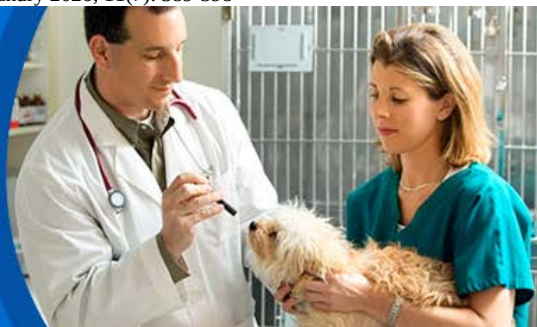




International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912

NAAS Rating (2026): 4.61

VET 2026; 11(7): 389-398

© 2026 VET

www.veterinarypaper.com

Received: 16-04-2026

Accepted: 20-05-2026

Naiknaware VS

Department of Veterinary
Gynaecology and Obstetrics,
College of Veterinary Science &
Animal Husbandry, amdheni
University, Anand, Gujarat,
India

Parmar KH

Department of Veterinary
Gynaecology and Obstetrics,
College of Veterinary Science &
Animal Husbandry, amdheni
University, Anand, Gujarat,
India

Optimization of reproductive potential in mare: A review

Naiknaware VS and Parmar KH

DOI: <http://doi.org/10.22271/veterinary.2026.v11.i7f.3659>

Abstract

The mare occupies a unique position among domestic livestock due to its historical and contemporary roles in agriculture, sports and breeding industries. Despite advances in equine reproductive technologies, reproductive efficiency in mares remains comparatively low, making optimization of fertility a critical concern for economic sustainability and genetic progress. Declining equine populations, particularly in India, further emphasize the importance of improving reproductive performance through scientific interventions. Mare reproduction is inherently complex, being influenced by seasonal breeding patterns, hormonal regulation and follicular dynamics. The estrous cycle is characterized by follicular waves, precise endocrine interplay and tightly regulated ovulatory mechanisms. Accurate prediction of ovulation through transrectal palpation and ultrasonography is essential for optimizing breeding timing and improving conception rates. However, multiple intrinsic and extrinsic factors are contributed to subfertility in mares. Intrinsic factors include age-related decline, infectious conditions and structural abnormalities. Persistent breeding-induced endometritis (PBIE) is a major cause of infertility, resulting from impaired uterine clearance mechanisms and extrinsic factors like poor management practices, subfertile stallions and logistical constraints further exacerbate reproductive inefficiency. The breeding evaluations, synchronization and artificial insemination provides a comprehensive framework that is essential for maximizing genetic potential and herd fertility. Techniques such as artificial insemination (AI), embryo transfer (ET) and intracytoplasmic sperm injection (ICSI) have revolutionized equine reproduction, allowing enhanced genetic dissemination and improved reproductive outcomes. Estrus synchronization protocols using altrenogest, prostaglandins and ovulation inducing agents like deslorelin enable precise breeding management. Diagnostic approaches including uterine cytology, culture, endometrial biopsy and ultrasonography are essential for identifying underlying reproductive disorders. Therapeutic management focuses on improving uterine health through lavage, ecboics, antibiotics and emerging therapies i.e. platelet-rich plasma and biofilm disruptors and also the surgical interventions like Caslick's procedure are crucial in correcting anatomical defects. In conclusion, optimizing reproductive potential in mares requires a comprehensive, multidisciplinary approach combining physiology, pathology, prediction of ovulation, artificial insemination and farm management practices. Such strategies are essential for enhancing fertility, improving foal crop and ensuring sustainability of the equine industry. Future prospects emphasize precision breeding using artificial intelligence driven ovulation prediction systems, genetic evaluation of fertility traits and development of cost-effective, breed-specific reproductive strategies. Integration of advanced diagnostics with evidence-based therapeutic protocols holds promise for improving reproductive efficiency in mares.

Keywords: Mare fertility, equine reproduction, artificial insemination, estrus synchronization, reproductive management, uterine health

1. Introduction

Horses are utilized in sport, racing, agriculture, military and recreational sectors and the capacity to produce healthy foals reliably underpins the commercial viability of breeding operations worldwide. Although their practical role has evolved substantially in contemporary times, their biological and reproductive efficiency remains vital for sustaining the equine industry across diverse sectors (Outram *et al.*, 2009) ^[1].

Infertility is the most common reproductive complaint reported by horse owners and breeders. Decreased pregnancy rates can also be attributed to logistical problems such as inappropriately timed breeding relative to ovulation, limited stallion availability (as in Thoroughbred natural service) or restricted semen availability when using cooled-transported semen (McCue *et al.*, 2015) ^[2, 3]. Fertility is defined as the ability to produce a live foal. Infertility is a temporary inability to reproduce, whereas subfertility refers to the inability to reproduce at full potential and

Corresponding Author:

Naiknaware V. S.

Department of Veterinary
Gynaecology and Obstetrics,
College of Veterinary Science &
Animal Husbandry, amdheni
University, Anand, Gujarat,
India

May be temporary or permanent (Morrell *et al.*, 2008) ^[4].

1.1 History

Early 20th Century (1900s-1930s)

Early Artificial Insemination (AI) the foundational techniques for equine AI including semen collection, processing and insemination were pioneered to facilitate the distribution of valuable genetics and improve biosecurity, circumventing the geographical limitations of live cover. By the 1930s, the development of the artificial vagina significantly improved the efficiency of stallion collection. (Ivanov, 1998) ^[5]

1970s - First Successful Equine Embryo Transfer (ET): The first successful documented cases occurred in the 1970s. This breakthrough allowed valuable, actively competing or subfertile mares to produce multiple foals per season without interrupting their athletic careers. (Oguri & Tsutsumi, 1974) ^[6]

Early 1980s - Transrectal Ultrasonography: The introduction of real-time B-mode transrectal ultrasonography revolutionized equine reproductive management (Palmer *et al.*, 1983) ^[7]. It enabled precise visualization of follicular dynamics, accurate prediction of ovulation and early pregnancy diagnosis, fundamentally optimizing the timing of AI and ET protocols.

1988 - Oocyte Transfer (OT): The first successful equine oocyte transfer was reported, providing an alternative assisted reproductive technology (ART) for infertile donor mares with patent oviducts, cervical lacerations or severe uterine pathology. Oocytes were aspirated from preovulatory follicles and surgically transferred into the oviduct of an artificially inseminated recipient mare (McKinnon *et al.*, 1988) ^[8].

1996 - The successful production of an equine embryo and subsequent foal via ICSI bypassed the need for conventional *in vitro* fertilization (IVF), which had historically failed in equines due to unique zona pellucida hardening and sperm capacitation barriers (Squires *et al.*, 1999) ^[9].

Late 1990s - The successful adaptation of flow cytometry for sorting equine spermatozoa by X and Y chromosome bearing populations allowed breeders to predetermine the sex of the foal. When combined with low dose AI or ICSI, this maximized the utility of sexed semen despite its reduced longevity and compromised motility post-sorting (Buchanan *et al.*, 2000) ^[10].

Current Scenario

Modern equine ART relies on altrenogest and *PGF2 alpha* for precise estrus synchronization, alongside domperidone to break anestrus, following hCG/deslorelin-induced ovulation, mitigating persistent breeding-induced endometritis utilizing lavage, ecobolics and immunomodulators is essential to optimize the uterine environment for conception and embryo survival (Khan *et al.*, 2025) ^[11].

2. Reproduction in mare

2.1 Reproductive anatomy

Ovaries (paired): The primary gonads responsible for follicle growth, estrogen secretion via follicular granulosa and theca cells. The mare's ovary is uniquely kidney-shaped and ovulates exclusively from the ovulation fossa, a depression located on the ventro-medial surface. Oviducts (Fallopian tubes): Connect each ovary to the respective uterine horn. Site of fertilization in the mare. The infundibulum (funnel-shaped opening) captures the released oocyte. Uterus: Consists of two uterine horns and a uterine body. It is the primary site for embryonic and foetal growth and maturation. A major source of *PGF2α* which triggers luteolysis at the end of diestrus in the nonpregnant mare. Cervix: Anatomical junction between the uterus and

vagina. Vagina: A muscular, fibromuscular tube connecting the external genitalia with the internal reproductive tract. The vagina maintains a second line of defense (the vestibulovaginal seal) against environmental contamination. Vulva: Consists of the vulvar lips (labia) and the clitoris. Proper vulvar conformation - with the labia positioned vertically and aligned with the anal opening - is essential for maintaining reproductive health (Aboelmaaty *et al.*, 2024) ^[12].

2.2 Reproductive physiology

The mare is classified as a seasonally polyestrous, long-day breeder. Reproductive cyclicity is governed primarily by photoperiod (day length), with active cycling during spring and summer when days are long. The mare has an average estrous cycle length of 21 days, with a normal range of 18 to 24 days. The follicular phase (estrus), during which the mare is receptive to breeding, typically lasts 4 to 7 days, while the luteal phase (diestrus) extends for approximately 17 days. A distinctive feature of equine reproduction is the prolonged elevation of luteinizing hormone (LH), which persists for 6 to 10 days, unlike the shorter LH surge observed in cattle. Ovulation generally occurs when the dominant follicle reaches a diameter of 35 to 50 mm, with follicles growing at a rate of about 2 to 3 mm per day. The gestation length in mares ranges from 335 to 342 days, averaging approximately 340 days. Puberty is usually attained between 12 and 18 months of age, depending on factors such as breed, nutrition and management. The hormonal regulation of the estrous cycle involves a precisely coordinated interplay between the hypothalamus, anterior pituitary, ovaries and uterus. GnRH from the hypothalamus stimulates FSH and LH release from the anterior pituitary; ovulation follows the LH surge; the corpus luteum produces progesterone during diestrus; and at the end of diestrus, the endometrium releases *PGF2α* causing luteolysis and initiating a new cycle (Khan *et al.*, 2025) ^[11].

2.3 Mechanism of seasonal breeding

Seasonal breeding pattern is primarily controlled by light perception and the hormonal regulation through the hypothalamic-pituitary-gonadal (HPG) axis. The cascade of events proceeds as follows: Increased day length in spring is detected by photoreceptors in the retina of the eye. The light signal is transmitted to the brain via the retinohypothalamic tract. Signals reach the suprachiasmatic nucleus (SCN) of the hypothalamus - the biological clock. From the SCN, the signal passes through the superior cervical ganglion (sympathetic nervous system). These signals reach the pineal gland. Normally, melatonin is secreted during darkness; when day length increases, pineal melatonin secretion is suppressed. Low melatonin levels stimulate the hypothalamus to increase GnRH secretion. GnRH acts on the anterior pituitary, which releases FSH and LH. FSH and LH act on the ovaries, resulting in follicular development, estrogen production and ultimately ovulation. Rising estrogen levels induce behavioural estrus - the mare becomes receptive to the stallion and capable of conception (Khan *et al.*, 2025) ^[11]

2.4 Follicular wave dynamics and the estrous cycle

Follicular development occurs in a wave-like pattern, driven by pulsatile FSH secretion. The sequential phases are: Recruitment: Under the influence of FSH, a cohort of small antral follicles (5–mm) begin to grow simultaneously from the ovarian pool. This marks the beginning of a follicular wave. Deviation: As the cohort grows, one follicle - the future dominant follicle - begins to grow slightly faster and larger than

the others (typically around 22-25 mm). At this point of 'deviation', the dominant follicle acquires greater sensitivity to LH and begins to suppress FSH through inhibin secretion. Dominance: The selected dominant follicle continues to grow (2-3 mm/day) to pre-ovulatory size (35-50 mm), producing increasing amounts of estradiol (E2). Subordinate follicles, deprived of FSH support, undergo atresia and degenerate. CL and Luteal Phase: If the previous cycle's dominant follicle ovulated and fertilization did not occur, the corpus luteum (CL) secretes progesterone throughout diestrus, suppressing overt estrous behaviour while follicular waves may continue. *PGF2α* and Luteolysis: At approximately day 14-of the cycle, the endometrium releases *PGF2α*, which causes functional and structural regression of the CL (luteolysis), with a consequent decline in progesterone. Pre-ovulatory Phase: As progesterone falls, the dominant follicle's estrogen production drives the LH surge. The follicle reaches maximum size, and the mare enters behavioural estrus. Ovulation: The LH surge triggers follicular rupture and release of the oocyte from the ovulation fossa, marking the beginning of a new cycle (Aboelmaaty et al., 2024) [12].

3. Importance of reproductive optimization in mare

Compared to other livestock, horses exhibit lower reproductive efficiency (Katila et al., 2010) [13] and as seasonal breeders, their reproductive performance is influenced by factors such as photoperiod, hormonal cycles, and age (Khan et al., 2025) [11]. Reproductive traits have a disproportionately high impact on profitability-estimated to be 3 to 9 times greater than other production traits (McCue et al., 2015) [2, 3]. Reproductive disorders further contribute to significant economic losses by reducing fertility, prolonging foaling intervals, decreasing lifetime production, and increasing breeding as well as treatment costs (Ravi et al., 2013) [14]. Despite advancements in equine reproductive technologies, subfertility remains a major constraint in mare breeding programs, with contributing factors including persistent breeding-induced endometritis, uterine infections, improper timing of insemination and inadequate estrus detection, all of which lead to reduced conception rates and economic losses (McCue et al., 2015) [2, 3]. Therefore, comprehensive breeding soundness evaluation, along with advanced diagnostic, microbiological and reproductive management strategies, is essential for identifying underlying causes of subfertility and implementing targeted interventions (Ravi et al., 2013) [14].

4. Current challenges in mare reproduction

Extrinsic factors

Management Issues: Lack of use of the mare or poor reproductive management. Stallion Factors: Use of a sub-fertile stallion. Logistical Constraints: Imposed breeding seasons and limited semen availability. Intrinsic Factors - Age: Fertility decline at approximately 12 years; mares ≥ 15 considered aged. Infectious Causes: Bacterial, viral, fungal or protozoal infections. Non-Infectious Causes: Divided into structural (anatomical) and functional abnormalities. Infectious Causes- Endometritis: Persistent Post-Breeding Endometritis (PBIE): Failure to clear uterine fluid and inflammatory by-products within 48 hours of mating (Fedorka et al., 2023) [15]. Chronic Infectious Endometritis: Caused by pathogens such as *Streptococcus zooepidemicus*, *E. coli* or *Pseudomonas* (Rocha et al., 2026) [16]. Fungal Endometritis: Often associated with the overuse of antibiotics or anatomical defects (e.g., *Candida*, *Aspergillus*) (Fedorka et al., 2023) [15]. Vaginitis & Cervicitis:

Inflammation often resulting from difficult labor (dystocia) or chronic contamination (Rocha et al., 2026) [16]. Salpingitis: Inflammation of the oviducts; if bilateral, it results in permanent sterility (Rocha et al., 2026) [16].

Endometrial Cysts

Fluid-filled structures (lymphatic or glandular) that may interfere with embryo migration or mimic early pregnancy (Rocha et al., 2026) [16].

Non-Infectious Structural Defects-Pneumovagina: If the closure of the vulva is compromised by poor perineal conformation - particularly in aged, multiparous, or thin mares - the vulva angles cranially and dorsally, drawing the anus over the tuber ischii. This results in aspiration of air, bacteria and faecal material into the vestibule and vagina, a condition termed pneumovagina or 'wind-sucking' (Canisso et al., 2020) [17]. Contamination of the caudal reproductive tract leads to vaginitis, cervicitis and acute then chronic endometritis, ultimately causing subfertility or embryonic death. Pneumovagina can develop or worsen during estrus when perineal tissues are most relaxed. Urovagina (Urine Pooling): In mares with poor perineal conformation or relaxed vestibulovaginal sphincters, urine accumulates in the vagina rather than being efficiently voided. The caustic, alkaline urine causes persistent chemical irritation of the vaginal mucosa, leading to vaginitis, cervicitis and ultimately endometritis. Uroscalding of the perineal skin and a characteristic pooling of urine in the cranial vagina on speculum examination are diagnostic features (Canisso et al., 2020) [17]. Cervical Defects: The cervix must function as a dynamic barrier - remaining firmly closed during diestrus, pregnancy and anestrus, while relaxing appropriately during estrus and parturition. Cervical lacerations (commonly acquired during foaling) result in a chronically incompetent cervix that fails to close completely, allowing bacterial contamination of the uterus. Conversely, cervical stenosis (narrowing or adhesions) prevents adequate drainage of uterine fluid, predisposing to endometritis (Fedorka et al., 2023) [15].

Persistent Hymen

The hymen may be a complete or partial tissue wall separating the vagina and vestibule. In most mares, it is ruptured at breeding or disrupted manually during artificial insemination. Occasionally, the hymen is very thick and accumulates significant secretions behind it. If not disrupted, it can interfere with breeding, cause accumulation of uterine secretions (hydrocolpos) and require surgical intervention for correction (Canisso et al., 2020) [17].

Functional abnormalities

Haemorrhagic Anovulatory Follicle (HAF): The most common cause of ovulatory failure is haemorrhage of the dominant follicle, producing a haemorrhagic anovulatory follicle (HAF). Approximately 90% of anovulatory follicles become luteinized (McCue & Squires, 2015) [2, 3]. The dominant follicle fails to collapse, instead filling with blood that initially remains unclotted due to anticoagulant factors in equine follicular fluid. Over time, blood clots and forms a fibrin scaffold allowing granulosa and theca cells to invade and luteinize. Pseudopregnancy: If prostaglandin release is inadequate or fails - due to embryonic loss after the time of maternal recognition of pregnancy, diestrus ovulations or severe uterine pathology - the CL persists beyond its normal

lifespan, producing progesterone and preventing return to estrus. This condition can last 2–3 months (Ginther, 2024) [18]. Granulosa Cell Tumour (GCT): Equine ovarian neoplasms, typically unilateral, slow-growing and benign. They produce inhibin (suppressing FSH from the anterior pituitary and rendering the contralateral ovary small and inactive), testosterone (causing stallion-like aggressive behaviour in some mares). Anti-Müllerian hormone (AMH) concentration ≥ 4 ng/mL is a valuable serum diagnostic marker (Ali et al., 2025) [19].

Abortion in Mare

Infectious causes Viral causes: Equine Herpesvirus-1 (EHV-1): Placentitis, vasculitis and fetal infection (last trimester). Fungal causes: (e.g., *Aspergillus*) Results in thickened, necrotic placenta with fungal plaques, which interfere with nutrient and oxygen exchange to the fetus. Bacterial causes: (e.g., *Streptococcus*, *Klebsiella*, *Salmonella*, *E. coli*): infects the placenta and fetus, leading to placentitis and fetal death (mid to late gestation) (LeBlanc et al., 2022) [20]. Genetic Causes: Twinning is responsible for up to 40% of abortions in some herds. High abortion incidence noted during 7th-8th months of gestation (Rocha et al., 2026) [16]. Hormonal causes: Progesterone deficiency due to inadequate support from corpus luteum or placenta. (Aboelmaaty et al., 2024) [12]. Fescue toxicosis and ergot alkaloids interfere with late-pregnancy hormone levels (Aboelmaaty et al., 2024) [12]. Other causes: Umbilical cord torsion, mycotoxins and fungal endophytes (e.g., *Neotyphodium coenophialum*) Poor placental health like thickened, edematous placentas and agalactia (Aboelmaaty et al., 2024) [12].

5. Components for optimization of breeding in mares

5.1 Perineal conformation assessment

Assessment of perineal conformation is an essential first step in any breeding soundness examination of the mare. It evaluates the functional integrity of the first physical barrier of the reproductive tract - the vulva and perineal region. Defects in perineal conformation predispose the mare to pneumovagina, faecal contamination and persistent endometritis (Talluri et al., 2017) [21]. The Caslick's Index provides an objective, reproducible measurement of perineal conformation by calculating the percentage of the vulvar cleft lying above the ischial arch (pelvic floor). If more than 50-75% of the vulvar cleft lies above the pelvic floor or if the vulvar angle exceeds 10° from vertical, the mare is at significant risk of pneumovagina and Caslick's vulvoplasty (episioplasty) is recommended. Assessment includes: Visual inspection of the vulva, perineum and anus for vertical alignment and labial integrity. Measurement of the length of vulvar cleft above and below the ischial arch. Assessment of anus position relative to the tuber ischii. Evaluation of labial tone and mucosal condition. Assessment for evidence of previous Caslick's surgery or perineal lacerations.

Surgical correctio

Episioplasty (Caslick's Procedure): Episioplasty is the most commonly performed surgical procedure in equine reproduction. Performed under local anaesthesia (lidocaine 5-10 mL per side deposited at the mucocutaneous junction), it involves excision of a narrow strip of tissue at the mucocutaneous junction of the dorsal vulvar lips, followed by suturing the cut edges (absorbable suture in a continuous or interrupted pattern). The vulva is closed from the dorsal

commissure to a point 1-2 cm ventral to the ischial arch, leaving a 3-4 cm ventral opening for urination. The mare must be reopened (vulvoplasty reversal) prior to foaling to prevent dystocia. When Caslick's procedure fails to prevent urovagina, urethral extension procedures (Brown technique or McKinnon technique) are indicated.

5.2 Palpation of the reproductive tract

Transrectal palpation of the reproductive tract, often performed in conjunction with ultrasonography, provides essential complementary information about reproductive status. Complete reproductive tract evaluation includes three components: Rectal Palpation (A): Assessment of follicular development and maturation; corpus luteum development and luteal activity; uterine edema pattern and cyclic changes; presence of intrauterine fluid or cysts; and cervical tone and patency. Perineal Evaluation (B): Visual assessment of vulvar conformation, labial tone, mucosal condition and presence of discharges. Assessment of Caslick's status. Vaginal Examination / Vaginoscopy (C): Speculum examination of the vaginal vault, vestibulo-vaginal junction and external os of the cervix. Identifies hyperemia, purulent discharge, cervical lacerations and urovagina. Vaginoscopy, while rapid and simple, may underestimate the true prevalence of endometritis in mares with closed cervixes (McCue et al., 2008) [22].

5.3 Ultrasound evaluation of the mare's reproductive tract

Transrectal ultrasonography using linear-array transducers (5-8 MHz) is the single most important diagnostic tool in equine reproduction. It provides dynamic, real-time visualization of all reproductive organs and enables precise monitoring of the estrous cycle, prediction of ovulation, early pregnancy diagnosis and evaluation of uterine and ovarian pathology. Key sonographic findings include: Dominant Preovulatory Follicle: Anechoic (black) lumen with thin follicular wall and gradual shape change from spherical to pear-shaped or irregular as ovulation approaches; typically, 35-50 mm at ovulation. Haemorrhagic Anovulatory Follicles (HAF): Retain their size post-expected ovulation; fill with echogenic internal fibrin strands; fail to collapse; become progressively more echogenic as luteinization proceeds. Corpus Haemorrhagicum: Forms immediately post-ovulation; shows an echogenic fibrin network within a hypoechoic structure; progressively luteinizes to form a hypoechoic corpus luteum. Estrus Uterus: Classic 'cartwheel' or 'spoked-wheel' endometrial edema pattern due to fluid accumulation between endometrial folds; maximal during estrus; graded 0 (no edema) to 3 (severe edema). Granulosa Cell Tumour: Affected ovary grossly enlarged (>10 cm); classic multicystic or 'honeycomb' appearance; contralateral ovary small and inactive. Uterine Fluid: Small amounts normal during estrus; persistent accumulation in diestrus or post-breeding suggests endometritis; large quantities suggest pyometra or mucometra. Endometrial Cysts: Appear as anechoic, non-mobile structures (unlike the mobile embryonic vesicle) within the endometrium; mapping their size and position on a schematic diagram is essential for monitoring during pregnancy (McKinnon et al., 2011) [23].

5.4 Estrous synchronization and artificial insemination

5.4.1 Why estrus synchronization is necessary

Estrus synchronization - the process of controlling the timing of the estrous cycle through hormonal manipulation - is a cornerstone of modern equine breeding management. Its application extends across multiple clinical scenarios: Embryo

Transfer (ET) Programmes

The uterine environment of the recipient mare must precisely mirror that of the donor. Recipients must ovulate within a defined window (typically ±1 day) relative to the donor to ensure appropriate progesterone priming for embryo survival and implantation.

Optimizing AI with Limited/Frozen Semen

Chilled semen survives approximately 24-48 hours in the mare's reproductive tract; frozen-thawed semen may only be viable for 12 hours. Synchronization with ovulation induction allows precise insemination timing, conserving valuable and expensive frozen semen doses.

The January 1st Advantage

Major breed registries designate

January 1st as a universal birth date in the Northern Hemisphere. To produce foals as early in the calendar year as possible (for size advantage at yearling sales and racing) breeders must use artificial photoperiod and synchronization protocols to advance the first ovulation to February or March.

Clinical Therapy

Hormonal manipulation can 'reset' a dysfunctional reproductive cycle - lysing persistent CLs, managing endometritis or promoting early cycling in transitional mares. Farm Logistics: Synchronizing groups of mares allows 'batching' of breeding events, making veterinary scheduling, semen ordering and breeding operations more efficient (Refaat *et al.*, 2025) ^[24].

5.4.2 Ovulation induction protocols

Table 1: Several hormonal agents are used for ovulation induction, each with distinct mechanisms and clinical advantages:

Agent	Dose and Route	Mechanism	Clinical Notes
hCG (human chorionic gonadotropin)	2,500-3,300 IU IV	Binds LH receptors → stimulates final follicular maturation and ovulation	Ovulation within 24-48 h; antibody formation reduces efficacy after repeated use
Deslorelin	1.5 mg IM	Stimulates	Preferred in mares sensitized to
(GnRH agonist)	(Ovuplant implant or injection)	endogenous LH surge → ovulation	hCG; ovulation within 36-48 h; criteria: follicle ≥35 mm + uterine edema
Combination (hCG + Deslorelin)	Standard doses of both	Synergistic LH stimulation	Research shows no significant advantage over deslorelin aloneKajaysri <i>et al.</i> (2023) ^[25]
PGF2α (luteolysis)	Dinoprost 10 mg IM or Cloprostenol 250 µg IM	Lyses functional CL → return to estrus	U0sed when CL is present (>day 5 of cycle); estrus 3–5 days post-injection
Altrenogest (progestin)	0.044 mg/kg PO daily (Regu-Mate)	Suppresses estrus and ovulation by negative feedback on LH secretion	14-day treatment followed by PGF2α withdrawal → synchronized estrusMckinnon <i>et al.</i> (2011) ^[23]

A critical insight from comparative trials (Refaat *et al.*, 2025) ^[24] is that standard bovine synchronization protocols (Ovsynch: GnRH-PGF2α-GnRH) do not translate effectively to horses due to the greater variability of equine follicular waves. The first GnRH injection does not reliably synchronize follicular development and at the time of the second GnRH injection (designed to trigger ovulation) dominant follicles may not yet be of pre-ovulatory size. Successful synchronization in horses requires individual follicular monitoring via ultrasound, with hormonal interventions timed to follicular status rather than a rigid calendar protocol.

5.4.2 Artificial Insemination: Methods and success rates

Artificial insemination (AI) in the mare encompasses several insemination

methods depending on semen type, stallion fertility and mare reproductive status: Uterine Body Insemination: Standard technique using 0.5-1 L semen volume for fresh or chilled semen; deposition at the uterine body via sterile pipette through the cervix. Deep Horn AI: Insemination of low-dose semen (frozen-thawed or sexed) into the tip of the uterine horn ipsilateral to the ovulating follicle; increases contact between semen and oviduct; particularly beneficial with frozen semen or low sperm numbers.

Hysteroscopic (Endoscopic) AI

Direct visualization and deposition of minimal-dose semen (as few as 1 million progressively motile spermatozoa) at the uterotubal junction; highest efficiency per sperm cell; requires specialized equipment and training.

Table 2: Reproductive Success Rates: India vs Global

Semen Type	India Success Rate	Global Benchmark	Key Insights	Reference
Fresh Semen	37.5%	75–85%	CASA now the reference standard for objective kinematic evaluation, replacing subjective visual scoring	ICAR-NRCE (2024)
Chilled Semen (4 °C)	58–68%	70–80%	Advanced extenders (e.g., OviPlus) maintain superior membrane integrity and motility for 48–96h	Janett <i>et al.</i> (2012) ^[26]
Frozen-Thawed	42–52%	55–65%	Cryocapacitation necessitates shortened pre-incubation (9h) for success with frozen doses	Uhlmannsiek, (2022) ^[46]
Deep Horn AI	50–60%	65%	Arabian mares: 57.9% PR, significantly linked to follicle diameter >47 mm at time of insemination	Yendim <i>et al.</i> (2025) ^[27]
Embryo Transfer	55–65%	70%	Up to 74% blastocyst production via optimized IVP protocols in indigenous lineages	Janett <i>et al.</i> (2012) ^[26]

5.5 Diagnostic approaches

5.5.1 Uterine culture collection

Uterine microbiological culture is a standard component of breeding soundness examination and infertility workup.

Samples are collected during early estrus (when the cervix is relaxed and open) using a double-guarded culture swab or cytobrush, introduced through the cervix under strict aseptic conditions to prevent contamination. Common uterine

pathogens include *Streptococcus equi* subsp. zooepidemicus (most common), *Escherichia coli* (second most common), *Klebsiella* spp., *Pseudomonas aeruginosa* and various fungi (Rocha *et al.*, 2026) [16]. Bacterial growth is typically evident within 24-48 hours; yeast cultures may require several days. Samples are considered positive if four or more colonies of recognized pathogens are isolated (McCue *et al.*, 2015) [2, 3].

5.5.2 Uterine lavage and endometrial cytology

Low-volume uterine lavage (LVL) using 60-120 mL of sterile physiological saline or lactated Ringer's solution provides a representative sample of the entire uterine lumen for cytological evaluation. This technique is significantly more sensitive than conventional swabbing for detection of subclinical endometritis. Cytological evaluation focuses on: Percentage of polymorphonuclear neutrophils (PMNs) among all cells counted (minimum 100 cells at $\times 1000$ magnification): $\leq 5\%$ = no inflammation; 5–15% = mild; 15–30% = moderate; $\geq 30\%$ = severe (Card, 2005). Identification of bacteria (cocci, bacilli, coccobacilli) - free or phagocytized within PMNs. Presence of

fungal organisms - yeast or hyphal elements. Amount and character of cellular debris

5.5.3 Endometrial biopsy - Kenney-doig grading system

Endometrial biopsy is the most definitive histological diagnostic tool for evaluation of endometrial health and prognosis for future reproductive performance. A small tissue sample is collected from the uterine body using an alligator-jaw biopsy instrument, fixed in Bouin's or 10% buffered formalin and examined histologically after H&E staining. The Kenney-Doig grading system (Kenney & Doig, 1986) [28] categorizes the endometrium based on: Degree and distribution of inflammatory infiltrates (PMNs in acute disease; lymphocytes, plasma cells in chronic disease). Extent of fibrosis (endometrosis) number of fibroblast layers surrounding endometrial glands; presence of 'glandular nests' (periglandular fibrosis with gland distension). Degree of glandular degeneration and dilatation.

Table 3: Kenney–Doig Grading and Estimated Foaling Rate

Kenney-Doig Grade	Histological Findings	Estimated Foaling Rate
Grade I	Normal endometrium. Minimal, focal, non-significant changes. No fibrosis, no significant inflammation.	80-90%
Grade IIA	Mild to moderate, multifocal inflammation. Mild periglandular fibrosis with <2 fibrotic nests per 5 mm field at $\times 100$ magnification.	50-80%
Grade IIB	Moderate, diffuse inflammation. Moderate periglandular fibrosis with 2–4 fibrotic nests per 5 mm field. Evidence of glandular nesting.	10-50%
Grade III	Severe, diffuse inflammation and/or extensive periglandular fibrosis. >5 fibrotic nests per 5 mm field. Severe glandular degeneration. This change is PERMANENT.	<10%

5.5.4 Comparison of diagnostic methods

Table 5: Comparison of Endometrial Sampling Methods

Parameter	Uterine Swab	Cytological Brush	Endometrial Biopsy
Primary Objective	Routine culture / cytology	Enhanced surface collection	Gold standard histology
Pathogen Isolation Rate	33% (highest for culture)	25%	25%
Cytology Sensitivity	0.00	0.17	0.25
Cytology Specificity	0.93	0.83	0.85
Culture Sensitivity	0.33	0.25	0.25
Culture Specificity	0.83	0.80	0.95
Combined Sensitivity (Culture+Cytology)	Moderate	0.42 (best combined)	Moderate

(de Amorim *et al.*, 2016) [29]

5.5.5 Ovarian and endocrine diagnostics

Transrectal ultrasonography with Colour and Power Doppler provides dynamic assessment of follicular vascularity (blood

flow), corpus luteum function and endometrial haemodynamics beyond what is possible with conventional B-mode imaging alone. Doppler applications in equine reproduction:

Table 6: Clinical Applications of Doppler Ultrasonography in Mares

Application	Key Doppler Finding	Clinical Utility	Reference
Ovulation Prediction	Decreased % of follicular wall circumference with color Doppler signals 4-1 h pre-ovulation	Non-invasive, highly specific sign of imminent ovulation	Gastal <i>et al.</i> (2011) [30]
CL Function Assessment	High pre-ovulatory follicular wall blood flow $\rightarrow$ highly functional CL	Predicts adequacy of post-ovulation progesterone production	
Early Pregnancy Diagnosis	Pregnant mares differentiated from non-pregnant at 8 days post-ovulation via power Doppler	Earliest currently available non-invasive pregnancy test	Nieto-Olmedo <i>et al.</i> (2020) [31]
Recipient Selection (ET)	Higher CL vascularity scores $\rightarrow$ significantly higher pregnancy maintenance rates	Improves recipient selection, reducing ET wastage	Pugliesi <i>et al.</i> (2014) [32]
PBIE Susceptibility	Higher BFV before insemination; higher PI after insemination in susceptible mares	Identifies at-risk mares before breeding for prophylactic treatment	Lüttgenau <i>et al.</i> (2021) [44]

Endocrine assays

Hormone measurement provides critical information for diagnosis of reproductive abnormalities and monitoring of treatment response: Progesterone (P4): Values >4 ng/mL indicate a functional CL (diestrus or pregnancy). Values <1 ng/mL indicate estrus or anestrus. A persistent P4 >4 ng/mL in a non-pregnant mare >days after ovulation indicates pseudopregnancy, retained CL or diestrus ovulation. Anti-Müllerian Hormone (AMH): Normal range 0.2-2.9 ng/mL. High ovarian reserve: above 3-4 ng/mL. AMH ≥14 ng/mL is diagnostic for Granulosa Cell Tumour (the only source of AMH in the mare is ovarian granulosa cells). Also used to assess ovarian reserve in subfertile mares (Squires, 2008) [33]. Estradiol-β (E2): Elevated during estrus (follicular phase); useful for monitoring follicular activity in seasonally anestrus mares. Inhibin: Markedly elevated in mares with Granulosa Cell Tumours, in conjunction with elevated AMH and testosterone and suppressed FSH (Squires, 2008) [33]

5.5.6 Diagnostic approach to abortion

When abortion occurs, a systematic diagnostic approach is essential to identify the cause, assess the risk to other mares on the property, implement appropriate biosecurity measures and prevent future reproductive losses. Ante-partum monitoring tools include. CTUP Measurement (Transrectal

Ultrasonography): The combined thickness of the uterus and placenta (CTUP) at the cervical pole is the most critical early indicator of ascending placentitis. Normal values: <7-8 mm at days 271-300; <10 mm at days 301-330; <12 mm beyond day 330. Thickening, separation or hyperechoic fluid accumulation at the cervical star indicates immediate medical intervention (Kimura *et al.*, 2018) [34]. Fetal Biometry and Echocardiography (Transabdominal Ultrasonography): Evaluates fetal distress via heart rate monitoring (normal 70-90 bpm; bradycardia indicates severe distress) aortic diameter measurement and assessment of amniotic and allantoic fluid echogenicity for meconium staining or inflammatory debris preceding abortion (Bucca *et al.*, 2005) [35]. Postabortion Examination: Complete examination of the fetus, fetal membranes and placenta is essential. Samples should be submitted for virology (EHV, EAV) bacteriology, mycology, histopathology and where indicated, karyotyping.

5.6 Therapeutic management

5.6.1 Uterine clearance protocols

The cornerstone of treatment for susceptible mares is the physical elimination of inflammatory debris, bacteria, and excess fluid from the uterus following breeding. This is achieved through two primary mechanisms: uterine lavage (mechanical removal) and ecboic therapy (pharmacological stimulation of myometrial contractions):

Table 7: Treatment Protocols and Conception Rates in Mares

Protocol	Dosage / Regime	Mares (n)	Conception Rate	Reference
Large-Volume Lavage (Saline 0.9%/LRS)	1-3 L IU; start 4 h post-breeding; 1-2 days	968	55.47%	Karam <i>et al.</i> (2021) [36]
Lavage + Oxytocin	1-3 L IU + Oxytocin 10–20 IU IM	968	85.02%	
Ecboics (Oxytocin, Cloprostenol, Carbetocin)	Oxytocin 10-20 IU IM; q4–6h for 1-2 days	220	24.09%	Katila & Ferreira-Das, (2022) [43]
Lavage + Oxytocin + Intrauterine Antibiotic	Lavage + Ecboic + IU antibiotic; 2-3 days	30	83.33%	Chaudhari <i>et al.</i> (2025)

5.6.2 Systemic antibiotic therapy

Systemic antibiotic therapy is increasingly preferred over intrauterine infusions to avoid chemical endometritis (uterine irritation from direct antibiotic instillation). Systemic therapy achieves uterine tissue levels above the minimum inhibitory

concentration (MIC) for target pathogens through haematogenous distribution. Antimicrobial sensitivity testing is mandatory to ensure appropriate antibiotic selection (LeBlanc *et al.*, 2022) [20].

Table 8: Antibiotic Treatment Protocols and Conception Rates in Mares

Protocol	Mechanism	Mares (n)	Conception (No.)	Conception (%)
Trimethoprim-Sulfonamide (TMS) 30 mg/kg PO	Dual blockade: blocks dihydropteroate synthase + dihydrofolate reductase; bactericidal	40	20	50.00%
TMS + Oxytocin 20 IU IM	TMS + myometrial contraction for clearance	15	11	73.33%
Ceftiofur Crystalline Free Acid 6.6 mg/kg IM	3rd-generation cephalosporin; inhibits cell wall synthesis; broad-spectrum; maintains uterine MIC for 6 days	35	23	65.71%
Ceftiofur + Uterine Lavage	Antibiotic + mechanical clearance synergy	20	15	75.00%
Procaine Penicillin G 22,000 IU/kg IM	β-lactam; cell wall synthesis inhibition; mainly Gram-positive coverage	25	11	44.00%
Enrofloxacin 5 mg/kg PO	Fluoroquinolone; inhibits DNA gyrase; Gram-negative spectrum	12	7	58.33%
Enrofloxacin + Oxytocin 20 IU	Fluoroquinolone + ecboic	10	7	70.00%
Marbofloxacin 2 mg/kg IV	Fluoroquinolone; good penetration of uterine tissue	15	8	53.33%

(LeBlanc *et al.*, 2022) [20].

5.6.3 Intrauterine antibiotic infusion

Intrauterine (IU) infusion delivers high local concentrations of antibiotic directly to the site of infection. Antibiotics are dissolved in sterile saline to a total volume of 50 mL per infusion. The addition of oxytocin (20 IU IM) following IU

infusion significantly improves conception rates by facilitating distribution of the antibiotic throughout the endometrium and stimulating expulsion of inflammatory contents (Troedsson, 2006) [37].

Table 9: Intrauterine Treatment Protocols and Conception Rates in Mares

Protocol	Spectrum	Mares (n)	Conception (No.)	Conception (%)
Control (no treatment)	-	45	18	40.00%
Gentamicin 2 g IU	Aminoglycoside; Gram-negative (<i>E. coli</i> , <i>Pseudomonas</i>)	8	5	62.50%
Gentamicin 2 g + Oxytocin 20 IU	As above + enhanced clearance	10	8	80.00%
Chloramphenicol 2.5 g IU	Broad-spectrum; inhibits 50S ribosome	13	8	61.50%
Chloramphenicol 2.5 g + Oxytocin 20 IU	As above + clearance	9	7	77.78%
Streptopenicillin 5 g + Kanamycin 1 g IU	Combined Gram-positive and Gram-negative coverage	10	6	60.00%
Streptopenicillin + Kanamycin + Oxytocin 20 IU	Combined antibiotics + clearance	14	12	85.71%
Norfloxacin 2 g IU	Fluoroquinolone; Gram-negative spectrum	12	7	58.33%
Norfloxacin 2 g + Oxytocin 20 IU	Fluoroquinolone + clearance	14	12	85.71%

(Troedsson, 2006) [37]

5.6.4 Immunomodulatory therapy

In mares with chronic endometritis, the primary problem is often immune dysfunction - an inability to mount an

appropriately regulated inflammatory response - rather than simply bacterial load. Immunomodulatory therapies are designed to correct this immune dysregulation:

Table 10: Advanced Therapies and Success Rates in Mares

Agent	Mechanism of Action	Dose	Mares (n)	Success (%)
Platelet-Rich Plasma (PRP)	Releases PDGF, TGF- β , EGF $\rightarrow$ $\downarrow$ PMN influx, $\uparrow$ endometrial repair, $\uparrow$ local immunity	IU infusion	12	83.33%
Dexamethasone	Glucocorticoid; inhibits NF- κ B $\rightarrow$ $\downarrow$ IL-1, TNF- α , $\downarrow$ PMN migration; controls post-breeding hyperinflammation	0.1 mg/kg IV post-breeding	30	70.00%
Resveratrol	Polyphenol antioxidant; activates SIRT1; $\downarrow$ oxidative stress and inflammation	Oral supplement (experimental)	6	66.67%
Mycobacterium Cell Wall Extract (MCWE)	Immunomodulator targeting monocytes/macrophages; produces cytokine profile with $\uparrow$ IL-8, $\downarrow$ IL-10	IU infusion	Variable	Moderate
Stem Cell EVs (Extracellular Vesicles)	Cell-free MSC therapy; anti-inflammatory cytokines; promotes endometrial regeneration in fibrotic endometrium	IU infusion or injection	Experimental	Promising

(Segabinazzi *et al.*, 2021; Chaudhari *et al.*, 2025) [38]

5.6.5 Biofilm disruptors and mucolytics

Biofilm formation by organisms such as *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* represents one of the most challenging aspects of chronic equine endometritis

management. Bacteria within biofilms are protected from both the host immune system and conventional antibiotics. Disrupting the biofilm matrix is therefore a prerequisite for successful antimicrobial therapy in these cases.

Table 11: Biofilm-Disrupting Treatments and Success Rates in Mares

Agent	Mechanism	Dose	Mares (n)	Success (%)
Tris-EDTA	Chelates Ca ²⁺ and Mg ²⁺ $\rightarrow$ destabilizes bacterial cell wall lipopolysaccharide membranes $\rightarrow$ biofilm disruption and cell lysis	250-500 mL IU	60	75%
Tris-EDTA + Antibiotic + Lavage	Sequential: Tris-EDTA pre-treatment $\rightarrow$ antibiotic exposure of unprotected bacteria $\rightarrow$ lavage	Combined	50	86%
N-Acetylcysteine (NAC)	Mucolytic: breaks disulphide bonds in mucus $\rightarrow$ liquefies secretions; also reduces biofilm biomass	3.3% solution IU	60	60%
DMSO (10-30%)	Anti-inflammatory; protein solvent; disrupts biofilm; enhances drug penetration through biofilm matrix; bacteriostatic for many species	10-30% in saline IU	40	5%(alone)
Hydrogen Peroxide 1%	Oxidant; produces ROS $\rightarrow$ cytotoxic to bacteria and biofilm biomass; effective vs. <i>E. coli</i> and <i>Klebsiella</i>	1% solution IU	60	Moderate

(LeBlanc *et al.*, 2022; Troedsson, 2006; Chaudhari *et al.*, 2025) [20, 37]

5.6.6 Artificial photoperiod management

Because the mare is a long-day seasonal breeder, extending the perceived day length to 14.5–16 hours using artificial lighting (minimum 100-200 lux at eye level; a single 200W incandescent or 400W fluorescent light is sufficient per 3.6 $\times$ 3.6 m box stall) initiated in early December effectively suppresses melatonin secretion, mimicking spring photoperiod. This advances the first ovulation by 8-10 weeks compared to untreated mares, achieving 70-90% cycling success in treated mares. Light treatment must be initiated at least 60–90 days before the desired early breeding date (Nagy *et al.*, 2000) [39].

5.7 Assisted reproductive technologies (ART)

Assisted reproductive technologies have transformed the equine breeding industry over the past five decades, allowing exploitation of the genetic potential of mares and stallions that would otherwise be unable to reproduce naturally due to athletic competition schedules, physical limitations or reproductive pathology.

5.7.1 Overview and success rates

Equine ART has progressed from AI and embryo transfer (ET) to oocyte transfer (OT) intracytoplasmic sperm injection (ICSI)

and nuclear transfer (cloning). However, *in vitro* oocyte maturation (IVM) and *in vitro* fertilization (IVF) have shown slow progress and lower success rates in horses compared to other domestic species, primarily due to unique equine oocyte

characteristics including morphology, gene expression patterns, developmental potential and zona pellucida hardening during maturation (Hinrichs *et al.*, 2025) ^[40].

Table 12: Success Rates and Status of Equine ART Procedures

ART Procedure	Global Success Rate (%)	Key Limitations	India Status
Embryo Transfer (ET)	33-38% (per flush)	Requires synchronization of donor and recipient; limited recipient availability	Available at select centres; first Marwari ET foal (Raj-Prathama) produced
Oocyte Transfer (OT)	23-27%	Requires surgical oviductal transfer; technically demanding	Limited availability; research stage
Intracytoplasmic Sperm Injection (ICSI)	13-18% (blastocyst production)	High technical expertise required; zona pellucida barriers; poor IVF in equines	Available at limited specialized centres

(da Silva, 2018; Hinrichs *et al.*, 2025) ^[40]

6. Conclusion

Optimizing breeding management in mares is essential for improving fertility, foal survival, and the sustainability of the equine industry, as mare fertility is influenced by complex interactions among physiological, infectious, hormonal, and management factors that make reproductive efficiency inherently challenging. Advances in diagnostic techniques, including USG, cytology, microbial culture, and hormonal monitoring, have significantly enhanced the early detection and management of reproductive disorders, while equine reproductive success relies on replacing rigid synchronization with precise prediction of ovulation and advances in AI. For Indian indigenous breeds, deep-horn insemination with aggressive post-breeding uterine clearance and biofilm disruptors is important to overcome subfertility bottlenecks. Successful reproductive outcomes depend on precise estrus detection, appropriate hormonal control, timely insemination, and maintenance of uterine health; therefore, a multidisciplinary approach combining advanced diagnostics, optimized breeding management, and targeted therapeutics is fundamental to enhancing reproductive efficiency in mares.

References

1. Outram AK, Stear NA, Bendrey R, Olsen S, Kasparov A, Zaibert V, *et al.* The earliest horse harnessing and milking. *Science*. 2009;323(5919):1332-1335.

2. McCue ME, Geor RJ, Schultz N. Equine metabolic syndrome: a complex disease influenced by genetics and the environment. *Journal of Equine Veterinary Science*. 2015;35(5):367-375.

3. McCue PM, Squires EL. *Equine embryo transfer*. Florence, OR, USA: Teton NewMedia; 2015.

4. Morrell JM, Johannisson A, Dalin AM, Hammar L, Sandebert T, Rodriguez-Martinez H. Sperm morphology and chromatin integrity in Swedish warmblood stallions and their relationship to pregnancy rates. *Acta Veterinaria Scandinavica*. 2008;50(1):2-9.

5. Ivanov VV. Horse Symbols and the Name of the Horse in Hurrian. *Buccellati and Kelly-Buccellati*. 1998:145-66.

6. Oguri N, Tsutsumi Y. Non-surgical egg transfer in mares. *Reproduction*. 1974;41(2):313-320.

7. Palmer E, Driancourt MA. Some interactions of season of foaling, photoperiod and ovarian activity in the equine. *Livestock Production Science*. 1983;10(2):197-210.

8. McKinnon AO, Squires EL. Morphologic assessment of the equine embryo. *Journal of the American Veterinary Medical Association*. 1988;192(3):401-406.

9. Squires EL, McCue PM, Vanderwall D. The current status of equine embryo transfer. *Theriogenology*. 1999;51(1):91-104.

10. Buchanan BR, Seidel Jr GE, McCue PM, Schenk JL, Herickhoff LA, Squires EL. Insemination of mares with low numbers of either unsexed or sexed spermatozoa. *Theriogenology*. 2000;53(6):1333-1344.

11. Khan IU, Khairullah AR, Khan AY, Rehman AU, Mustofa I. Strategic approaches to improve equine breeding and stud farm outcomes. *Veterinary world*. 2025;18(2):311-328.

12. Aboelmaaty AM, Elgharieb AE, El-Debaky HA, Alkhadrawy JM, Abou-Ahmed MM, Ghallab AM. Fluctuations of antimüllerian hormone, ovarian follicular reserve, and antioxidant status throughout the estrous cycle in aged mares. *Open Veterinary Journal*. 2024;14(11):3132-3143.

13. Katila T, Nivola K, Reilas T, Sairanen J, Peltonen T, Virtala AM. Factors affecting reproductive performance of horses. *Pferdeheilkunde*. 2010;26(1):6-9.

14. Ravi SK, Legha RA, Pal Y, Sharma RC. Characteristics and freezability of Kathiawari horse semen. *Indian Journal of Animal Science*. 2013;83(11):1146-1148.

15. Fedorka CE, Troedsson MH. The immune response to equine ascending placentitis: A narrative review. *Theriogenology*. 2023;203:11-20.

16. Rocha IB, Araujo F, Rosa LP. Pedigree-Based Assessment of Genetic Structure and Disease-Associated Variants in Friesian Horses in Brazil. *Journal of Equine Veterinary Science*. 2026;105860.

17. Canisso IF, Segabinazzi LG, Fedorka CE. Persistent breeding-induced endometritis in mares—A multifaceted challenge: From clinical aspects to immunopathogenesis and pathobiology. *International journal of molecular sciences*. 2020;21(4):1432.

18. Ginther OJ. Uteroovarian pathway for embryo-empowered maintenance of the corpus luteum in farm animals. *Theriogenology*. 2024;216:103-110.

19. Ali A, Derar DR, Alaeyari AA, Alharbi YM. Fetometry in Arabian horses. *Frontiers in Veterinary Science*. 2025;12:1689769.

20. Leblanc M, Huet B, Saury J. 'Contact' as a Manifestation of Sensorimotor Empathy: The Experience of Expert Écuyers in Interaction with Horses. *Journal of Consciousness Studies*. 2022;29(11-12):80-107.

21. Talluri TR, Mal G, Ravi SK. Biochemical components of seminal plasma and their correlation to the fresh seminal

- characteristics in Marwari stallions and Poitou jacks. *Veterinary world*. 2017;10(2):214-220.
22. McCue PM, Patten M, Denniston D, Bruemmer JE, Squires EL. Strategies for using eFSH for superovulating mares. *Journal of Equine Veterinary Science*. 2008;28(2):91-96.
 23. McKinnon AO, Squires EL, Vaala WE, Varner DD. *Equine reproduction*. John Wiley & Sons; 2011.
 24. Refaat D, Ali A, Aljibali A, Ali M. *International Journal of Veterinary Science*. 2025;14(1):181-187.
 25. Kajaysri J, Wutthiwitthayaphong S. Comparison of the efficacy of altrenogest *versus* transdermal progestin patches on estrus synchronization and ovulation in mares. *Veterinary World*. 2023;16(8):1667-1672.
 26. Janett F, Sacher K, Hassig M, Thun R. Quality of raw and of cold-stored semen in Icelandic stallions. *Journal of Equine Veterinary Science*. 2012;32(9):590-595.
 27. Yendim SK, Aksen OU, Yildirim S, Uzabaci E, Oğlu SS, Yildiz GE, *et al*. The evaluation of fertility following foal heat or the subsequent postpartum estrus in purebred arabian mares. 2025.
 28. Kenney RM, Doig PA. Equine endometrial biopsy. In Morrow DA (Ed.), *Current Therapy in Theriogenology* 2. 1986:723–729.
 29. da Silva MAC. *Advances in Diagnostic and Therapeutic Techniques in Equine Reproduction, An Issue of Veterinary Clinics of North America: Equine Practice* (Vol. 32, No. 3). Elsevier Health Sciences. 2016. de Amorim MD, Nairn D, Manning S, Dedden I, Ripley E, Nielsen K, Card C. Evaluation of diagnostic utility, safety considerations, and effect on fertility of transvaginal ultrasound-guided ovarian biopsy in mares. *Theriogenology*. 2016;85(6):1030-1036.
 30. Gastal EL, Gastal MO. Equine preovulatory follicle: blood flow changes, prediction of ovulation and fertility. *Revista Brasileira de Reproducao Animal*. 2011;35(2):239-252.
 31. Nieto-Olmedo P, Martín-Cano FE, Gaitskill-Phillips G, Ortiz-Rodríguez JM, Peña FJ, Ortega-Ferrusola C. Power Doppler can detect the presence of 7–8 day conceptuses prior to flushing in an equine embryo transfer program. *Theriogenology*. 2020;145:1-9.
 32. Pugliesi G, Fürst R, Carvalho GR. Impact of using a fast freezing technique and – different thawing protocols on viability and fertility of frozen equine spermatozoa. *Andrologia*. 2014;46(9):1055-1062.
 33. Squires EL. Hormonal manipulation of the mare: a review. *Journal of Equine Veterinary Science*. 2008;28(11):627-634.
 34. Kimura Y, Sasaki M, Watanabe K, Dhakal P, Sato F, Taya K, *et al*. Expression of activin receptors in the equine uteroplacental tissue: an immunohistochemical analysis. *Journal of Equine Science*. 2018;29(2):33-37.
 35. Bucca S, Fogarty U, Collins A, Small V. Assessment of foeto-placental well-being in the mare from mid-gestation to term: transrectal and transabdominal ultrasonographic features. *Theriogenology*. 2005;64(3):542-557.
 36. Karam B, Wilson WD, Chambers TM, Reedy S, Pusterla N. Hemagglutinin inhibition antibody responses to commercial equine influenza vaccines in vaccinated horses. *The Canadian Veterinary Journal*. 2021;62(3):266.
 37. Troedsson MH. Breeding-induced endometritis in mares. *Veterinary Clinics: Equine Practice*. 2006;22(3):705-712.
 38. Segabinazzi LG, Canisso IF, Podico G, Cunha LL, Novello G, Rosser MF, *et al*. Intrauterine blood plasma platelet-therapy mitigates persistent breeding-induced endometritis, reduces uterine infections, and improves embryo recovery in mares. *Antibiotics*. 2021;10(5):490.
 39. Nagy P, Guillaume D, Daels P. Seasonality in mares. *Animal reproduction science*. 2000;60:245-262.
 40. Hinrichs K, Schnobrich M, Fernandes CB, Fleury P, Barillari V, Bruggeworth S. Complications associated with equine transvaginal ultrasound-guided follicle aspiration: Practitioner survey and field results. *Journal of Equine Veterinary Science*. 2025;146:105363.
 41. Abu Seida AM. Physiological and behavioural considerations for managing horses with tail disorders. *Equine Veterinary Education*. 2024;36(10):512-514.
 42. Chaudhari DB, Chaudhari DV, Bharai MJ, Mahla JK. Prevalence and Diagnostic Evaluation of Endometritis in Infertile Mares: Bacteriological, Cytological, and Haematological Correlations. *Indian Journal of Veterinary Sciences & Biotechnology*. 2026;22(1).
 43. Katila T, Ferreira-Dias G. Evolution of the concepts of endometrosis, post breeding endometritis, and susceptibility of mares. *Animals*. 2022;12(6):779.
 44. Lüttgenau J, Imboden I, Wellnitz O, Romer R, Scaravaggi I, Neves AP, *et al*. Intrauterine infusion of killed semen adversely affects uterine blood flow and endometrial gene expression of inflammatory cytokines in mares susceptible to persistent breeding-induced endometritis. *Theriogenology*. 2021;163:18-30.
 45. Nielsen JM. Endometritis in the mare: a diagnostic study comparing cultures from swab and biopsy. *Theriogenology*. 2005;64(3):510-518.
 46. Uhlmannsieck L. *Stability of cryopreserved stallion sperm during storage in dry ice*. Hannover: Tierärztliche Hochschule Hannover; 2022.