe that it is more likely that the emphysema resulted from air within the abdomen dissecting caudally from the wall of the vagina through the perineal tissues. Positive pressure insufflation of the abdomen was not used or considered necessary to obtain adequate viewing,

In 7 mares, the procedure was well tolerated without apparent complications. In 1 mare, although vital signs were considered normal during her entire recovery, abdominal discomfort (pawing and laying down) occurred on Day 5 but resolved with medical treatment. The cause of colic signs is uncertain and whereas it seems unlikely that they were associated with the surgical procedure (incisional pain, peritonitis, or early adhesion formation), we cannot rule this out. No further signs of colic occurred.

A single portal for abdominal entry allows instrumentation and observation through the same portal and permits minor procedures (eg, biopsy) to be performed without need for multiple incisions. This results in minimal scar formation and in people, it results in less postoperative pain, reduced hospitalization, and a faster return to normal activity.[25] Whereas, a single portal technique can be accomplished using an operating laparoscope, an endoscope is versatile, readily available in longer lengths, and does not rely on a direct or straight path for use. Although there are some current technical limitations, with further

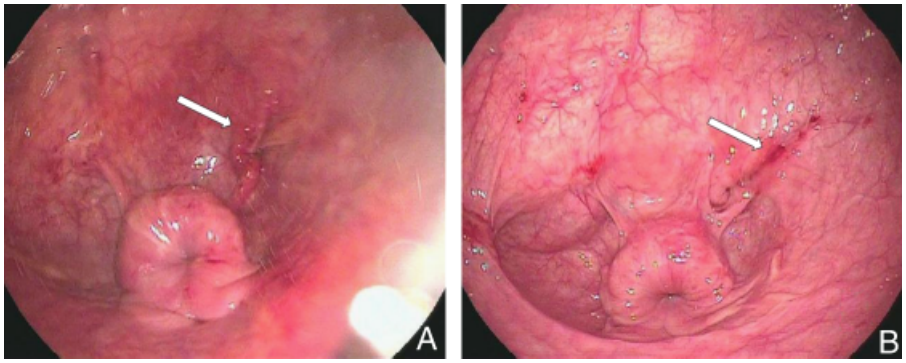

Figure 4 Vaginoscopic images on days 3 (A) and 7 (B) confirm closure of a right-sided approach (white arrow).

instrumentation and technique refinement, increased capability of NOTES techniques in horses should be possible. Modifications like the use of the second portal should expand the range of procedures possible. Combining this approach with conventional laparotomy could provide an orthogonal view of the abdomen as well as improve three-dimensional appreciation of visceral anatomy for diagnostic or therapeutic procedures. Though this would require a team approach, it may prove useful in mares where complex instrumentation might be required through a narrow paralumbar fossa.

A potential concern of using a NOTES approach in horses is postoperative adhesion formation at the entry site. NOTES may reduce the incidence of adhesion formation in people,[25] but adhesions with varying frequency in experimental swine, most notably with use of a transcolonic approach.[20,26] Another potential disadvantage is technical difficulty performing the procedure. There is a learning curve associated with efficient manipulation of the endoscope within the abdomen. A team approach improves efficiency by having 1 person pass the endoscope and guide it intravaginally when needed, while the second person controls the endoscope's visual angle. A team approach has been reported in porcine models where total exploration time to identify all pertinent abdominal viscera was < 3 minutes.[26]

We found that overall viewing within the abdomen using a transvaginal approach with a flexible endoscope was good. With continued innovation and use of more advanced operating endoscopes,[24] the feasibility of further developing a transvaginal approach to the equine abdomen for diagnostic and therapeutic application should be possible.

REFERENCES

1. Heinze H, Klug E, von Lepel JD: Optical demonstration of internal genitalia for diagnostics and therapy in equines. *Dtsch Tierarztl Wochenschr* 1972;79:49–51
2. Witherspoon DM, Talbot RB: Ovulation site in the mare. *J Am Vet Med Assoc* 1970;157:1452–1459
3. Fischer AT, Lloyd KC, Carlson GP, et al: Diagnostic laparoscopy in the horse. *J Am Vet Med Assoc* 1986;189:289–292
4. Fulton IC, Brown CM, Yamini B: Adenocarcinoma of intestinal origin in a horse: diagnosis by abdominocentesis and laparoscopy. *Equine Vet J* 1990;22:447–448
5. Mehl ML, Ragle CA, Mealey RH, et al: Laparoscopic diagnosis of subcapsular splenic hematoma in a horse. *J Am Vet Med Assoc* 1998;213:1171–1173
6. Ragle CA, Southwood LL, Galuppo LD, et al: Laparoscopic diagnosis of ischemic necrosis of the descending colon after rectal prolapse and rupture of the mesocolon in two postpartum mares. *J Am Vet Med Assoc* 1997;210:1646–1648
7. Scheffer CJ, Drijfhout PN, Boerma S: Subperitoneal cyst in a Friesian mare. *Tijdschr Diergeneesk* 2004;129:468–470
8. Hassel DM, Ragle RA: Laparoscopic diagnosis and conservative treatment of uterine tear in a mare. *J Am Vet Med Assoc* 1994;205:1531–1536
9. Fischer AT: Laparoscopic biopsy techniques, in Fischer AT (ed): *Equine Diagnostic and Surgical Laparoscopy*. Philadelphia, PA, W. B. Saunders, 2002, pp 143–148
10. Fischer AT: Laparoscopic evaluation of horses with acute or chronic colic, in Fischer AT (ed): *Equine Diagnostic and Surgical Laparoscopy*. Philadelphia, PA, W. B. Saunders, 2002, pp 131–142
11. Walmsley JP: Review of equine laparoscopy and an analysis of 158 laparoscopies in the horse. *Equine Vet J* 1999;31:456–464
12. Kalloo AN, Singh VK, Jagannath SB, et al: Flexible transgastric peritoneoscopy: a novel approach to diagnostic and therapeutic interventions in the peritoneal cavity. *Gastrointest Endosc* 2004;60:114–117
13. Onders RP, McGee MF, Marks J, et al: Natural orifice transluminal endoscopic surgery (NOTES) as a diagnostic tool in the intensive care unit. *Surg Endosc* 2007;21: 681–683
14. Wallace MB: Take NOTES (natural orifice transluminal endoscopic surgery). *Gastroenterol* 2006;131:11–12
15. Hussain A, Mahmood H: NOTES: current status and expectations. *Eur Surg* 2008;4:176–186
16. Embertson RM: Ovaries and uterus, in Auer JA, Stick JA (eds): *Equine Surgery* ((ed 3).). St. Louis, MO, W. B. Saunders, 2006, pp 855–864
17. Walker DF, Vaughan JT: Surgery of the ovaries and adnexa, in Walker DF, Vaughan JT (eds): *Bovine and Equine Urogenital Surgery*. Philadelphia, PA, Lea & Febiger, 1980, pp 241–253
18. Colbern GT, Reagan WJ: Ovariectomy by colpotomy in mares. *Contin Educ Pract Vet* 1987;9:1035–1038
19. Jagannath SB, Kantesevoy SV, Vaughn CA, et al: Peroral transgastric endoscopic ligation of fallopian tubes with long-term survival in a porcine model. *Gastrointest Endosc* 2005;61:449–453
20. Pai RD, Fong DG, Bundga ME, et al: Transcolonic endoscopic cholecystectomy: a NOTES survival study in a porcine model. *Gastrointest Endosc* 2006;64:428–434
21. Freeman L: Innovation in surgery: take NOTES! Surgery meets gastroenterology. *Proceedings of the 2008 ACVS Symposium*, San Diego, CA, 2008, pp 208–210.
22. Freeman LJ, Rahmani EY, Sherman S, et al: Oophorectomy by natural orifice transluminal endoscopic surgery: feasibility study in dogs. *Gastrointest Endosc* 2009;69:1321–1332
23. Freeman L, Rahmani EY, Al-Haddad M, et al: Natural orifice transluminal endoscopic surgery—technique description. *Proceedings of the 2008 ACVS Symposium*, San Diego, CA, 2008, pp 359–365.
24. Bardaro SJ, Swanstrom L: Development of advanced endoscopes for natural orifice transluminal endoscopic surgery. *Minimal Invasiv Ther* 2006;15:378–383
25. Pearl JP, Ponsky JL: Natural orifice translumenal endoscopic surgery: a critical review. *J Gastrointest Surg* 2008;12:1293–1300
26. Fong DG, Pai RD, Thompson CC: Transcolonic endoscopic abdominal exploration: a NOTES survival study in a porcine model. *Gastrointest Endosc* 2007;65:312–318