



Development of a Hand-Assisted Laparoscopic Model of Induced Abdominal Cryptorchidism in Equids for Surgical Training and Reproductive Research



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Abstract

THIS study developed and evaluated a hand-assisted laparoscopic technique for inducing abdominal cryptorchidism in equids as a novel surgical model. Five healthy animals (2 horses, 3 donkeys) aged 5 months to 17 years underwent standardized procedures under general anesthesia. The technique involved laparoscopic-guided testicular relocation through manually dilated inguinal rings, with confirmation of intra-abdominal positioning and external ring closure. All procedures were successfully completed with a mean operative time of 52.4 ± 8.3 minutes, demonstrating consistent reproducibility across age groups. Juvenile animals required less surgical time (47.5 ± 4.9 min) than adults (55.3 ± 8.1 min), reflecting anatomical differences in inguinal canal development. Intraoperative visualization enabled precise testicular manipulation without hemorrhage or visceral injury in all cases. A single instance of self-resolving subcutaneous emphysema represented the sole complication. Postoperative pain scores (EQUUS-FAP) remained low (median 4/20), confirming the technique's minimal invasiveness. The model addresses a critical gap in large animal reproductive research by providing a standardized platform for studying testicular pathophysiology and refining cryptorchidism treatments. While results show excellent short-term feasibility, limitations include small sample size and mixed-species composition. Future studies should validate long-term testicular changes histologically and compare outcomes with natural cryptorchid cases. This laparoscopic approach offers significant advantages over open techniques, including enhanced visualization, reduced morbidity, and potential applications in surgical training programs. The study establishes a foundation for translational research in equine reproductive surgery with implications for understanding cryptorchidism across species.

Keywords: Animal Model, Cryptorchid, Equine, Laparoscopy, Surgery.

Introduction

Animal models have long been indispensable in the advancement of veterinary and human medicine, providing critical insights into diagnostic and surgical interventions. Among these, live animal models offer a dynamic environment that closely mimics clinical scenarios, making them essential for refining surgical techniques and ensuring translational applicability before clinical use [1-4].

Despite their importance, large animal models, particularly equine models, remain underrepresented in many fields of research [5]. Equids (horses and donkeys) have been utilized in studies of musculoskeletal disorders such as osteoarthritis, and cartilage repair [6-11], abdominal surgeries [12, 13], tumor surgery [14, 15] and reproductive system manipulations. Their size and anatomical similarity to humans makes them ideal for surgical training and translational research, yet their potential in

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(Received 03 June 2025, accepted 16 November 2025)

DOI: 10.21608/ejvs.2025.392024.2890

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reproductive studies, such as cryptorchidism, remains underexplored [16].

Cryptorchidism, the failure of one or both testes to descend into the scrotum, is a common reproductive disorder in equines, affecting ~8–12% of stallions [17]. This condition serves as a valuable model for studying testicular dysfunction, endocrine disruptions, and surgical corrections [18]. While small animal models as rodents, and rabbits have dominated cryptorchidism research [19]. or instance, rodent models lack the inguinal canal complexity and testicular size variability seen in equines, limiting their utility for surgical training [20].

To bridge this gap, large animal models including pigs, dogs, and sheep have been employed in surgical studies [16, 21]. For instance, porcine models have been extensively used in abdominal surgery research due to their anatomical similarities to humans, while canine models have provided insights into orthopedic and cardiovascular surgeries [16]. However, equine models remain underrepresented despite their potential to enhance surgical training and experimental research in veterinary medicine [22]. Equine models offer unique advantages for cryptorchidism studies, including surgical training potential and clinical relevance as their size allows for realistic practice of minimally invasive techniques [23].

Despite these advantages, no standardized equine model for induced abdominal cryptorchidism exists, hindering progress in surgical training and pathophysiological studies. This study aims to develop a laparoscopic-induced cryptorchidism model in equids., evaluate its feasibility, operative efficiency, and short-term outcomes, and establish a foundation for future studies on testicular degeneration and corrective surgeries.

Material and Methods

Ethical Approval and Animal Selection

This study was conducted in accordance with the ethical guidelines for animal research and approved by the Institutional Animal Care and Use Committee (IACUC) of King Faisal University. Five healthy equids comprising two horses and three donkeys, ranging in age from 5 months to 17 years and weighing 120-350 kg, were selected for this study. All animals underwent thorough clinical examination including complete blood count, serum biochemistry, and ultrasonographic confirmation of normally descended testes prior to inclusion. The animals were stratified into two age groups for analysis: juveniles (5-7 months, n=2) and adult (>2 years, n=3).

Preoperative Preparation

Prior to surgery, animals were fasted for 12-24 hours for solids and 4-6 hours for water to reduce abdominal pressure during the procedure.

Premedication was administered using xylazine (0.5 mg/kg IV) for sedation and analgesia. General anesthesia was induced with sodium thiopental (5 mg/kg IV) via jugular catheter, a protocol selected based on its rapid onset and established use in equine laparoscopy. Anesthesia was maintained with isoflurane (1.5-2% in oxygen) using mechanical ventilation with tidal volumes of 10-15 mL/kg.

Surgical Procedure

For the surgical procedure, animals were positioned in dorsal recumbency with a 15° Trendelenburg tilt to facilitate abdominal organ displacement. The ventral abdomen was aseptically prepared by clipping and scrubbing with chlorhexidine (4%) and alcohol (70%). Laparoscopic equipment included a 10-mm 30° rigid laparoscope (Karl Storz®) and atraumatic graspers. The primary 10-mm port was established at the umbilicus using an open technique, followed by abdominal insufflation with CO₂ to maintain intra-abdominal pressure between 10-13 mmHg using an electronic insufflator.

The cryptorchidism induction procedure began with a scrotal incision to expose the testis, spermatic cord, and cremaster muscle. The deep inguinal ring was manually dilated using blunt technique with the index finger under laparoscopic visualization. The testis was then gently retracted into the abdominal cavity while maintaining direct visualization to avoid vascular trauma. The external inguinal ring was closed with 2-0 poliglecaprone (Monocryl®) in a continuous pattern. Complete intra-abdominal testis positioning was confirmed laparoscopically before closure. The procedure is illustrated in Figure 1. Although the internal inguinal ring (IIR) was visualized laparoscopically, no direct suturing was performed at this level. Closure of the external inguinal ring using 2-0 poliglecaprone was sufficient to prevent testicular descent, based on equine anatomical configuration and the aim of maintaining abdominal retention.

Postoperative Care

Postoperative care included administration of flunixin meglumine (1.1 mg/kg IV every 24 hours for 3 days) for analgesia and ceftiofur (2.2 mg/kg IM every 24 hours for 3 days) as prophylactic antibiotics. Animals were monitored every 6 hours for 48 hours using the EQUUS-FAP pain scoring system, with particular attention to potential complications such as subcutaneous emphysema, surgical site infection, or signs of colic. All animals were maintained in stall rest for 48 hours before being utilized for subsequent cryptorchidectomy procedures.

Data Collection and Analysis

Primary outcome measures included total operative time (from induction of anesthesia to port

closure) and successful testis relocation confirmed laparoscopically. Secondary outcomes assessed intraoperative complications such as hemorrhage or visceral injury, and postoperative morbidity including infection or emphysema. Data were analyzed using descriptive statistics (mean $\pm$ SD) with GraphPad Prism version 9.

Results

All five equids (2 horses, 3 donkeys) successfully underwent the hand-assisted laparoscopic cryptorchidism induction procedure and recovered from anesthesia without immediate complications. The surgical technique proved consistently reproducible across both age groups, with successful testicular relocation achieved in all cases as confirmed by laparoscopic visualization. The mean operative time from induction of anesthesia to final port closure was 52.4 ± 8.3 minutes (range: 43-61 minutes), with juvenile animals requiring slightly less time (47.5 ± 4.9 minutes) compared to adults (55.3 ± 8.1 minutes).

Intraoperative observations revealed that manual dilation of the inguinal canal using the index finger technique provided adequate space for testicular relocation in all subjects. Laparoscopic visualization offered excellent exposure of the deep inguinal ring and permitted real-time monitoring of testicular positioning within the abdominal cavity. No cases of significant hemorrhage or visceral injury were recorded during any procedure. The surgical field remained bloodless throughout all operations, facilitating clear visualization of anatomical structures.

One adult donkey developed moderate subcutaneous emphysema postoperatively, which resolved spontaneously within 24 hours with conservative management. No other postoperative complications were observed, including surgical site infections or signs of systemic illness. All animals maintained normal appetite and vital parameters during the recovery period. Pain scores using the EQUUS-FAP system [24] remained within acceptable limits (median score 4/20, range 3-6) throughout the 48-hour monitoring period, indicating adequate pain control with the administered protocol.

Discussion

The successful development of this laparoscopic-induced cryptorchidism model in equids addresses a significant gap in large animal reproductive research. Although the juvenile group included only two animals, this sample size was deemed appropriate for the model's preliminary validation. The study was designed as a pilot feasibility trial to establish procedural reproducibility, particularly given the ethical and logistical constraints of using large animal models. Therefore, statistical comparisons between age groups were not the primary aim. Future

studies with larger, age-stratified cohorts are necessary to confirm age-related anatomical implications and generalize findings. Our results demonstrate that hand-assisted laparoscopy provides a safe and effective method for testicular relocation, with all five animals achieving successful abdominal cryptorchidism induction. The mean operative time of 52.4 minutes compares favorably with reported durations for laparoscopic cryptorchidectomy in clinical cases (45-75 minutes) [25], suggesting this technique could serve as both a research model and surgical training platform.

The absence of major intraoperative complications aligns with previous reports on equine laparoscopic procedures [26]. Notably, our bloodless surgical field contrasts with open cryptorchidectomy approaches that typically report 10-15% hemorrhage rates [27], highlighting an advantage of minimally invasive techniques. The single case of subcutaneous emphysema (resolving spontaneously) mirrors complication rates (8-12%) reported in other laparoscopic studies [28-30], likely related to CO₂ insufflation rather than the cryptorchidism induction technique itself.

Our findings support the growing evidence that laparoscopy offers superior visualization of equine inguinal anatomy compared to traditional approaches [31, 32]. Given the anatomical depth and relative fixation of the equine IIR, its direct closure was not required. External ring suturing effectively maintained testicular position within the abdomen, consistent with prior approaches in equine laparoscopy. The ability to precisely manipulate the testis while monitoring spermatic vessels in real-time may explain our 100% success rate, outperforming blind manual relocation attempts described in earlier studies [33, 34]. This visual confirmation is particularly valuable for research applications requiring exact testicular positioning.

The age-related differences in operative times (shorter in juveniles) corroborate anatomical studies showing wider inguinal canals in younger equids [35]. This suggests our model may be particularly suitable for studying developmental aspects of cryptorchidism. The low pain scores (EQUUS-FAP median 4/20) [24] postoperatively reinforce the welfare benefits of laparoscopic versus open techniques, which typically require more aggressive analgesia [36].

While this study demonstrates short-term feasibility, it aligns with long-term observations from clinical cryptorchid cases where abdominal testes show predictable degenerative changes [37]. This supports the potential for our model to study testicular pathophysiology without relying on rare clinical presentation.

Conclusion

This study demonstrates that hand-assisted laparoscopic induction of abdominal cryptorchidism in equids is a technically feasible and reproducible model for both surgical training and reproductive research. While the technique offers distinct advantages in visualization and perioperative outcomes compared to conventional approaches, the study's limitations include its small cohort size and the inclusion of both horses and donkeys, which may affect the model's generalizability. Limitations of the current study include the small number of juvenile animals and absence of long-term histological follow-up, which are critical for assessing testicular viability and translational application. Future investigations should focus on longitudinal assessments of testicular changes, standardization across homogeneous populations, and direct comparisons with naturally occurring cryptorchid cases to fully establish the model's translational value.

Acknowledgments

The author's sincere acknowledgment to the Deanship of Scientific Research at King Faisal University for the continuous support.

Funding statement

This study was supported through the Annual Funding track by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Proposal Number: KF253936].

Declaration of Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical of approval

The study adhered to ARRIVE 2.0 reporting standards and institutional guidelines.

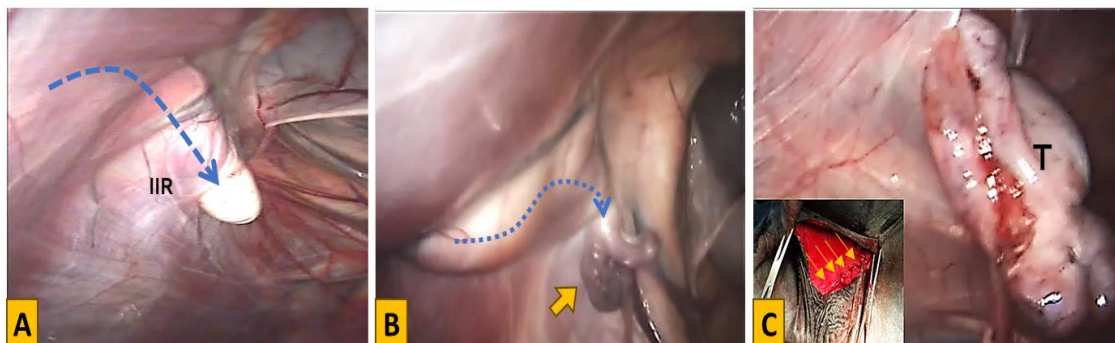


Fig. 1. A) Blunt dissection of the external inguinal orifice by advancing the index finger caudally through the inguinal canal to the internal inguinal orifice (IIR); B) Retraction of the testicle through the canal into the abdominal cavity (yellow arrow = spermatic cord); C) Testis positioned within the abdominal cavity. This figure illustrates the induction of the cryptorchid condition, not surgical correction. No pre-existing testicular damage was present.

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استحداث وتقييم نموذج الخصية المعلقة البطنية المحقزة في الخيول باستخدام المنظار الجراحي

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الملخص

هدفت هذه الدراسة إلى تطوير وتقييم تقنية منظارية بمساعدة اليد لتحفيز حالة الخصية المعلقة البطنية في الخيول كنموذج جراحي جديد. خضع خمس حيوانات سليمة (حصانان وثلاثة بغال) تتراوح أعمارها بين 5 أشهر و 17 عاماً لإجراءات معيارية تحت التخدير العام. اشتملت التقنية على إعادة وضع الخصية إلى البطن عبر القناة الأربية الموسعة يدوياً تحت التوجيه المنظاري، مع التأكيد على الموقع البطني وإغلاق الفتحة الأربية الخارجية. اكتملت جميع العمليات بنجاح بمتوسط زمن جراحي 52.4 ± 8.3 دقيقة، مما يُظهر قابلية تكرارية عالية عبر الفئات العمرية. احتاجت الحيوانات الصغيرة (47.5 ± 4.9 دقيقة) وقتاً أقل من البالغة (55.3 ± 8.1 دقيقة)، مما يعكس الاختلافات التشريحية في تطور القناة الأربية. مكّنت الرؤية المنظرية من معالجة دقيقة للخصية دون حدوث نزيف أو إصابات أحشائية في جميع الحالات. تمثلت المضاعفات الوحيدة في حالة واحدة من انتفاخ تحت الجلد تم حلها تلقائياً. ظلت درجات الألم بعد الجراحة على مقياس-EQUUS (FAP) منخفضة (متوسط 20/4)، مما يؤكد طبيعة التقنية الباضعة الدنيا. يُقدم هذا النموذج حلاً لمشكلة نقص النماذج الحيوانية الكبيرة في أبحاث الجهاز التناسلي، حيث يوفر منصة معيارية لدراسة الأمراض الخصوية وتحسين علاجات الخصية المعلقة. على الرغم من النتائج الواعدة، فإن القيود تشمل صغر حجم العينة وتنوع الأنواع. تُوصي الدراسات المستقبلية بإجراء تقييمات نسجية طويلة المدى للتغيرات الخصوية ومقارنة النتائج مع الحالات الطبيعية للخصية المعلقة. تقدم هذه الطريقة المنظرية مزايا كبيرة مقارنة بالتقنيات المفتوحة، بما في ذلك تحسين الرؤية الجراحية وتقليل المضاعفات، مع تطبيقات محتملة في برامج التدريب الجراحي..

الكلمات الدالة: منظار البطن الجراحي، الخصية المعلقة، الخيول، نموذج جراحي.