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A brief overview on Equine Asthma

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Área científica: Medicina e/ou cirurgia de equinos

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ABSTRACT

Equine Asthma (EA) is a highly prevalent, chronic inflammatory condition that affects the horse's lower airways and has significant impact on the health and athletic performance of horses. Nowadays, it is recognised as a syndrome that ranges from mild-moderate equine asthma (MEA) to severe equine asthma (SEA). This work aims to review the current understanding of this pathology, focusing on its classification, pathogenesis, clinical presentation, diagnostics, treatment options and prognosis.

Both MEA and SEA have proven to be complex, multifactorial diseases. Although its etiology is not fully understood, hypersensitivity reactions to environmental allergens is thought to be the primary triggering agent provoking immunologic changes that lead to inflammation, mucus hypersecretion, obstruction and potentially remodeling of the airways. Horses with MEA are usually young athletic horses who present with poor performance and occasional coughing many times being clinically sound during evaluation. Horses with SEA are usually older with increased respiratory effort at rest, chronic cough, exercise intolerance and sometimes marked airway obstruction that raise concern and require immediate treatment.

At the moment, reaching a diagnosis requires a combination of interpreting the horse's clinical history, respiratory endoscopy, tracheal wash cytology and bronchoalveolar lavage fluid cytology ("gold standard") for the majority of clinics and field clinicians, as they are the only readily available tools.

Treatment relies heavily on long term environmental management to reduce exposure to inhaled irritants. Medical treatment with corticosteroids, bronchodilators and supportive therapies should be used appropriately when environmental measures are insufficient or in moments of acute exacerbation.

New research is allowing us to understand, diagnose and treat this condition in a more targeted and individual way. These are exciting news, as it is a way to further improve respiratory health and welfare in affected horses.

PALAVRAS-CHAVE: Equine Asthma, Lower Airway Inflammation, Multifactorial, Bronchoalveolar lavage, Environmental management

RESUMO

A Asma Equina (EA) é uma condição inflamatória crónica e de elevada prevalência que afeta as vias aéreas inferiores, tendo impacto na saúde e capacidade atlética dos equinos. Atualmente, é reconhecida como uma síndrome que varia entre asma equina leve-moderada (MEA) e asma equina severa (SEA). Este trabalho tem como objetivo analisar o conhecimento atual sobre a patologia, focando-se na sua classificação, patogénese, apresentação clínica, meios de diagnóstico, opções de tratamento e prognóstico.

Tanto a MEA como a SEA são condições complexas e multifatoriais. Apesar da sua etiologia não ser totalmente compreendida, reações de hipersensibilidade a estímulos ambientais parecem ser responsáveis pelo efeito primário na doença e desencadearem reações imunológicas que levam à inflamação, hipersecreção de muco, obstrução e potencial remodelação das vias aéreas. A MEA afeta geralmente cavalos novos e atléticos que manifestam essencialmente "poor performance" e ocasionalmente tosse. Cavalos com SEA são normalmente mais velhos e apresentam aumento do esforço respiratório em repouso, tosse crónica e intolerância ao exercício que suscitam preocupação e necessitam de tratamento imediato.

Atualmente, alcançar um diagnóstico requer uma combinação entre a interpretação do exame clínico, endoscopia respiratória, citologia de lavagem traqueal e citologia de lavagem broncoalveolar ("gold standard) para a maioria das clínicas/ambulatório, visto serem os únicos métodos comercialmente disponíveis.

O tratamento baseia-se na implementação de medidas ambientais a longo prazo, de modo a reduzir a exposição a irritantes inalatórios. Tratamento médico com corticosteroides, broncodilatadores e outras terapias de suporte devem ser usadas quando as medidas ambientais são insuficientes ou em momentos de agudização do caso.

Novos avanços têm permitido perceber, diagnosticar e tratar a EA de uma forma mais individual. Estas são notícias positivas, uma vez que visam melhorar a saúde respiratória de muitos cavalos afetados.

KEYWORDS: Asma Equina, Inflamação das vias aéreas inferiores, Multifatorial, Lavagem broncoalveolar, Maneio ambiental

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"The least I can do is speak out for those who cannot speak for themselves." Jane Goodall

Termino assim o capítulo que me permite afirmar que a partir de agora, das 9h às 17h (e com bastantes horas extra e turnos da noite...) me apresento com "Bom dia, o meu nome é Zé Lobo e sou o seu médico veterinário". É para mim surreal perceber que o meu sonho de infância é agora uma realidade, e não podia estar mais orgulhoso de todo o percurso que fiz até aqui.

As palavras que deixo nesta página serão sempre insuficientes para agradecer a todos aqueles que acompanharam esta longa caminhada. Serei eternamente grato por todos os momentos e memórias que vivi ao longo destes belos anos, uma vez que todas foram importantes a moldar a pessoa (incrível e humilde) que sou hoje.

Vorrei dedicare la mia tesi a una persona davvero speciale. La donna che mi ha insegnato a rispettare la natura, a prendermi cura di chi ne ha bisogno (che sia una persona o un animale) e che un sorriso vale davvero più di mille parole. Oggi mi insegni a lottare e a non mollare mai. Quello che un tempo era un sogno che mi avevi instillato, oggi è una realtà perché mi hai insegnato a inseguirlo. Grazie, zia Rita per essere una fonte di ispirazione. Ci vediamo presto!

Aos meus pais, Pedro e Sara, que sempre alinharam nas minhas aventuras malucas. Sem vocês nada disto seria possível. Obrigado por sempre me mostrarem o quão orgulhosos estão e por me fazerem sempre querer mais e melhor. Nos momentos mais difíceis mostraram-me que desistir nunca foi uma opção e que com trabalho e dedicação tudo se consegue. Espero um dia poder retribuir tudo aquilo que fazem por mim, até lá vou oferecendo mais uma planta ou animalzinho para vocês cuidarem.

Aos meus Avós, Jorge e Lourdes, que foram os meus segundos pais. Sempre cuidaram de mim, sempre 110% disponíveis, mostrando-me que o amor não tem limites. Com o sorriso mais belo, e a gargalhada mais contagiante serão sempre casa para mim. Obrigado por me fazerem ver o quão sortudo sou por vos ter por perto.

Ao meu Alf, o imortal companheiro de todos os dias, que mesmo a comer chocolate e papel higiénico constantemente me acompanhou do primeiro ao último dia desta aventura - não é por acaso que dizem que o cão é o melhor amigo do Homem. Por todo o carinho e lambidelas e alegrias que me deu, vai ser sempre uma parte de mim.

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Com muito amor,
Zé Lobo

CASE-LOG

Throughout my 16 week curricular externship at Pool House Equine Hospital, I was able to follow EBVS and AVMA specialists and discuss clinical cases in the areas of equine internal medicine, sports medicine, surgery, reproduction, and diagnostic imaging. Pool House Equine Hospital is an RCVS accredited 24 hour referral practice with a diverse caseload. Due to its privileged location in the West Midlands area, I was exposed to a wide range of clinical cases, from orthopaedic and surgical emergencies to routine work involving leisure horses.

Reflecting on my experience, I was able to improve my theoretical knowledge across the different areas of equine medicine, while also benefiting from a highly hands-on learning environment. I was also fortunate to be integrated into the University of Nottingham students' rota, which allowed me to participate in teaching sessions and share different personal and clinical experiences.

In the months prior to my externship in the UK, I completed two extracurricular externships in the Netherlands: one at Paardenkliniek Wolvega and another at Dierenkliniek Emmeloord. Both externship programmes were very similar in structure to the UK placement, as students were involved in following different clinicians' routines and discussing the daily cases observed with them. As these placements were extracurricular, their activities are not included in the case-log tables below.

Diagnosis		Number of cases
Dermatology	Cellulitis	3
	Chorioptic mange	3
	Dermatophilosis "rain scald"	2
	Equine Pastern Dermatitis "Mud fever"	4
	Lymphangitis	4
	Melanoma	3
	Pemphigus foliaceus	1
	Proliferative Pododermatitis "canker"	2
	Sarcoid	12
Respiratory	Aspiration Pneumonia	1
	Dorsal Displacement of the soft palate	1
	Equine Asthma	4
	Laryngeal Hemiplegia	1
	Pharyngitis	1
	Pleural Effusion	1
Cardio	Aortic Regurgitation	3
	Atrial Fibrillation	1
	Idiopathic Anemia	2

	Jugular Thromboplhebitis	3
	Mitral Regurgitation	2
	Tricuspid regurgitation	1
	Vasculitis	1
Gastroenterology	Acorn toxicosis	1
	Acquired megaesophagus	1
	Clostridial Colitis	1
	Colitis due to salmonella infection	2
	Cyathostominosis	4
	Enteritis	1
	Epiploic foramen entrapment	2
	Equine glandular gastric disease	9
	Equine Liver disease	3
	Equine squamous gastric disease	11
	Gastric impaction	2
	Gastrosplenic entrapment	2
	Inflammatory bowel disease	1
	Large colon impaction	6
	Large colon volvulus	1
	Nephrosplenic entrapment	4
	Parascaris equorum infection	1
	Pedunculated lipoma with small intestine strangulation	5
	Peritonitis	4
	Rectal prolapse	1
	Rectal tear	1
	Right dorsal colitis	4
	Right dorsal displacement	9
	Sand enteropathy	5
	Small colon impaction	1
	Small intestine obstruction	2
	Tapeworm impaction	1
Dentistry	Diastema	6
	EOTRH	2
	Infundibular caries	9
	Periodontal disease	2
	Tooth fracture	3
Musculoskeletal	Annular ligament desmitis	2
	Biceps Brachii tendinitis	1
	Bone cyst: P3	1
	Bone cyst: stifle	2
	Check ligament desmopathy	2
	Condylar fracture of the 3rd metacarpal bone	1
	Deep digital flexor tendon tendinopathy	3
	Deltoid tuberosity fracture	1
	Fetlock collateral ligament desmitis	1
	Injection-site myopathy	1
	Keratoma	3
	Navicular syndrome	2
	OCD: Dorsal extensor process of P3	2
	OCD: Dorsal proximal 1st phalanx	1
	OCD: Lateral trochlear ridge of the femur	1

	OCD: Trochlear ridge of the talus	1
	Osteoarthritis: Cervical articular process joints	5
	Osteoarthritis: Distal interphalangeal joint	1
	Osteoarthritis: Fetlock joint	2
	Osteoarthritis: Lumbosacral joint	9
	Osteoarthritis: Proximal interphalangeal joint	1
	Osteoarthritis: Sacroiliac joint	6
	Osteoarthritis: Tarsometatarsal joint	5
	Osteoarthritis: Thoracic/lumbar spinous processes	3
	Overriding dorsal spinous processes (Kissing spines)	5
	Penetrating foreign body on the solar surface	1
	Peroneus tertius rupture	1
	Proximal sesamoid bone fracture	1
	Proximal suspensory desmopathy	11
	Quittor	1
	Rib fracture	1
	Septic arthritis: Carpus	2
	Septic arthritis: Metatarsophalangeal joint	1
	Solar abcess	3
	Splint bone fracture	1
	Superficial digital flexor tendon tendinopathy	4
	Tarsal collateral ligament desmitis	2
	Tenosynovitis: Digital flexor tendon sheath	3
	Tenosynovitis: Manica flexoria	2
	Tibial fracture	1
	TMJ Osteoarthritis	1
Ophthalmology	Anterior Uveitis	3
	Conjunctivitis	4
	Corneal Ulcer	3
	Keratitis	1
	Retinal Detachment	1
	Senile Cataract	1
	Stromal Abscess	1
Neurology	Epilepsy	1
	“Head Shaking Syndrome”	3
	Hepatic Encephalopathy	2
	Intraspinal Melanoma	1
	Stringhalt	2
Endocrinology	Equine Metabolic Syndrome	6
	Laminitis	4
	Pituitary Pars intermedia dysfunction (Equine Cushing’s syndrome)	3
Reproduction	Balanoposthitis	2
	Cryptorchidism	3
	Endometritis	1
	Granulosa cell tumor	1
	Inguinal Hernia	3
	Mastitis	2
	Retained placenta	3

Neonatology	Foal Septic Arthritis	1
	Meconium impaction	2
	Neonatal Maladjustment syndrome	1
	Umbilical Hernia	3
Infectiology	Equine herpesvirus-1 (EHV-1)	1
	Equine herpesvirus-4 (EHV-4)	2
	Equine Viral Arteritis (EVA)	1
	Strangles	5

Table 1: Case-log observed between the 4th of January 2026 until the 27th of April 2026 in the hospital and ambulatory services at Pool House Equine Hospital.

Procedure	Number	Procedure	Number
Physical examination	342	Abdominal ultrasound	80
Ophthalmic examination	7	Lymph node ultrasound	2
Neurological examination	4	Thoracic ultrasound	12
Poor performance check	64	Ocular ultrasound	4
Dental health check	15	Echocardiogram	11
Emergency: Colic workup	47	Trans-rectal ultrasound	13
Emergency: Wound workup	8	Proximal limb ultrasound	5
Emergency: Diarrhoea workup	2	Distal limb ultrasound	45
Emergency: Pyrexia workup	6	Thoracolumbar ultrasound	6
Vetting	2	Magnetic Resonance Imaging study	13
Vaccination	45	Electrocardiogram	5
Intravenous injection	130	Gastroscopy	19
Intramuscular injection	80	Endoscopy: upper airway	5
Naso-gastric tubing	23	Endoscopy: guttural pouches	3
Intra-articular injection: articular process joints	5	Trans-rectal palpation	22
Intra-articular injection: proximal limb	3	Anaesthesia	32
Intra-articular injection: distal limb	6	Arthroscopy: proximal limb	2
Intra-articular injection: sacro-iliac	6	Arthroscopy: distal limb	9
Local chemotherapeutic injection	3	Deep branch neurectomy + fasciotomy	3
Phlebotomy	112	Laparoscopy: ovariectomy	1
Intravenous catheter placement	6	Laparoscopy: castration	1
Perineural block	90	Laparotomy with intestinal resection	5
Regional perfusion	2	Laparotomy with emptying of intestinal segments	10
Synoviocentesis	7	Umbilical hernia repair	2
Abdominocentesis	46	Partial phallectomy	1

Thoracocentesis	1	Castration	6
Urinary catheter placement	6	Spinous process ostectomy	3
Naso-lacrimal duct flush	1	Interspinous ligament desmotomy	3
Uterine flush	13	Enucleation	2
Tracheal wash	4	Melanoma removal	1
Bronchoalveolar lavage	4	Sarcoid removal	7
Administration of oral medication	6 (yard responsibility)	Wound debridement	7
Administration of ocular medication	3	Keratoma removal	4
Bandage: abdominal surgery	21	Hoof debridement (proliferative pododermatitis)	2
Bandage: distal limb	15	Remedial shoeing	20
Bandage: full limb	9	Rectal biopsy	1
Head radiography	1	CSF tap	2
Cervical radiography	4	Liver biopsy	2
Thoracolumbar radiography	13	Haematology/Biochemistry	180
Sacro-caudal radiography	1	Dentistry endoscopy	5
Proximal limb radiography	12	Wolf teeth removal	3
Distal limb radiography	55	Nasal swab	3
Thoracic radiography	3	Cytology: Blood	3
Abdominal radiography	4	Blood transfusion	3
Radiography dentistry	4	Euthanasia	19

Table 2: Case-log with the clinical procedures observed/done between the 4th of January 2026 and the 27th of April 2026 in the hospital/ambulatory services at Pool House Equine Hospital.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABG Arterial blood gas
ACVIM American College of Veterinary Internal Medicine
AHR Airway hyperresponsiveness
BAL lavage
BID Twice daily
cm Centimetre
CpG-GBP Cytosine-phosphate-guanine - gold nanoparticle
CXCL13 C-X-C motif chemokine ligand 13
DHA Docosahexaenoic acid
DNA Deoxyribonucleic acid
EA Equine asthma
EBUS Endobronchial ultrasound
EDTA Ethylenediaminetetraacetic acid
EHV-1 Equine herpesvirus 1
EHV-2 Equine herpesvirus 2
EHV-5 Equine herpesvirus 5
EIT Electrical impedance tomography
ERBV Equine rhinitis B virus
H_2O Water
HOARSI Horse Owner Assessed Respiratory Signs Index
IAD Inflammatory airway disease
IDEASS Improved Clinical Detectable Equine Asthma Scoring System

IFN-γ	Interferon gamma
IgE	Immunoglobulin E
IL	Interleukin
IL4Rα	Interleukin-4 receptor alpha
IV	Intravenous
kg	Kilogram
L	Liter
MEA	Mild-to-moderate equine asthma
mg/kg	Milligrams per kilogram
mL	Millilitre
mmHg	Millimetres of mercury
mRNA	Messenger ribonucleic acid
NETs	Neutrophil extracellular traps
PO	By mouth / orally
RAO	Recurrent airway obstruction
RCVS	Royal College of Veterinary Surgeons
SAA	Serum Amyloid A
SEA	Severe equine asthma
SID	Once daily
SPAOPD	Summer pasture-associated obstructive pulmonary disease
TNF-α	Tumour necrosis factor alpha
TW	Tracheal wash
µg	Microgram
µg/kg	Micrograms per kilogram
µg/mL	Micrograms per milliliter
µm	Micrometer
°C	Degrees Celsius

1.INTRODUCTION

The term Equine Asthma (EA) was formally introduced by the 2016 American College of Veterinary Internal Medicine (ACVIM) revised Consensus Statement and strengthened by the international Havemeyer Workshops to combine and simplify the terminology used to describe chronic inflammatory lower airway pathologies in horses [1,2,3]. Previously, several different terms - such as heaves/recurrent airway obstruction (RAO), inflammatory airway disease (IAD), and summer pasture-associated obstructive pulmonary disease - were used to describe conditions that shared many clinical and pathological features [2,4]. As research advanced, this number of overlapping names became confusing and impractical for both veterinarians and horse owners. The term “Equine Asthma” bettered communication, provided a clearer, more universally understandable classification system between owners and veterinarians and simplified discussions about diagnosis, treatment and its management [2,3].

The new nomenclature was also chosen because these equine respiratory disorders are similar to human asthma in their pathophysiology and clinical presentation, as both are characterized by chronic airway inflammation, airflow limitation, bronchoconstriction, mucus hypersecretion, airway hyperresponsiveness, airway remodelling, coughing, and exercise intolerance. Recognizing these similarities also highlights the value of horses as possible biologically relevant models for studying human asthma. [1,2,4]

In addition, the term “equine asthma syndrome” reflects the idea that these conditions fall under a spectrum of disease severity rather than completely different diseases. Under the updated classification, IAD is now called mild-to-moderate equine asthma (MEA), where horses typically show subtle signs such as occasional coughing or poor performance, many times presenting as clinically sound during examination. RAO/heaves are now classified as severe equine asthma (SEA), characterized by marked airway obstruction and increased expiratory effort at rest [1,3]. Although these conditions are grouped under one umbrella term, the consensus emphasizes that mild disease does not mandatorily progress to severe asthma in every affected horse [1].

2.EQUINE ASTHMA PHENOTYPES AND ENDOTYPES

In the last 15 to 20 years, human medicine progressed to the concept that asthma should not be viewed as a single allergic disease but a group of biologically distinct diseases, determined by different molecular mechanisms, genetic variation and treatment response which we now call “Endotypes”. This not only revolutionized human medicine, but also equine medicine as we found a parallelism between multiple immunologic mechanisms between human and equine asthma.

When mentioning phenotypes, we are talking about observable physical properties of an organism, which will include laboratory findings if they are measurable, which is the result of the

expression of genes in response to the environment [5]. A phenotype is not randomly identified and described, only being done when this facilitates the diagnosis, the prognosis or implementation of a targeted therapy [2].

The aim of discovering and identifying endotypes and phenotypes is to shift from a symptomatic treatment approach toward a more precise and targeted strategy backed by evidence-based medicine [2,6].

2.1. Endotypes

Current evidence suggests three main endotypes in EA, extrapolated from human asthma: an allergic or Th2 mediated, a non-allergic or Th1/Th17 mediated and late-onset asthma. However, these categories often overlap, and many horses show features of multiple endotypes at the same time [2,4,7].

The Th2 mediated pathway is most commonly associated with MEA, involving increased activity of Th2 lymphocytes and cytokines such as IL-4 and IL-5 [2,4,7]. IL-4 promotes IgE production and contributes to allergic hypersensitivity. However, labelling EA as a “true allergy” remains controversial within the veterinary community, largely because the role of IgE has shown conflicting evidence in equine studies [7,8,9]. Genetic studies show considerable variability between horses, with genes linked to disease susceptibility in different populations [7]. Unlike human allergic asthma, allergic equine asthma is more frequently associated with mast cell inflammation, although eosinophilic inflammation can occur, particularly in young horses exposed to dusty environments [1,10].

The Th1/Th17 endotype is thought to correlate with SEA, which is portrayed by chronic neutrophilic inflammation and increased expression of pro-inflammatory cytokines including IL-1β, IL-8, IFN-γ, TNF-α, IL-17 and IL-23 [7,10]. Alveolar macrophages also play an important role in disease progression and may show altered function in affected horses [7,10]. IL-17 expression is particularly significant because it promotes neutrophil recruitment and prolongs neutrophil survival by delaying apoptosis, contributing to chronic inflammation [7,12,13]. In human medicine, this Th17 endotype is often associated with corticosteroid resistance. Nevertheless, horses typically show apparent clinical improvement with corticosteroid therapy, including improving airway function despite the fact that systemic corticosteroids may fail to fully suppress IL-17 mRNA expression. This highlights both similarities and differences between human and equine asthma biology [12,13].

The late onset endotype correlates with age related immune dysfunction, including a physiological decline of the immune system and chronic low-grade inflammation [2,4]. Ageing has been associated with increased baseline inflammatory activity in both the lungs and peripheral blood. SEA commonly affects mature or elderly horses, which may demonstrate reduced pulmonary function even outside acute exacerbations, resembling adult-onset asthma in humans [2,4,14].

Equine asthma is complex, and many horses exhibit mixed immune profiles, including combined Th1/Th2 or Th2/Th17 responses [2,4,7]. In severe equine asthma, Th17-associated responses may promote CXCL13-mediated recruitment of B cells into the lower airways, potentially contributing to secondary allergic response [10,15]. Transcriptomic studies have also identified dysregulated microRNAs associated with impaired cell cycle regulation and shifts between inflammatory pathways [15,16].

2.2 Phenotypes

EA is commonly classified into phenotypes based on disease severity (clinical phenotype), bronchoalveolar lavage (BAL) fluid inflammatory profiles, environmental triggers, and airway remodelling [2,4,6].

Based on severity, EA is divided into mild, moderate, and severe forms. Mild equine asthma is often subclinical, with horses showing no increased respiratory effort at rest or obvious respiratory signs, but presenting with poor performance, especially when ventilation demands exceed the horse's pulmonary capacity. Because horses might show no symptoms, it can be incredibly difficult to diagnose [1,2,6,11,18]. Moderate equine asthma is associated with more evident signs, including occasional or chronic coughing, excess tracheobronchial mucus, and poor performance, but without laboured breathing at rest [1,2,6]. Severe equine asthma is characterized by marked airway inflammation and obstruction, frequent coughing, exercise intolerance, abnormal lung sounds, laboured breathing at rest and is more common in mature to older horses, often involving structural lung changes [1,2,3,6].

EA phenotypes may also be defined by BAL fluid inflammatory patterns. Neutrophilic asthma is typical of SEA, with BAL neutrophils ≥25%, but may also occur in MEA [1,2,6,7,10]. Mastocytic asthma is more common in milder disease and younger horses, where increased BAL mast cells release mediators such as histamine, contributing to airway hyperreactivity and subclinical obstruction [1,6]. Eosinophilic asthma is less common, usually affects younger horses, and is linked mainly to respirable dust exposure rather than internal parasitism, with an association with airway hyperresponsiveness [1,3]. Pangranulocytic asthma involves increased numbers of several inflammatory cell types in BAL fluid and is generally associated with mild-to-moderate disease and response to standard therapy [6]. On the other hand, paucigranulocytic asthma presents with clinical signs but minimal BAL fluid inflammatory changes, possibly because mucus plugging traps neutrophils within small airways [2,6].

Environmental triggers further distinguish EA phenotypes. Classical stable/hay associated EA is triggered by organic dust, moulds, endotoxins, mites, and particulates from hay and bedding, with signs often worsening indoors, particularly during winter and spring [2,3,6,19]. Summer pasture-associated severe equine asthma occurs mainly in hot, humid climates and is related to pasture exposure, grass pollens, and fungal spores. Affected horses develop reversible airway obstruction during summer, which

may improve rapidly after moving them to a controlled indoor environment [2,6]. It is possible for horses to have both classical and pasture-associated EA, making management incredibly difficult [19].

Finally, airway remodelling is most relevant in chronic severe asthma and includes increased airway smooth muscle mass, subepithelial extracellular matrix deposition, epithelial alterations, angiogenesis, and increased airway innervation. These structural changes contribute to bronchoconstriction and more persistent airflow limitation in advanced cases [2,3,6].

3.EPIDEMIOLOGY OF EQUINE ASTHMA

MEA and SEA differ in prevalence, age distribution, clinical expression, environmental associations and prognosis [1,6,21,22].

MEA is more prevalent than SEA and affects a broader range of ages and disciplines. It is particularly common in young athletic horses, especially racehorses entering training. In some BAL fluid cytology-based studies, MEA has been reported in 80-95% of Thoroughbred and Standardbred racehorses, whereas estimates in sport and pleasure horses range from approximately 20% to 77%, depending on population and diagnostic method [2,6,21,22,23]. Unlike SEA, MEA may be transient in many young horses and can improve with environmental modification, rest, or medical therapy [1,6,24]. SEA is a chronic and recurrent disease that mainly affects mature horses. Its prevalence is estimated at approximately 10-20% of adult horses in the northern hemisphere and other temperate regions, although values vary with geography, management, and diagnostic criteria [7,25]. It is typically diagnosed in horses above 7 years old, with no consistent sex differences, and the classical form is most common in cool, humid climates where horses are frequently stabled and fed forage indoors [1,2,18,25,26]. Genetic susceptibility may also play a part, with familial aggregation described in breeds such as Warmbloods and Lipizzaners. A foal of two affected parents has a substantially increased risk of disease, and genetic studies have identified signals on ECA13 and ECA15, with *IL4Rα* proposed as a candidate gene [7,27,28,].

Summer pasture-associated SEA is a distinct phenotype in which exacerbations are connected to pasture exposure rather than stable dust. It has been reported mainly in hot, humid climates, including the southeastern United States, and typically worsens between June and September, coinciding with grass pollen and fungal spore exposure. However, it has been reported in colder parts of the world such as the UK [6,26,29,30]. It generally affects mature horses and has been associated with genetic predisposition in the quarter Horse breeds [26,29].

Environmental exposure is one of the risk factors for EA. Stabling, poor ventilation, dry hay, straw bedding, and high concentrations of respirable organic dust have shown to be statistically significant in disease exacerbation [21,22,31]. Although EA is considered a non infectious condition, previous viral

respiratory disease or early life airway colonization may contribute to later susceptibility, while emerging evidence suggests that obesity may also increase asthma risk in some populations [2,6,32,33].

In summary, the epidemiology of EA reflects an interaction between age, use, environment, genetic susceptibility, and possibly early-life respiratory events or metabolic status.

4. AETIOLOGIES OF EQUINE ASTHMA

The aetiology of both MEA and SEA is highly complex and thought to be multifactorial, driven by interactions between environmental aeroallergens, genetic susceptibility, infectious agents, and localized immune responses [1,2,3,6].

4.1. Aetiology of mild-moderate equine asthma

The biggest etiological factor in MEA is exposure to respirable dust, in particular particles ≤4 µm, which are able to reach the distal airways. Horses housed in poorly ventilated barns, with straw beds, or fed dry hay are exposed to increased concentrations of aerosolized dust, moulds, endotoxins, and other organic particles [34,35,36,37,38]. In MEA, increased respirable dust exposure has been associated with higher neutrophil and eosinophil proportions in BAL fluid, particularly in young Thoroughbred racehorses in training [21,22,39,40]. Organic dust contains multiple biologically active components, including endotoxins, fungal particles, β-glucans, mites, plant material, and inorganic dust, which may interact to amplify airway inflammation [3]. Synergy between pro-inflammatory effects of endotoxin and organic dust have been demonstrated in SEA studies. These findings support the concept that mixed stable dust exposure can contribute to lower airway inflammation in susceptible horses [41]. The risk of clinically apparent respiratory disease appears to decrease with age in some racehorse populations, suggesting that maturity, prior exposure, or an increase in tolerance to environmental stimuli may influence disease expression, although this mechanism is not completely understood [3,42].

The horse's genetics probably influences the inflammatory response to environmental exposure, although these genetic components of MEA are less clearly established than those described for SEA. Polymorphisms in immune related genes such as IL4R have been linked to equine asthma and may help explain why some horses develop exaggerated inflammatory responses to similar environmental conditions [27,43]. Fungal components may also contribute to specific inflammatory phenotypes of MEA. Stable dust often contains β-glucans from fungal cell walls, and respirable β-glucan exposure has been associated with increased BAL fluid mast cell proportions, suggesting a possible mastocytic or hypersensitivity related phenotype [40]. EA is not thought to be a strictly a classic allergic condition, and neutrophilic inflammation may involve a combination of innate immune and adaptive pathways [2,3].

Oxidative imbalance may contribute to airway injury and persistence of inflammation, but current evidence for markers such as non-protein-bound iron is stronger in SEA than in MEA; therefore, oxidative stress should be interpreted as a potential pathophysiological modifier rather than a primary MEA cause [44].

The role of infectious agents in MEA remains inconclusive and debatable. Although MEA is considered a non-infectious inflammatory pathology, bacteria may contribute in some cases, particularly in young racehorses with clinical signs such as cough and increased tracheal mucus. *Streptococcus spp., Pasteurella/Actinobacillus spp., Bordetella spp.,* and *Mycoplasma equirhinis* have been described in airway inflammation and respiratory pathology [42,45,46,47]. Nevertheless, bacteria are not consistently isolated, and their presence does not necessarily indicate primary infection [3]. Similarly, respiratory viruses such as ERBV, EHV-1, EHV-2, and EHV-5 have been linked to airway inflammation in some studies, but they are also found in healthy horses, so they are best considered possible modifiers rather than established primary causes [48,49,50,51,52]. Airway dysbiosis may also influence MEA, as altered lower airway microbial communities, including changes in *Streptococcus spp*. populations have been reported in horses with mild asthma. Nonetheless, whether dysbiosis is a cause or consequence of inflammation remains unclear [53,54].

Physical stressors such as intense exercise in cold air and long distance transportation may further increase airway susceptibility by promoting epithelial stress, transient neutrophilic inflammation, impaired mucociliary clearance, and bacterial colonization of the lower airways [55,56,57].

In conclusion, MEA is best understood as a multifactorial inflammatory airway condition in which respirable dust and organic particulates are central risk factors, while host susceptibility, fungal components, microbial exposure, airway dysbiosis, viral agents, exercise, transport, endotoxin-containing dust, oxidative stress, and immune responses may modify disease expression.

4.2. Aetiology of severe equine asthma

The aetiology of SEA is strongly associated with hypersensitivity type IV response to inhaled environmental aeroallergens and organic dust in genetically susceptible horses [3,6]. Hence, a relationship between environment and genetic component.

The main trigger for classical/hay SEA is exposure to airborne organic dust from the stable environment, especially dry hay and bedding [1]. Indoor housing and dry hay feeding increase exposure to respirable particulates, moulds, endotoxins, mites, and plant fragments [34,35,36,38,108]. Exposure to these can induce marked airway neutrophilia, mucus hypersecretion, bronchoconstriction, and impaired lung function [1,3]

Fungi and moulds are important components of the organic dust implicated in SEA. *Aspergillus fumigatus, Faenia rectivirgula, Thermoactinomyces vulgaris, Eurotium amstelodami,* and *Lichtheimia corymbifera* have been identified as relevant aeroallergens or inflammatory stimuli [1,3,32]. Experimental exposure to hay dust or dust that contain fungal suspensions can replicate clinical signs and airway inflammation in susceptible horses, supporting the central role of inhaled organic dust in pathogenesis [3,41]. However, SEA is unlikely to result from a single fungal species and is more likely caused by complex exposure to mixtures of fungal spores, microbial products, plant particles, endotoxins, and inorganic dust [40,41].

Endotoxins, particularly lipopolysaccharides from Gram-negative bacteria, may amplify SEA inflammation. Stable dust contains higher endotoxin concentrations than pasture environments, and endotoxin exposure can contribute to neutrophilic airway inflammation [3,41,109]. Its pro-inflammatory effect appears to be stronger when in combination with dust or fungal components, intensifying neutrophil recruitment and clinical signs in susceptible horses [41].

The horse's genetic makeup is an important modifier of SEA. Familial aggregation and genome studies support a heritable component, although inheritance patterns differ between families and breeds [27,43]. Regions on equine chromosomes 13 and 15, and immune-related genes such as IL4R, have been implicated [27]. These genetic factors likely influence the type and intensity of immune responses to environmental triggers rather than acting as independent causes and it is an important area for future research.

New evidence suggests that gut lung axis alterations may influence SEA. Changes in faecal microbiota, including reduced microbial diversity or altered bacterial populations, have been reported in horses with severe asthma [54]. However, currently this evidence remains associative, thus gut dysbiosis should be considered a potential modifier of inflammation rather than an established primary cause and more science-based evidence is needed.

Summer pasture-associated severe equine asthma represents a distinct phenotype triggered by outdoor environmental exposure due to fungal spores and grass pollens. Genetic susceptibility is also thought to play a part in this condition, since these horses develop exaggerated immune responses to these types of allergens. [2,3,29,30].

Oxidative stress may contribute to disease persistence and severity. Horses with SEA show evidence of oxidative imbalance in the lower airways, including changes in bronchoalveolar lavage fluid markers such as reactive iron species, which may promote epithelial injury and ongoing inflammation. However, oxidative imbalance is better interpreted as part of the pathophysiological response rather than a proven primary etiological factor. [44]

In summary, SEA is a multifactorial disease in which inhaled allergens and organic dust are the main recognized triggers, while genetic susceptibility, fungi, endotoxins, immune dysregulation, seasonal

allergens, microbiota changes, oxidative imbalance, and management-related stressors influence disease expression and severity.

5. PATHOPHYSIOLOGY OF EQUINE ASTHMA

5.1. Pathophysiology of mild-moderate equine

The immune mechanisms that are the fundamentals of MEA pathogenesis were discussed thoroughly in the 2nd chapter.

In terms of lung function, even mild lower airway inflammation can impair performance in athletic horses. During intense exercise, horses depend on very high ventilatory capacity, and small changes in airway diameter, mucus accumulation or peripheral airway obstruction may compromise gas exchange by decreasing blood oxygenation and consequently tissue oxygenation. Racehorses with MEA have been reported to experience more pronounced exercise induced arterial hypoxemia and hypercapnia (low oxygen and carbon dioxide in the blood, respectively) than healthy horses, likely due to ventilation/perfusion mismatch and peripheral airway obstruction [3,58]. Adding to that, neutrophilic inflammation in the lower airways has been associated with a reduced aerobic threshold and earlier onset of blood lactate accumulation, which may contribute to reduced athletic performance [59]. Nevertheless, the severity of functional impairment can vary between individuals, and the relationship between BAL fluid cytology and performance limitation should be interpreted with some caution [3].

In conclusion, while the multifactorial aetiology of MEA is widely recognized, the specific mechanisms responsible for decreased performance and inflammatory cell influx remain largely speculative [3,21,22]. Although lower airway inflammation negatively impacts gas exchange and aerobic capacity during exercise [3,58,59], the pronounced heterogeneity in individual clinical responses suggests the presence of multiple overlapping asthma endotypes and its genetic makeup [2,4]. Therefore, future longitudinal studies utilizing large, standardized cohorts are required to fully decode the complex pathophysiology of MEA and define its impact on equine athletic capacity.

5.2. Pathophysiology of severe equine asthma

Severe equine asthma represents the more severe end of the equine asthma spectrum. In susceptible horses, repeated exposure to inhaled organic particles induces an exaggerated inflammatory response within the lower airways leading to bronchoconstriction, mucus accumulation and airflow obstruction [3,60].

The pathogenesis of SEA involves a complex interaction between environmental exposure, genetic susceptibility and dysregulated immune responses. Inhaled endotoxins and organic dust have a synergic pro-inflammatory effect, amplifying neutrophil recruitment into the airways beyond the effect produced by each trigger alone [41]. Genetic susceptibility likely modifies the intensity and type of immune response to these inhaled triggers [27,43].

As mentioned in the MEA section of pathophysiology, the immunological component of SEA was already explained in the 2nd chapter although it is worth mentioning again that SEA is dominated by chronic BAL fluid neutrophilia [1]. Neutrophils play a central role in the tissue damage associated with SEA. Once recruited into the airways, they release reactive oxygen species, elastase and other inflammatory mediators that can damage the respiratory epithelium and amplify local inflammation. Neutrophil extracellular traps (NETs) may also contribute to epithelial injury, mucus viscosity and persistence of inflammation. These processes generate a local pro-oxidative airway environment and may reduce the effectiveness of normal resolution mechanisms [7,44]. Emerging evidence also suggests that systemic factors, such as obesity and altered neutrophil metabolism, may influence the intensity of inflammatory responses in some asthmatic horses, although these mechanisms still require further clarification [61]

A major consequence of chronic inflammation in SEA is airway remodelling. Repeated cycles of inflammation, bronchoconstriction and repair lead to structural changes in the airway wall. These include airway smooth muscle hypertrophy and hyperplasia, which increase the capacity for bronchoconstriction and contribute to airflow limitation [60,62]. Changes in the extracellular matrix, including collagen deposition and disruption of elastic fibres, may reduce airway compliance and contribute to persistent obstruction [62,63]. In more severe cases, accumulation of high molecular weight hyaluronic acid may also contribute to fibrotic remodelling of the airway wall [63]. Although some components of airway dysfunction are reversible with treatment and environmental management, chronic remodelling may be only partially reversible, particularly in horses with long standing disease [3].

Mucus hypersecretion is also important in SEA. Pro-inflammatory cytokines and epithelial irritation promote goblet cell metaplasia and increased mucin production. The resulting accumulation of mucus within the bronchi and bronchioles physically obstructs airflow and further worsens ventilation/perfusion mismatch [3,7,60]. Impaired mucociliary clearance may intensify this process, allowing mucus and inflammatory debris to stay in the lower airways.

Together, bronchoconstriction, mucus obstruction and airway wall thickening produce the increased respiratory effort and expiratory airflow limitation typical of clinically affected horses.

The functional consequences of SEA are therefore more severe than those seen in MEA. During exacerbations of disease, gas exchange can be compromised due to ventilation/perfusion mismatch and reduced ventilation of obstructed peripheral airways. In advanced or poorly controlled cases, chronic hypoxemia and increased pulmonary vascular resistance may contribute to pulmonary hypertension and secondary right-sided cardiac pathology. These cardiovascular effects are best portrayed as potential consequences of severe or prolonged disease rather than universal features of all affected horses [64].

In addition to pulmonary changes, SEA is increasingly being investigated as a condition with systemic associations. Chronic airway inflammation may influence, and be influenced by, broader immune and metabolic pathways. Increased peripheral airway innervation may contribute to heightened cough reflexes and bronchospastic responses in affected horses [64]. Emerging research on the gut-lung axis suggests that multi-kingdom intestinal dysbiosis including alterations in archaea, environmental fungi, and a reduction in beneficial fibrolytic bacteria may exacerbate systemic inflammation. These microbial shifts compromise the production of short-chain fatty acids, worsening the inflammatory tone of the airways. However, current evidence remains hypothetical. Therefore, gut dysbiosis should be interpreted as secondary, rather than a definitive, causal mechanism in the pathogenesis of SEA [54]

In conclusion, while a multifactorial aetiology is well established in SEA, even though its exact biological and immunological mechanisms are not fully understood [7,62]. The profound discrepancy of individual immune response suggests that future research on the genomics, transcriptomics, proteomics and metabolomics is essential to fully decode these complex mechanisms. [2; 6].

6. ANAMNESIS, CLINICAL SIGNS AND PHYSICAL EXAMINATION

A structured clinical history and physical examination are essential in the evaluation of horses suspected EA because it is a spectrum ranging from MEA to SEA. The initial clinical assessment helps differentiate clinical phenotypes, estimate disease severity, identify relevant environmental and guide further diagnostic testing [26].

Clinical signs are fundamental to phenotype differentiation. Horses with MEA often appear clinically sound at rest, which is one of the main clinical features distinguishing this phenotype from SEA. In these cases, the most common complaints are reduced athletic performance (poor performance), delayed recovery of respiratory rate after exercise and occasional or intermittent coughing, particularly in athletic horses [1,23,26,65]. However, the absence of cough does not exclude MEA, as coughing is reported only in a proportion of affected horses [1,65]. Mild mucus nasal discharge may also be present, although it is not sufficiently sensitive to confirm the diagnosis [26,66]. Mild historical signs should not

be dismissed, as occasional coughing associated with mucous nasal discharge has been linked to an increased risk of developing SEA later in life [67].

Contrasting with MEA, SEA is usually associated with clinical abnormalities that are evident at rest, especially during active periods of acute disease. Affected horses commonly present with tachypnoea, increased respiratory effort at rest, nostril flaring, deep breathing, extension of the head and neck, and increased expiratory effort [1,26,32]. Forced expiration over time may lead to hypertrophy of the external abdominal oblique muscles, producing the characteristic “heave line” along the flank [1,3,26]. In more severe cases, abdominal paradoxical breathing, reluctance to move, anxious facial expression, and protrusion of the anus synchronous with expiratory effort may be observed [26]. Coughing in SEA is typically frequent, deep, and often paroxysmal, particularly after exposure to dusty environments [1,3,26,32]. Bilateral serous, mucoid, or mucopurulent nasal discharge has already been reported in literature [26,68].

Environmental history is a major component of the clinical assessment as it strongly influences EA pathogenesis. Verbal descriptions of the environment may be incomplete or inaccurate… so, direct inspection of the stable, hay storage area, bedding, ventilation, and feeding conditions, or evaluation via photographs and videos, is recommended when possible [2,21,22,26]. Questions about the current diet plan should also be made [2,26,34,35]. As per seasonality, classical SEA is commonly associated with winter and spring months stabling, whereas equine pasture severe asthma is typically exacerbated during hot and humid summer conditions at pasture during summer months [3,26,29].

Signalment and previous history provide additional diagnostic context. MEA is more frequently described in young athletic horses, whereas SEA is typically an adult-onset condition, often diagnosed in horses older than seven years [1,26]. A family history of respiratory disease should be investigated, particularly in the sire and dam, because SEA has a recognized heritable component, with reported prevalence in offspring of affected parents reaching 38-48% in some particular populations [32,43]. The history should also include previous respiratory infections, recent fever, vaccination status, transport, travel, as exposure to respiratory pathogens may contribute to the development or exacerbation of chronic airway inflammation and help rule out possible differentials [47,50].

Physical examination should focus on the respiratory system by analysing respiratory effort, breathing pattern, nasal discharge, any coughing, thoracic and cardiac auscultation, thoracic percussion, and systemic health. In MEA, thoracic auscultation at rest is often normal, although subtle abnormal sounds or coughing may become evident after a rebreathing examination [26,65]. In SEA, auscultation may reveal increased bronchovesicular sounds, an extended caudoventral auscultation field, expiratory wheezes and crackles, and tracheal rattles or clicks caused by mucus accumulation [26,65,69,70]. Because

the equine thoracic wall thickness reduces sensitivity when auscultating, the rebreathing bag test is commonly used to deepen respiration and accentuate abnormal lung sounds or induce coughing. However, horses with EA, particularly SEA, may tolerate this test poorly and rapidly develop laboured breathing [3,26]. Thoracic percussion can further support the assessment, as caudal extension of the lung field suggests pulmonary overinflation and air trapping in chronic lower airway obstruction [26].

Fever, marked lethargy, anorexia, fetid nasal discharge, or clearly purulent discharge are not typical features of EA so further investigation of infectious or alternative respiratory diseases is advised and should be properly addressed [3,26]. To improve objectivity, standardized clinical tools such as the Horse Owner Assessed Respiratory Signs Index (HOARSI), Improved Clinical Detectable Equine Asthma Scoring System (IDEASS), visual analogue scales, modified clinical scores, and endoscopic mucus scoring may be used to quantify respiratory signs, mucus accumulation, disease phenotype, and response to treatment [2,11,18,26,71,72].

In conclusion, the integration of clinical history, environmental assessment, phenotype specific signs, and physical examination findings provides a rational basis to identify the most likely EA phenotype, estimating disease severity, and selecting appropriate diagnostic and management strategies.

7. DIAGNOSTIC WORK-UP OF THE ASTHMATIC HORSE

Although anamnesis, environmental assessment, clinical signs, and physical examination are essential for identifying horses suspected of EA, these findings are not sufficient to confirm the diagnosis. Clinical signs may be absent or subtle in MEA, while horses with SEA may show variable clinical severity of disease. Therefore, complementary exams are required to objectively assess airway mucus accumulation, exclude infectious or structural differential diagnoses, characterize lower airway inflammation, and evaluate lung function [1,3]. The diagnostic workup should be interpreted as an integrated process rather than as a single definitive test.

Haematology

Routine haematological evaluation, including a complete blood count, is generally unremarkable in horses with EA [1]. Consequently, its primary diagnostic utility lies in the exclusion of differential diagnoses rather than in confirming lower airway inflammation. Specifically, haematology is essential for identifying systemic infectious diseases which might present with leucocytosis, neutrophilia, or elevated acute phase proteins like SAA or fibrinogen and for detecting underlying conditions that decrease the blood's oxygen carrying capacity, such as severe anaemia [3]. While anaemia does not cause true arterial hypoxemia, it leads to tissue hypoxia and compensatory hyperventilation that can closely mimic the

exercise intolerance or respiratory distress observed in asthmatic patients [3]. In some athletic horses suffering from subclinical or MEA, slight decreases in red blood cell parameters (such as haematocrit, mean corpuscular volume, and haemoglobin concentrations) have been reported, but these alterations are considered unspecific physiological markers of impaired athletic performance rather than direct indicators of the respiratory disease itself [1,23].

Endoscopy provides information on upper airway function and tracheobronchial mucus. Tracheal wash is useful when infection is suspected. BAL cytology remains fundamental for confirming lower airway inflammation. Pulmonary function testing allows objective evaluation of airflow obstruction or airway hyperresponsiveness. More advanced methods may provide additional information in referral or research settings but are not yet replacements for established diagnostic procedures [1; 2; 18; 26; 75].

Airway Endoscopy

Airway Endoscopy is an important diagnostic tool in horses suspected of EA because it allows direct visualization of both the upper airway and the tracheobronchial tree. This is particularly relevant in athletic horses, where poor performance, abnormal respiratory noise, or exercise intolerance may be caused by upper airway disorders rather than lower airway inflammation. Therefore, abnormalities such as laryngeal hemiplegia, dorsal displacement of the soft palate, pharyngeal collapse, arytenoid dysfunction, or other upper airway conditions should be considered before attributing clinical signs instantly to EA [3,26]. The endoscope can then be advanced into the trachea to assess the presence, accumulation, location, viscosity and colour of the tracheobronchial mucus. Mucus accumulation is one of the most useful endoscopic findings in horses with suspected EA, especially in MEA, where respiratory effort at rest is often normal. Standardized mucus scoring systems, particularly the 0-5 scale described by Gerber et al. (2004), improve consistency between examinations and allow mucus accumulation to be monitored over time. In general, higher mucus scores are associated with lower airway inflammation, although the clinical relevance of a given score may vary according to discipline, age, recent exercise, and environmental exposure [1,71].

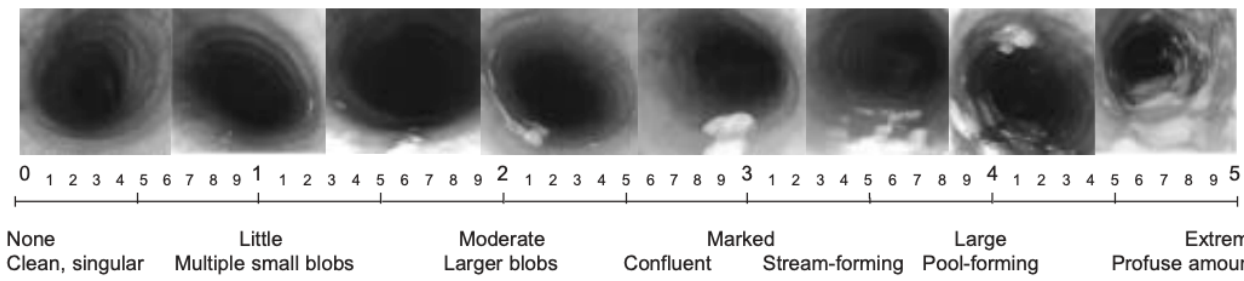


Figure 1: Scoring system for tracheal mucus accumulation. Gerber, V., Straub, R., Marti, E., Hauptman, J., Herholz, C., King, M., Imhof, A., Tahon, L., & Robinson, N. E. (2004). Endoscopic scoring of mucus quantity and quality: observer and horse variance and relationship to inflammation, mucus viscoelasticity and volume. Equine veterinary journal, 36(7), 576–582.

The diagnostic value of tracheal mucus is particularly important in performance horses as subclinical disease may account for a performance reduction [23]. In racehorses, relatively mild mucus accumulation may be clinically relevant because small changes in airway diameter or secretion burden can affect airflow during intense exercise. On the other hand, pleasure or sport horses may tolerate a greater mucus score before performance limitations become obvious. Mucus scoring should be interpreted in relation to the horse's use, clinical history, and other diagnostic findings [1,2].

In horses with SEA, endoscopy may reveal more marked mucus accumulation, mucosal hyperaemia, airway oedema, bronchial narrowing, and thickening or blunting of the carina. These changes may reflect chronic airway inflammation, mucus hypersecretion, impaired mucociliary clearance, and airway remodelling. However, none of these findings is pathognomonic for EA. Increased mucus may also be observed after respiratory infection, transport, dusty environmental exposure, or other inflammatory airway disorders. Similarly, a low mucus score does not exclude EA, particularly if the horse has recently received treatment or has been removed from a dusty environment [1,2].

Diagnostic imaging

Diagnostic imaging techniques like radiography and ultrasonography cannot definitively confirm EA on their own. Instead, clinicians primarily rely on these tools to rule out other respiratory conditions, including pleural effusion, pulmonary abscesses, or bacterial bronchopneumonia [3,75]. When evaluating horses for subclinical lung disease including MEA, standard thoracic X-rays offer very little diagnostic value due to their poor sensitivity [2,18]. In more advanced cases of SEA, radiographic images might demonstrate trapped air, which is visible as enlarged, radiolucent lung fields and a flattened diaphragm along with diffuse broncho-interstitial or interstitial opacities [18,30]. Clinicians must be careful not to overinterpret these interstitial markings, because normal aging processes can cause similar radiographic appearances in healthy senior horses [30]. Echocardiography serves as a valuable complementary diagnostic tool to assess secondary cardiovascular complications of SEA, such as pulmonary hypertension and possible right-sided heart failure [2,74]. Standard examinations in affected horses often reveal right ventricular hypertrophy and an abnormally enlarged pulmonary artery [74]. Furthermore, highly sensitive modalities, specifically tissue Doppler imaging and speckle tracking echocardiography, have demonstrated that SEA causes persistent, subclinical right ventricular dysfunction (including altered diastolic filling and septal flattening) that remains detectable even when the horse is in clinical remission [73].

Similarly, traditional transthoracic ultrasonography is not highly specific for diagnosing EA. It often reveals comet-tail artifacts, but these simply point to general inflammation at the lung periphery and are regularly seen in horses suffering from exercise-induced pulmonary haemorrhage as well as in

completely healthy equine athletes [3,18,75]. To bypass the shortcomings of conventional imaging, researchers have explored endobronchial ultrasound (EBUS). By advancing a specialized high-frequency probe through an endoscope, veterinarians can directly measure structural changes in the airways, such as increased smooth muscle mass [3,75]. Despite its ability to detect the severe airway remodelling present during acute SEA crises, EBUS is not yet practically useful for everyday diagnosis, as it struggles to detect subclinical MEA or identify SEA patients that are currently in remission [2,18,75].

Tracheal wash (TW)

Tracheal wash (TW) cytology is useful in the diagnostic evaluation of horses with suspected respiratory disease, but its role differs from that of BAL. TW sample secretions from the trachea represent the lower airway in a general manner and are particularly valuable when an infectious process is suspected. In horses presenting with fever, dullness, systemic illness, purulent nasal discharge, focal auscultatory abnormalities, or imaging findings suggestive of pneumonia, TW cytology and bacterial culture and its sensitivity test can help identify infection and guide therapy [3,26,75].

Cytological findings suggestive of infection include degenerate neutrophils, intracellular bacteria, fungal elements, and marked septic inflammation (3,18,75,76). In such cases, the diagnostic focus should shift away from EA and toward bacterial bronchopneumonia, pleuropneumonia, pulmonary abscessation, or other infectious conditions [3,26,76] TW culture is particularly useful because it allows identification of bacterial pathogens and selection of appropriate antimicrobial treatment [18,76].

However, TW cytology has limitations for diagnosing diffuse lower airway inflammation (1). Because TW samples secretions from the larger airways, it may not accurately represent inflammation in the smaller bronchioles and alveolar regions, which are more directly assessed by BAL fluid cytology [18,77,78]. TW results may also be influenced by proximal airway contamination, mucus accumulation and environmental exposure [18,69,79]. Therefore, TW is generally less reliable than BAL fluid for phenotyping MEA or SEA [1,18,75]. Using TW alone to diagnose EA may lead to misclassification, particularly in horses with mild or subclinical disease [1,18,78].

A transtracheal aspirate can also be used collect fluid from the horse's lower airway. Technique is thoroughly described by Bishop et al. (2025) in the article titled "How to perform a transtracheal aspirate in horse for diagnosis of lower respiratory tract disease".

Bronchoalveolar lavage (BAL)

BAL cytology is widely considered the gold standard for diagnosing and characterizing EA, as it provides an accurate assessment of lower airway inflammation and identifies the predominant inflammatory cell populations [1,75,80]. In healthy horses, BAL fluid is predominantly composed of

alveolar macrophages (50-70%) and lymphocytes (30-60%), with reference values for healthy horses generally accepted as (<5-10%) neutrophils, (0.1%) eosinophils, and (<2%) mast cells [1,75]. Horses affected by MEA typically exhibit mild to moderate increases in neutrophils, mast cells, eosinophils, or a mixed inflammatory pattern. In contrast, SEA is characterized predominantly by marked neutrophilic inflammation, frequently exceeding 20-25% neutrophils in the BAL fluid alongside a relative decrease in macrophages and lymphocytes [2,3,75]. Cytological phenotyping is especially important because clinical signs can overlap among asthma phenotypes, and subclinical or mild disease may only be identifiable through objective BAL fluid analysis [1,26].

It is advised that the procedure is performed under standing sedation, most commonly using an alpha-2 agonist such as xylazine (0.2-0.5 mg/kg IV) or detomidine (0.005-0.02 mg/kg IV), frequently combined with butorphanol (0.01-0.04 mg/kg IV) to reduce coughing and create a safe environment for the horse and staff [21,22,24]. A flexible BAL catheter (for example 300 cm in length) or a video endoscope is introduced through the ventral nasal meatus into the trachea and advanced distally until wedged in a peripheral bronchus. To further suppress the cough reflex, local anaesthesia can be achieved using a 0.2-2% lidocaine solution administered at the level of the trachea, carina, or bronchi [24,68]. Once in place, sterile isotonic fluid (most commonly 0.9% saline) is instilled in volumes between 250 mL and 500 mL, both of which are recommended in the literature [1,82]. Recovery volume via manual suction should be around 50% to 80% of the instilled volume be moderately turbid with a superficial layer of foam, indicating the presence of pulmonary surfactant [3,75,83].

Historically, standard practice recommended sampling a single lung lobe. However, recent evidence suggests that neutrophil percentages can differ significantly between the right and left lungs [80]. Therefore, pooling fluid collected from both the left and right lungs is highly representative and provides excellent diagnostic reliability. Sampling both lungs mitigates potential minor regional variations in cell distributions and offers a comprehensive assessment of the lower airways [75,80].

Crucially, the volume of fluid instilled significantly influences the resulting cytology. Instilling 500 mL results in a significantly higher fluid recovery percentage but yields a lower relative percentage of neutrophils compared to a 250 mL instillation, owing to a dilution effect from sampling a larger alveolar surface area [3,18,84]. Maintaining a standardized instillation volume is vital for accurately interpreting results against established reference ranges [3,80].

Sample processing is another important consideration. Collection and processing should ideally be completed within 1 to 2 hours, or the sample should be placed in EDTA tubes and stored at 4°C to preserve cell morphology [3,80]. Cytocentrifugation remains the preferred method for BAL cytology preparation because it provides more accurate differential cell counts and better cellular distribution than sediment smear preparations [3,85]. Furthermore, fast Romanowsky stains (for example Diff-Quik) poorly stain mast cell granules, often leading to underestimations. Therefore, proper metachromatic

staining of all cells should be performed using Leishman, May-Grünwald Giemsa, Wright-Giemsa, or Toluidine Blue stains [3,86].

Despite being considered a safe and minimally invasive procedure, BAL may induce transient airway neutrophilia for up to 48 hours after sampling, irrespective of the lavage solution used, so repeated sampling within short intervals should be interpreted cautiously to avoid misclassification of airway inflammation [18,80].

Pulmonary function testing

Pulmonary function testing provides objective information about how EA is affecting lung mechanics and oxygen exchange. This is especially important because clinical signs and cytological inflammation do not always correlate closely with functional impairment. Some horses with MEA may appear normal at rest but demonstrate airway hyperresponsiveness during testing, while horses with SEA may retain functional abnormalities even after clinical improvement [65,87].

Traditional pulmonary mechanics in horses may involve the use of an oesophageal balloon catheter to estimate pleural pressure changes, often combined with airflow measurements [3,18,75]. Parameters such as maximal change in pleural pressure, pulmonary resistance, and dynamic compliance allow objective assessment of airway obstruction [1,3,75]. A markedly increased pleural pressure change, for example greater than approximately 15 cm H_2O, supports the presence of severe airflow obstruction and is most consistent with SEA when compatible clinical signs are present [3,26,75]

In horses with respiratory distress at rest, bronchoprovocation testing is contraindicated because it may worsen airway narrowing and clinical compromise. In these cases, a bronchodilator challenge is more appropriate [26,75]. Administration of a fast-acting bronchodilator, such as inhaled albuterol or N-butylscopolammonium bromide, followed by reassessment of pulmonary mechanics, can demonstrate reversible bronchoconstriction [3,26,88]. A marked reduction in airway resistance or pleural pressure following bronchodilation supports the diagnosis of reversible airflow obstruction, a major feature of SEA [26,75,89].

In stable horses, especially those suspected of MEA or SEA in remission, histamine bronchoprovocation may be used to evaluate airway hyperresponsiveness [3,75]. This technique involves the administration of increasing concentrations of nebulized histamine while monitoring pulmonary function [68,75]. Horses with airway hyperresponsiveness develop measurable bronchoconstriction at lower histamine concentrations than healthy horses [75,90]. The association between airway reactivity measured by flowmetric plethysmography and indicators of airway inflammation in horses with

suspected inflammatory airway disease has been demonstrated, supporting the relevance of bronchoprovocation in detecting functional abnormalities not apparent at rest [87].

Pulmonary function testing is also useful for monitoring disease progression and treatment response [75,90]. Horses with recurrent airway obstruction may maintain abnormal pulmonary function and airway cytological changes even when kept in low dust environments, indicating that clinical improvement does not necessarily mean complete resolution of airway dysfunction [91]. This is particularly relevant in SEA, where chronic inflammation and airway remodelling may contribute to persistent functional impairment [60,91].

Despite these advantages, pulmonary function testing is not routinely available in all clinical settings [18,75]. Therefore, pulmonary function testing should be regarded as a highly valuable adjunctive diagnostic method, particularly in referral settings, rather than as an obligatory test for every suspected case of EA [3,18,75].

Arterial blood gas

Beyond assessing airway mechanics, the evaluation of pulmonary gas exchange via arterial blood gas (ABG) analysis provides critical functional insights into the respiratory system's efficiency. In healthy horses, the arterial oxygen tension at rest is typically maintained above 90 mmHg [58]. However, horses experiencing an acute exacerbation of SEA frequently demonstrate marked resting hypoxemia (80 mmHg) and occasionally hypercapnia, driven by severe ventilation/perfusion mismatching and alveolar hypoventilation resulting from profound airway obstruction [3,92]. In contrast, horses affected by MEA typically present with normal ABG values when resting. To objectively detect functional impairment in these subclinical cases, clinicians must evaluate blood gases dynamically during a standardized high-speed treadmill test [3,58]. Under these intense and difficult conditions, horses with MEA exhibit significantly more pronounced exercise induced arterial hypoxemia compared to their healthy status, confirming the functional impact of the lower airway inflammation during exertion [3,58].

Other diagnostic tools

Newer technologies are being investigated to improve the objective assessment of airway dysfunction in horses with EA [18,93]. Electrical impedance tomography (EIT), impulse oscillometry, and within-breath oscillatory mechanics may provide more detailed information about regional ventilation, airflow limitation, and airway resistance than conventional clinical examination alone [75]. EIT is a non-invasive imaging technique that evaluates changes in thoracic electrical impedance to estimate regional

ventilation distribution [94]. This technique may be particularly useful for identifying ventilation heterogeneity and exercise induced airflow changes in horses with EA [94,95].

Impulse oscillometry and oscillatory mechanics have also been investigated in horses with severe asthma [96]. These approaches may allow the assessment of airway mechanics with less invasiveness than traditional oesophageal balloon methods [97]. Studies evaluating within-breath oscillatory mechanics and impulse oscillometry suggest that these techniques may help identify airway obstruction and monitor the response to treatment in horses with SEA or subclinical disease [96,98].

Currently, these methods are almost only available in a research context [3,75]. Their wider clinical adoption depends on further standardization, the availability of equipment, the establishment of reliable reference values, and the demonstration that they improve diagnostic or therapeutic choice [18,75].

There is also increasing interest in new biomarkers that may support the diagnosis, phenotyping, or monitoring of EA [18]. Blood biomarkers are commercially beneficial because they are easier to collect than lower airway samples, but their diagnostic value remains, at this point, very limited [18,99]. Blood biomarkers were investigated for the diagnosis of mild to moderate asthma in horses, including markers such as haptoglobin, secretoglobin, and surfactant protein D [99]. These biomarkers may reflect systemic or airway-associated inflammation and could support diagnostic interpretation in selected cases [18,99]. However, their individual sensitivity and specificity are not currently sufficient to replace BAL fluid cytology or pulmonary function testing [18,99]. Their greatest value may lie in combination with other diagnostic findings (such as clinical scoring indices) or in monitoring disease activity over time [18,99,100].

In SEA, the predominance of neutrophilic inflammation has led to an interest in neutrophil activation markers, including neutrophil extracellular traps (NETs) [75,101]. Janssen et al. (2022) demonstrated that neutrophil extracellular traps are present in BAL fluid from horses with severe asthma and correlate with disease severity. This suggests that SEA involves not only increased neutrophil numbers but also altered neutrophil behaviour and inflammatory activity [75,102].

Cell-free DNA has also been proposed as a potential marker of severe neutrophilic airway inflammation, partly because it reflects NET formation and tissue injury. Cell-free DNA was significantly elevated in tracheal wash and BAL fluid supernatant samples from horses with SEA using a portable fluorometer. This may eventually provide a more practical, stall-side, and objective method of estimating the inflammatory profile. Currently, this remains an emerging diagnostic area and requires further scientific validation before routine clinical application [101].

8.TREATMENT OF EQUINE ASTHMA

8.1. Environmental Management

Environmental management is the base of long-term control of EA including MEA and severe SEA. Management aims to reduce airborne respirable particles in the horse's breathing zone, especially those small enough to reach the distal airways and promote inflammation [1,6,21,22,31].

Forage is one of the main sources of respirable organic dust. Conventional dry hay may contain dust, mould spores, endotoxins, and fungi [6,21,22,25]. Replacing dry hay with low-dust alternatives such as haylage, grass silage, or complete pelleted feeds can markedly reduce dust exposure. Complete pelleted diets may reduce the dust burden in the breathing zone to only a small fraction of that produced by conventional hay [1,21,22,108]. Recent evidence also suggests that alfalfa pellets may improve lung function more than steamed hay in some horses with SEA, although nutritional suitability, availability, and owner compliance must be considered [103].

When forage replacement is not an option, hay modification can reduce dust exposure. Soaking hay for approximately 15-45 minutes can substantially decrease respirable particles, but prolonged soaking may leach crude protein, soluble carbohydrates, and minerals, and soaked hay should be fed right away to limit bacterial proliferation (prone in humid environments) [31,34,35,104]. High-temperature steaming, using specialized steamers that reach approximately 100 °C, reduces respirable particles and microbial viability while preserving nutrients better than soaking. However, in some SEA cases, its clinical effect may be less consistent than complete forage replacement with pelleted feeds [31,103,105,106]. A study from Olave et al. (2022) found out that both steamed hay and haylage significantly reduce dust exposure compared with dry hay. Haylage was also found to significantly reduce BAL fluid cytology neutrophilia within a 3 to 6 week period stating that haylage might be a superior option when compared with hay. Feeding method is also important, as hay nets can increase dust exposure in the breathing zone, whereas feeding from the ground promotes a more natural head position and may reduce inhalation of suspended particles [6,21,22,31].

Stabling and bedding strongly influence aeroallergen exposure. Stables generally contain higher concentrations of irritants than pasture [21,22,108,109]. For most horses with classical SEA, full-time pasture turnout is therefore preferred when feasible, provided pasture associated triggers are not involved. When stabling is necessary, straw should generally be avoided because it is a major reservoir of dust, moulds, and endotoxins. Lower dust alternatives include wood shavings, shredded cardboard, paper, and peat moss, with cardboard bedding reported to contain lower respirable dust and aeroallergen concentrations than straw or some wood shavings [6,31,108]. Mucking out, sweeping, hay distribution, and grooming can cause increases in respirable dust, so susceptible horses should be removed from the stable during these activities and ideally kept outside until particles have settled

[31,39]. Because horses share a common airspace, dust from neighbouring stalls can compromise a low-dust stall. Consequently, effective control often requires low-dust practices throughout the barn, especially in adjacent stalls and shared storage areas [33,34,104].

Adequate ventilation is essential to reduce triggering irritants. Opening doors and windows, improving airflow between stalls, and using more open stable designs can reduce particulate and ammonia concentrations across seasons [31,39,108]. Dusty hay, straw, or bedding should not be stored near or above stalls, as these materials contribute to background airborne contamination.

A different strategy is required for summer pasture-associated SEA. Unlike classical SEA cases, affected horses may require removal from pasture during the higher risk months of the season and housing in a low dust indoor environment with good ventilation or climate control [6,21,22,29].

Clinical signs and lung function may improve within days after strict reduction of antigen exposure, whereas resolution of airway inflammation and reversal of structural remodelling require longer term control [31,108]. Prolonged antigen avoidance over several months has been associated with partial reversal of airway smooth muscle remodelling, suggesting that environmental management may influence not only clinical signs but also how the disease progresses [6,32,110]. However, owner compliance remains a major limitation, as effective control often requires several changes that can be difficult to maintain long term. [31,111].

Summing up, environmental management should be considered the foundation of equine asthma treatment. The most effective approach combines low dust forage, appropriate bedding, improved ventilation, avoidance of dusty stable activities, and consideration of the horse's specific asthma phenotype. Pharmacological therapy may be a necessary push, but long-term remission is unlikely without consistent reduction of environmental triggers [1,3,6].

8.2. Medical treatment

Medical treatment of EA should be adapted to disease severity, inflammatory phenotype, clinical presentation, and intended use of the horse. In both MEA and SEA, pharmacological therapy should be complementary to management because continued exposure to respirable dust and aeroallergens can maintain airway inflammation and limit treatment response [1,3,6].

8.2.1. Treatment of MEA

The medical treatment of MEA aims to reduce airway inflammation, relieve airflow obstruction, and decrease airway hyperresponsiveness (AHR) [1,6]. Because specific clinical trials for MAE are limited,

many pharmacological protocols are extrapolated from SEA studies. Generally lower doses within SEA treatment ranges are generally considered appropriate for MEA cases [3].

Corticosteroids may be used for short term control of airway inflammation and AHR. Intramuscular dexamethasone at 0.05 mg/kg once daily for approximately two weeks has been shown to reduce airway hypersensitivity and hyperreactivity in MEA affected horses, although improvement in clinical signs or BAL fluid inflammatory cell profiles is not always observed [112]. Dexamethasone may also be administered orally at 0.05 mg/kg once daily or intravenously at 0.04 mg/kg, while prednisolone is commonly used at 1.1-2.2 mg/kg orally once daily [1, 112]. Prednisolone is preferred over oral prednisone because prednisone is poorly absorbed and inconsistently converted to its active metabolite in horses [3]. If treating a horse at risk of developing laminitis or with previous history of the disease it is recommended that respiratory rescue should be based on management and bronchodilators, avoiding corticosteroids [26].

Inhaled corticosteroids are often preferred when prolonged pharmacological treatment is required, because they deliver high regional drug concentrations to the airways while reducing systemic risks such as laminitis or hypothalamic-pituitary-adrenal axis suppression [3,113]. A recent meta-analysis reported that inhaled corticosteroids are effective across all equine asthma syndrome, with a positive overall Number Needed to Treat of 3.2, meaning that approximately three horses must be treated for one additional horse to achieve a clinically meaningful response compared with control treatment [113]. Inhaled fluticasone propionate at 3000 µg every 12 hours via a metered-dose inhaler and equine spacer for approximately two weeks has shown comparable efficacy to intramuscular dexamethasone in reducing AHR in MEA [112]. Ciclesonide is approved for SEA and has a favourable safety profile, with no statistically significant cortisol suppression reported at the recommended dosing program [114]. More recent evidence also supports its use in Thoroughbred racehorses with moderate asthma, where a 10 day protocol improved clinical signs and reduced mastocytic airway inflammation [112,114]. It is described that nebulized dexamethasone sodium phosphate used as an injectable is not effective when nebulized but studies were made on horses with SEA, therefore should be subjective to interpretation and further investigation in the treatment of MEA is needed [115].

Bronchodilators may be useful in MEA when airway hyperresponsiveness or bronchospasm contributes to coughing, poor performance, or prolonged recovery after exercise. However, because they do not control airway inflammation, they should not be used as the only therapeutic agent [1,3,6]. Short acting β2-agonists, such as albuterol (salbutamol), provide rapid bronchodilation and may be used as rescue or pre-exercise therapy. Reported inhaled doses are approximately 1-2 µg/kg, corresponding to about 450-900 µg total dose in a 450 kg horse [1,6]. Levalbuterol, the R-enantiomer of albuterol, may

provide similar bronchodilation with potentially less adverse effects, although clinical advantage over albuterol remains limited [3,117].

Longer acting β2-agonists such as salmeterol xinafoate may provide sustained bronchodilation, but they are not appropriate for acute rescue because of their slower onset of action [6,142]. Oral clenbuterol hydrochloride is another option, usually starting at 0.8 µg/kg every 12 hours and gradually increasing every 3-5 days up to 3.2 µg/kg every 12 hours if needed [3]. Prolonged clenbuterol monotherapy is limited by tachyphylaxis after approximately 14-21 days. Some studies suggest that concurrent corticosteroid therapy may help reduce β2-receptor downregulation [3,133]. Inhaled ipratropium bromide has also been used as a bronchodilator. In one MEA study, it was administered at 250µg every 12 hours, although ipratropium alone was less effective than fluticasone containing protocols in reducing airway inflammation [3,144].

8.2.2. Treatment of SEA

Medical treatment of SEA aims to achieve clinical remission, improve lung function, and rapidly relieve respiratory distress during exacerbations [3,6].

Systemic corticosteroids are indicated for rapid clinical improvement in horses with SEA exacerbation, particularly when respiratory distress is present and severe airway obstruction may limit peripheral deposition of inhaled drugs [118,6]. Dexamethasone is commonly used because of its potency and rapid onset. IV dexamethasone at 0.1 mg/kg once daily can produce marked clinical and lung function improvement within hours to days [3,119]. For oral administration, efficacy is influenced by feeding status. Doses of 0.164 mg/kg in fed horses and 0.082 mg/kg in fasted horses have shown comparable mean effects, which shows reduced oral bioavailability when administered with feed [119]. Prednisolone can be administered orally at 1.1-2.2 mg/kg once daily, but it is generally considered less potent than dexamethasone [3].

Longer acting corticosteroid options include intramuscular triamcinolone acetonide, which can improve lung function for approximately 2-4 weeks, although risks such as laminitis and Hypothalamic-pituitary-adrenal axis suppression must be considered [3]. Intra-articular triamcinolone acetonide administered for orthopaedic indications may also provoke systemic anti-inflammatory effects and improve lung function in horses with SEA, whereas intra-articular methylprednisolone acetate appears to provide only mild and transient respiratory benefit [120,121].

Inhaled corticosteroids are preferred for longer term pharmacological management of SEA because they deliver high local concentrations to the lower airways while reducing systemic exposure

compared with systemic corticosteroids [114,122]. In severe cases, the Number Needed to Treat for inhaled corticosteroids is approximately 3.0, indicating strong clinical usefulness compared with control treatment [113]. Ciclesonide is a prodrug converted in the lung to desisobutyryl-ciclesonide, which has high glucocorticoid receptor affinity [114,123]. The approved SEA protocol consists of 8 actuations, equivalent to 2744 µg, twice daily for 5 days, followed by 12 actuations, equivalent to 4116 µg, once daily for 5 days. This protocol reduces clinical signs in most SEA affected horses and is usually well tolerated [114].

Other inhaled corticosteroids include fluticasone propionate, beclomethasone dipropionate, and budesonide. Fluticasone is commonly administered at 2000-3000 µg twice daily via metered-dose inhaler and equine spacer, although higher doses may be required in horses with severe clinical signs [3,118,124]. When combined with salmeterol, fluticasone may improve lung function and reduce airway smooth muscle mass and neutrophilic inflammation more effectively than monotherapy in some affected horses [125]. Beclomethasone dipropionate can improve lung function, sometimes within 24 hours, but systemic absorption and adrenal suppression may occur at higher doses. So, careful dose selection after prolonged or high dose treatment may be appropriate [3,122,126]. Nebulized Budesonide can produce dose dependent improvement in airway obstruction, but high-dose protocols may suppress serum cortisol, indicating systemic absorption [127].

Bronchodilators are useful adjunctive therapies in SEA because they relieve airway smooth muscle contraction and improve airflow. They are especially relevant during acute bronchoconstriction or for assessing reversibility of airway obstruction [3,126]. Systemic anticholinergics can provide rapid bronchodilation in severe cases. Atropine sulphate administered IV at approximately 0.02 mg/kg produces bronchodilation within 10-30 minutes, lasting up to approximately 2 hours, but its use is limited by adverse effects including ileus, tachycardia, and reduced mucociliary clearance [3,128,129,130]. N-butylscopolammonium bromide, also known as Buscopan®, administered intravenously at 0.3 mg/kg, acts within minutes and reaches maximal effect around 10 minutes, but its duration is generally less than 1 hour [88,131,132].

Systemic clenbuterol may be used for reversible bronchospasm, using the same protocol described for MEA, with prolonged monotherapy limited by β2-receptor desensitization [3,133]. Methylxanthines such as theophylline and aminophylline have bronchodilatory effects but are less commonly used because of their narrow therapeutic index and adverse effects, including tachycardia, hyperexcitability, arrhythmias, and seizures [3,89,134,135]. Magnesium sulphate may moderately improve clinical scores but has not consistently improved lung function, while furosemide has shown experimental improvement in pulmonary resistance and dynamic compliance but is not considered routine SEA therapy [136,137].

Inhaled bronchodilators allow targeted airway delivery with fewer systemic effects [118,122]. Albuterol/salbutamol is an important short-acting rescue medication, administered at approximately 360-720 µg per horse, or 1-2 µg/kg, by metered-dose inhaler and equine spacer. It reaches maximal effect within minutes, but its duration is short, lasting approximately 1-3 hours [138,139,140]. Levalbuterol, pirbuterol, and fenoterol have also shown bronchodilatory efficacy, although their clinical advantages over albuterol are limited [117,138,140]. Salmeterol provides longer-lasting bronchodilation and may be useful for sustained control, but it is not appropriate for acute rescue because of its slow onset of action [114,142,143]. Ipratropium bromide is an inhaled anticholinergic with limited systemic absorption; it produces bronchodilation with later peak effect than albuterol and a duration of approximately 4-6 hours, without the same impairment of mucociliary clearance associated with atropine [144, 108,118,144].

8.2.3. Mucolytics and supportive therapies

Mucolytic agents aim to improve mucociliary clearance by reducing mucus viscosity, increasing secretion hydration, or enhancing ciliary transport [3]. Although acetylcysteine, bromhexine, ammonium chloride, potassium iodide, dembrexine, and related agents have been used for a long time in equine respiratory disease, their use in MEA and SEA remains largely empirical, with limited randomised controlled evidence [1]. Therefore, mucolytic therapies should be considered complementary.

N-acetylcysteine is a sulfhydryl-containing compound that disrupts disulfide bonds within mucoproteins and may also exert antioxidant effects as a glutathione precursor [145]. Oral dosages at 15 mg/kg once daily for 3 days reduced tracheal mucus accumulation and BAL fluid neutrophilia in a prolonged head-confinement model, but this model does not fully represent naturally occurring MEA or SEA so results should be carefully interpreted [6,145]. Dembrexine, bromhexine, ammonium chloride, potassium iodide, and guaifenesin may facilitate mucus clearance, but evidence for their efficacy in equine asthma is scarce, and they should not be recommended as “go-to” therapies [1,3].

Nebulized 0.9% sodium chloride is commonly used empirically to hydrate airway secretions, but evidence that isotonic saline is an effective mucolytic treatment for equine asthma is again limited. Earlier reviews concluded that nebulized saline lacked supportive evidence in heaves/recurrent airway obstruction (old nomenclature for SEA), and saline is frequently used as a placebo or comparator in several nebulizing studies [1,146,147]. Dry saline aerosol therapy, or halotherapy, has been proposed to improve airway surface hydration and mucus clearance. A 7-day protocol of 60-minute daily sessions helped in improving clinical status and arterial blood gas parameters in horses with MEA, but objective mucus and BAL fluid outcomes were limited, so this therapy should be described as preliminary and supportive [6,148]. Systemic overhydration with 30-40 L of IV isotonic saline is not recommended because it has shown no benefit for SEA and may carry risks, including pulmonary oedema and death [146-149].

8.2.4 Other therapies and supplementation

Other therapies may be considered in selected horses, especially when targeted to inflammatory phenotype or specific clinical limitations, but their evidence base is generally weaker than that of environmental management, corticosteroids, and bronchodilators [1,3,6].

Dietary omega-3 supplementation, particularly docosahexaenoic acid (DHA), has shown beneficial effects when combined with a low-dust diet. DHA at approximately 1.5-3.0 grams per day for 8 weeks has been associated with reduced coughing, improved respiratory effort, and decreased BAL fluid neutrophilia, likely through modulation of inflammatory mediator production [3,6,150]. Antioxidant and herbal nutraceuticals have also been investigated. Garlic may improve some respiratory health scores but should be used cautiously because of potential hematologic adverse effects, while formulations containing Arthrospira platensis and fermented pineapple have shown potential to improve clinical scores and reduce mucus production in athletic horses, although further studies are needed [3,6].

Low dose oral human interferon-alpha, administered at 50-150 U daily for 5 days, has shown benefit in young Standardbreds with MEA, reducing coughing and BAL fluid cellularity for up to two weeks after treatment [1,3]. Sodium cromoglycate, or cromolyn, may be useful in horses with mastocytic MEA, particularly when BAL fluid mast cells are increased by stabilizing mast cell membranes and possibly reducing mediator release. Nebulization at 80-200 mg SID is recommended [3,6].

Emerging or experimental approaches include inhaled CpG oligonucleotides, cell-based therapies, tamoxifen (selective oestrogen receptor modulator), and macrolides. CpG-GNP immunotherapy has shown improvement in clinical signs and arterial oxygenation in SEA and may be valuable when corticosteroids are contraindicated, although it remains an emerging rather than first-line treatment [6,151]. Autologous bone marrow-derived mononuclear cell therapy has shown potential anti-inflammatory effects in SEA, including increased IL-10 expression, but requires further validation before routine use [6,152]. Tamoxifen may improve pulmonary resistance but has uncertain effects on airway neutrophilia, while azithromycin has been evaluated for immunomodulatory effects but should not be used routinely in non-infectious asthma without specific justification because of antimicrobial stewardship concerns [6,153,154].

New therapeutic studies using nebulized alfa-2-macroglobulins are being conducted by the company Alpha2EQ®. These alfa-2-macroglobulins are blood proteins with the capacity of inhibiting proteases and influence immune regulation by binding with cytokines, growth factors and other inflammatory mediators. Currently, scientific evidence on their application on EA remains limited, although pilot studies promoted by the company seem to have promising results.

9. PROGNOSIS

The prognosis of equine asthma differs between MEA and SEA, depending on disease severity, reversibility of airway obstruction, degree of airway remodelling, early diagnosis, and consistency of environmental management [1,6].

MEA generally has a good to excellent prognosis, particularly for return to athletic function [1]. In many horses, it is transient or reversible and improves with environmental modification, rest, and pharmacological therapy when in need [1,24]. Recurrence may occur with continued exposure to respirable dust or aeroallergens. Although the relationship between MEA and SEA remains uncertain, chronic or recurrent mild airway disease may increase the risk of later severe asthma [6]. Horses with occasional coughing and mucoid nasal discharge have been reported to have a higher risk of developing SEA within one to four years, suggesting that persistent mild signs should not be ignored [67].

SEA has a more guarded prognosis because it is chronic and recurrent, with repeated exacerbations, mucus hypersecretion, reversible bronchospasm, and variable airway remodelling [6,32]. However, clinical remission and continued athletic or pleasure use are possible with strict environmental control and appropriate medical therapy [31,155]. In one longitudinal study, horses with SEA had a median survival time of approximately 8 years after diagnosis, with 87% surviving at least 3 years, and 74% still used for athletic activity [3,155]. Re-exposure to environmental triggers commonly causes recurrence of clinical signs, reflecting the relapsing-remitting nature of the disease [31].

Airway remodelling is a major determinant of long-term outcome in SEA. Although bronchospasm and active inflammation are at least partially reversible, structural changes such as airway smooth muscle hypertrophy, epithelial alterations, and chronic mucus gland changes may persist during clinical remission [6,62]. Long-term antigen avoidance for 6-12 months, often combined with anti-inflammatory therapy, can reduce airway smooth muscle mass by approximately 30%, although values may remain higher than in healthy horses [6,62]. Consequently, some horses in apparent remission may still show peripheral airway obstruction or airway hyperresponsiveness [91].

Owner compliance is one of the most important practical determinants of prognosis, because effective control requires sustained changes in forage, bedding, ventilation, and turnout strategy [31]. In some cases, euthanasia is related less to immediate fatality than to the cost or impracticality of maintaining adequate environmental control [7]. End-stage cases may develop right sided heart failure secondary to chronic pulmonary hypertension, which worsens the prognosis [74].

As a result, MEA usually has a favourable prognosis when recognized and managed appropriately, whereas SEA has a more guarded prognosis because of its chronicity, recurrent nature and potential for

persistent airway remodelling. Long-term outcome is strongly influenced by environmental control, owner compliance, and the extent to which airway obstruction remains reversible [1;6,31].

10. CLINICAL CASES

10.1. Case 1 - Dolly

10.1.1 Anamnesis and clinical findings

Dolly is a 16-year-old cob mare used for small level schooling and hacking, who was presented to Pool House Equine Hospital in January 2026 for further investigation of respiratory system abnormalities and poor performance at low-level exercise. Her body condition score was a 4.5/5 in the Carroll and Huntington (1988) scale and weighed 495 kg. Dolly was turned out every day and stabled during the night and her diet consisted of 2% of body mass (for the ideal weight of 450kg), that equaled 9kg of hay a day, that was soaked for 8 hours and fed from the floor.

Dolly's vaccination status and deworming protocols were up to date. Her medical/surgical history included laser surgical excision of several sarcoids during general anaesthesia; two episodes of ventral oedema (2018 and 2021) - no major abnormalities were detected after investigation; in 2020 a previous episode of intermittent coughing that resolved with low dose corticosteroids (dexamethasone and oral prednisolone) and use of bronchodilators (buscopan® IV and oral clenbuterol®); an episode of idiopathic fever in 2020; an episode of spasmodic colic in 2021 and equine squamous gastric disease in 2025 and obesity that has been constant for the past few years.

During a recent routine visit a blood sample was obtained for investigation of insulin dysregulation, that documented a high basal insulin concentration (105.7 μIU/mL - laboratory reference range 2.0-21.1 μIU/mL). This test was performed due to Dolly's overweight, with an increased body condition score, which raised concerns for insulin dysregulation (ID) and associated risk of endocrinopathic laminitis. The combination of obesity with marked basal hyperinsulinemia was consistent with the diagnosis of Equine Metabolic Syndrome - collection of risk factors for endocrinopathic laminitis, of which insulin dysregulation plays a central role and is commonly associated with increased adiposity [156].

At admission to the hospital, the owner reported that the respiratory signs started in December 2025, when Dolly started to display increased laboured breathing and flared nostrils after very mild exercise. More recently, the patient experienced worsening of these signs and a veterinarian had to attend to Dolly. On examination a mildly increased respiratory rate (36 bpm) and effort, with a mild heave

line were noted at rest. Using a rebreathing bag, mild expiratory wheezes and increased respiratory sounds were present on thoracic auscultation bilaterally.

After a soft lunge, Dolly had a marked increase in respiratory rate, flared nostrils and a heave line. There were no signs of coughing or nasal discharge at this point. Given recent diagnosis of ID and EMS and worsening of the respiratory pathology, the attending veterinarian recommended a course of a compounded formulation of levothyroxine (0.1 mg/kg) PO SID, alongside with clenbuterol (Ventipulmin ® 16 μg/g at 0.8 μg/kg) PO BID. It was also discussed with the owner the possibility of performing a BAL for a more definitive diagnosis on the lower airway pathology. As not much improvement was achieved during the following weeks, Dolly was referred for further investigation.

On clinical examination, Dolly was bright, alert and reactive. Her temperature and heart rate were normal. Dolly had increased respiratory rate at rest and showed a heave line bilaterally at rest. The other aspects of physical examination, including mucous membranes and CRT, digital pulses, gastrointestinal auscultation and cardiac auscultation at rest were unremarkable.

While examining Dolly, excursion of the hindlimb fetlocks was evident at walk. Due to this finding and the poor performance complaint, a lameness examination was also conducted during the appointment. Mild bilateral hindlimb lameness (3/5 AAEP scale) was noted during trotting in a straight line and during lunging in both reins of while in soft surface.

After exercise, lung auscultation was similar to what was reported by the referring veterinarian. Cardiac auscultation revealed a regularly irregular dysrhythmia that was confirmed by an exercise ECG. However, this sinoatrial dysrhythmia was only noted in the period immediately post-exercise and because her heart rate was considered appropriate for the level of exercise performed, the clinical significance of this dysrhythmia was not clear at this stage. It was possible that the respiratory pathology and possible musculoskeletal pain could have affected the cardiovascular response to exercise.

The problem list that arises from this appointment includes increased respiratory rate, a visible heave line bilaterally, increased laboured breathing and flared nostrils after exercise, increased respiratory sounds and abnormal respiratory sounds (expiratory wheezes) after exercise, obesity (overweight), EMS (associated with insulin dysregulation), poor performance, mild hindlimb lameness.

10.1.2. Differential Diagnosis

Lower chronic airway inflammatory disease suggestive of Mild-Moderate Equine Severe Asthma. This is the top differential diagnosis. This is supported by Dolly's clinical signs including poor performance, increased respiratory effort and abnormal respiratory sounds after exercise without indication of

systemic disease (Dolly was bright and alert, with normal rectal temperature and a normal haematology and biochemistry when respiratory pathology was first noted).

Severe equine asthma is also a possibility as on the day she arrived at the hospital, an increased respiratory rate and marked heave line was detected. However, cautious interpretation should be taken as Dolly showed to have a normal clinical examination at rest the following day before further investigation to reach the diagnosis.

An infectious process should be on the differential list as increased respiratory effort and exercise intolerance can occur in lower airway bacteria - such as *Streptococcus equi subsp. zooepidemicus, Actinobacillus spp., Pasteurella spp., Bordetella bronchiseptica, Escherichia coli* and *Pseudomonas aeruginosa* - or viral disease - Equine Influenza Virus, Equine Herpesvirus-1/4, Equine Rhinitis A and B Viruses. However, Dolly's clinical examination makes it a less probable cause.

Upper airway pathology was less likely in this case but should be evaluated as it's a differential in cases of an altered breathing pattern and airway pathology. An upper airway endoscopy is always advised.

Cardiac disease, more specifically those contributing to left-sided heart failure and consequently to pulmonary hypertension, such as mitral regurgitation and aortic regurgitation, or dysrhythmias (especially atrial fibrillation) can cause poor performance and secondary respiratory pathology.

Obesity/EMS can also cause poor performance and exercise intolerance, as an overweight horse will have an increased mechanical workload, causing excessive stress on the horse's limbs and have negative impacts on inflammatory and metabolic processes that may affect the horse systemically and locally on the respiratory system [158].

To reach an accurate diagnosis, an airway endoscopy, BAL and TW cytologies should be performed.

10.1.3. Complementary Examination

In order to perform a safe examination for the horse and the clinician, and minimize contamination of fluids for cytology, intravenous sedation was administered: detomidine 10 mg/ml (0.1 mg/kg) and butorphanol 10 mg/ml (0.1 mg/kg).

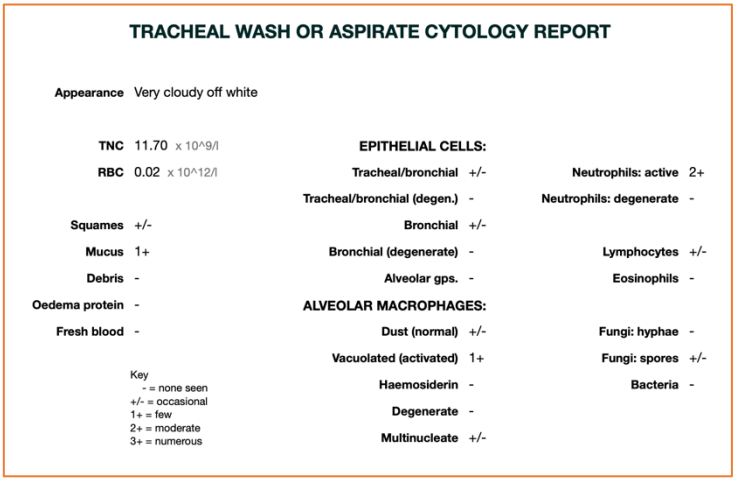
Airway endoscopy was performed using a 9mm diameter and 160cm length flexible endoscope passed via the ventral nasal meatus through the nasal passage, so visualization of the pharynx, larynx and trachea was achieved. The upper respiratory tract had no abnormalities detected. When inspecting the

trachea and bronchi bifurcation, there was no mucus accumulation (score of 0/5 from Gerber et al. (2004) scale), but a hyperactive airway was noted.

For the **tracheal wash**, the endoscope was stabilized within the trachea and 30 ml of sterile 0.9% NaCl solution was instilled using a guarded catheter passed via the endoscope port. The fluid was immediately aspirated, being cautious to maintain sterility. The fluid was mildly cloudy and mucoid, with no food material present. After being stored in EDTA and a Cytospin solution to preserve cell morphology, the sample was sent to an external laboratory for cytology. A plain tube was also selected in case culture, and sensitivity testing was needed.

For the **bronchoalveolar lavage** a Mila Equine BAL Catheter, 30 FR, 300cm was blindly introduced, the same way the endoscope was introduced previously, and advanced until it became wedged within a distal bronchus. Then 250 ml of sterile 0.9% NaCl solution was instilled into the distal airway using five 50 mL syringes. The fluid was then retrieved and stored in EDTA tubes and Cytospin solution and sent to an external laboratory for fluid cytology.

The cytologic evaluation was made by a RCVS recognized specialist in veterinary pathology and results from TW supported a moderate neutrophilic lower airway inflammatory response and mild to moderately increased mucus within the samples. From a cytological perspective, the predominance of non-degenerate neutrophils and overall pattern strongly favoured an allergic/hypersensitivity response (equine asthma) rather than a response to bacterial infection. The BAL fluid cytology was compatible with the TW findings. There was a mild increase in neutrophil percentage (13%) supporting a mild-moderate lower airway inflammatory response. The pattern was not supportive of infectious aetiology at the lower airway level as there was no presence of bacteria nor degenerate neutrophilia.



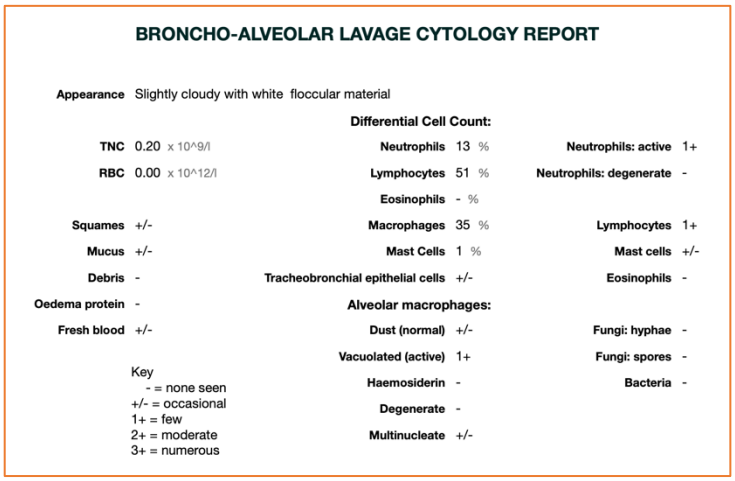
TRACHEAL WASH OR ASPIRATE CYTOLOGY REPORT

Appearance Very cloudy off white

TNC	11.70 x 10^9/l	**EPITHELIAL CELLS:**			
RBC	0.02 x 10^12/l	**Tracheal/bronchial**	+/-	**Neutrophils: active**	2+
		Tracheal/bronchial (degen.)	-	**Neutrophils: degenerate**	-
Squames	+/-	**Bronchial**	+/-		
Mucus	1+	**Bronchial (degenerate)**	-	**Lymphocytes**	+/-
Debris	-	**Alveolar gps.**	-	**Eosinophils**	-
Oedema protein	-	**ALVEOLAR MACROPHAGES:**			
Fresh blood	-	**Dust (normal)**	+/-	**Fungi: hyphae**	-
		Vacuolated (activated)	1+	**Fungi: spores**	+/-
		Haemosiderin	-	**Bacteria**	-
		Degenerate	-		
		Multinucleate	+/-		

Key
- = none seen
+/- = occasional
1+ = few
2+ = moderate
3+ = numerous

Figure 2: Dolly's Tracheal Wash report (courtesy of Regina Pereira)



BRONCHO-ALVEOLAR LAVAGE CYTOLOGY REPORT

Appearance Slightly cloudy with white floccular material

		Differential Cell Count:			
TNC	0.20 x 10^9/l	**Neutrophils**	13 %	**Neutrophils: active**	1+
RBC	0.00 x 10^12/l	**Lymphocytes**	51 %	**Neutrophils: degenerate**	-
		Eosinophils	- %		
Squames	+/-	**Macrophages**	35 %	**Lymphocytes**	1+
Mucus	+/-	**Mast Cells**	1 %	**Mast cells**	+/-
Debris	-	**Tracheobronchial epithelial cells**	+/-	**Eosinophils**	-
Oedema protein	-	**Alveolar macrophages:**			
Fresh blood	+/-	**Dust (normal)**	+/-	**Fungi: hyphae**	-
		Vacuolated (active)	1+	**Fungi: spores**	-
		Haemosiderin	-	**Bacteria**	-
		Degenerate	-		
		Multinucleate	+/-		

Key
- = none seen
+/- = occasional
1+ = few
2+ = moderate
3+ = numerous

Figure 3: Dolly's Bronchoalveolar lavage report (courtesy of Regina Pereira)

10.1.4. Diagnosis

Following clinical examination and laboratory diagnostic results interpretation, a diagnosis of Moderate Equine Asthma was made. The presence of increased respiratory effort and increased respiratory sounds after exercise, presence of airway hyperreactivity during endoscopy, increased mucus on TW and cytological evidence of lower airway inflammation markers on BAL and TW supports the diagnosis.

10.1.5. Treatment

Treatment was divided in two different sections, one regarding environmental management of Dolly's respiratory and metabolic pathology, and another regarding medical treatment.

Regarding environmental management, soaking the hay for 6-8 hours was recommended as it would not only decrease the amount of organic dust but also to reduce its water-soluble carbohydrates [157]. This would be helpful in both addressing Dolly's weight and MEA management. It was also recommended to continue feeding from ground level to reduce suspended particles and aid airway clearance. Pasture turnout on a dry lot full time was also recommended, reducing grass intake to minimize calories and sugar consumption and when stabling was necessary, opting for lower dust alternatives such as wood shavings. It was also advised to keep the neighbouring environment as dust free as possible, and to only clean when the horse is not stabled. Adequate ventilation is also essential to reduce possible irritants. It was also discussed that owner compliance and environmental changes are fundamental for an adequate treatment response and to only perform medical management wouldn't be sufficient.

Regarding medical management, Dolly's insulin dysregulation and being overweight put her at high risk of developing laminitis. This could be aggravated by systemic corticosteroid treatment. Therefore, to treat airway inflammation a nebulization of 4 ml of injectable dexamethasone (Rapidexone®) in 2 mL of isotonic sterile 0.9% NaCl using the Flexineb® mask was recommended once daily for three weeks, alongside with clenbuterol (ventipulmin®) at 0.8 µg/kg PO BID for 2 weeks to reduce airway hyperresponsiveness the bronchodilator.

To keep on addressing the insulin deregulation, levothyroxine at 0.1 mg/kg SID was continued for three more weeks.

Follow-up was recommended in three weeks' time.

10.1.6. Follow-up

Three weeks later, the owner reported that Dolly had improved significantly. Her breathing had returned to normal, and she accepted the use of the nebulizer. On examination every clinical parameter was within normal limits, with no abnormalities detected on auscultation.

Her BCS was now a 4/5 and her weight had decreased 3% from previous examination now being 472kg, confirming success in her medication and diet. Her insulin had also decreased to 51.8 µIU/ml which is an improvement compared to previous testing. The plan was to continue nebulizing dexamethasone plus saline solution for one more week, then transition to saline alone for another week and then stop. Levothyroxine was also tapered before stopping treatment. Ridden walk was to be started for 15 minutes daily and re-examination to repeat bloods and check her respiratory system.

A month after her last appointment, Dolly's owner reported she was doing well and with ridden walking exercise. No concerns regarding respiratory issues were voices. On clinical examination, every parameter was again within normal limits, except for BCS that did not improve since the previous appointment (weight was now 480kg). Her insulin levels had returned to reference range (31.9 µIU/ml). The plan was to gradually increase exercise and keep Dolly on a diet of 7kg of soaked hay distributed throughout 24hours and re-examination in five weeks. After five weeks Dolly had no respiratory issues, and so the orthopaedic signs were addressed.

10.1.7 Prognosis

Dolly's prognosis for control of her MEA appears to be very positive. Her response to treatment was excellent as clinical improvement after environmental and medical treatment was rapidly observed and normal respiratory function was achieved.

However, owner compliance and dedication to keeping environmental risks controlled will be a key factor in management of this condition as it is typically a chronic condition with possible flare-ups. Management of her EMS is also important as they limit therapeutic options in case of future crises.

In terms of her riding prognosis, her respiratory system shouldn't be a limiting factor for the type of light work she is expected to do. However, Dolly has several orthopaedic issues that are currently being investigated and treated that may be a limiting factor in her being a riding horse in the future.

It is recommended that Dolly's owner keeps managing her as a horse with MEA. Regular monitoring of her insulin and body condition is also advised. Keeping a strict diet and adopting weight control strategies are key to keeping her metabolic condition under control.

If respiratory signs occur in the future, early reassessment is the ideal scenario.

10.2. Case 2 - Herbie

10.2.1 Anamnesis and clinical findings

Herbie is a 20-year-old cob gelding used primarily for hacking. He was admitted to Pool House Equine Hospital on March 26, 2026 for further investigation of intermittent coughing, episodes of respiratory distress, and nasal discharge. The owner reported that he had been experiencing intermittent coughing for approximately two months. This condition acutely worsened on March 18, 2026 when Herbie developed a marked episode of respiratory distress. This episode was characterized by flared nostrils, audible wheezes, pronounced abdominal effort, laboured breathing with a clear expiratory component and was accompanied by serous nasal discharge. Following this acute event, no further severe episodes were reported, although intermittent coughing persisted.

The owner reported that the coughing episodes were mostly observed during feeding time and at the beginning of exercise, particularly when entering the arena. Prior to referral to the clinic, the horse had been treated by an ambulatory clinician with clenbuterol (Subestin® syrup 25 µg/ml) at 0.8 µg/kg PO BID for 10 days. In addition to it, it was administered butylscopolamine bromide (buscopan® 20 mg/ml) at a 0.2 mg/kg IV, flunixin meglumin (Finadyne® 50 mg/mL) at a 1.1 mg/kg IV and dexamethasone (Rapidexon® 2 mg/mL) at a dose of 0.04 mg/kg IV. No adverse effects were observed, with special consideration to laminitis after administration of corticosteroids.

Herbie's vaccination and deworming status were reported to be up to date. His medical history included an episode of acute laminitis two years previously, which had been successfully managed with no recurrence since that time. There was no reported surgical history, except castration when he was younger. Regarding management, he is turned out every day for longer periods in the summer and on a bare paddock because of a previous acute laminitis diagnosis. When stabled during the night, he is kept on a wood shaving bed. His diet consisted of soaked hay, and the only recent dietary change was the introduction of a new bale of hay. No new horses had been introduced into the environment, and it was unclear whether he had contact with other animals. The horse was exercised lightly three times per week and had not travelled recently except for transport to the clinic.

On presentation, Herbie was bright, alert, and responsive. His body condition score was a 3/5 in the Carroll and Huntington (1988) scale and weighed 525 kg. All vital parameters were within normal limits, including temperature, respiratory rate, heart rate, mucous membrane colour, capillary refill time, digital pulses, and gastrointestinal auscultation. Initial thoracic auscultation did not reveal any abnormalities. However, to further evaluate respiratory function, auscultation was repeated following the use of a rebreathing bag and after lunging exercise. Under these conditions, increased respiratory

effort and respiratory sounds were detected, although the horse demonstrated an appropriate recovery following exercise.

In addition to the respiratory findings, dermatological abnormalities were noted during clinical examination. These included evidence of chorioptic mange infestation and pastern dermatitis, with the presence of scabs on the plantar aspect of the hindlimbs.

With all this in mind, the main clinical concerns identified in this case included a recent acute episode of respiratory distress characterized by expiratory effort and wheezing, increased respiratory effort and abnormal lung sounds following exercise, chronic intermittent cough, and the presence of serous nasal discharge.

10.2.2 Differential Diagnosis

Lower airway inflammatory disease, consistent with Severe Equine Asthma, was the top differential at this point. This would be supportive of Herbie's clinical signs including intermittent coughing, his previous episode of acute respiratory distress when at rest with marked increased respiratory effort, abnormal thoracic auscultation and nasal discharge. One of the etiological points of this condition is exposure to allergen exposure, which fits Herbie's flare-ups during feeding, stabling and entering a dusty arena. It is also relevant to note that Herbie had no sign of systemic disease as he was bright and alert, with normal rectal temperature at clinical examination.

An infectious disease should also be a differential diagnosis. Herbie's vaccination status was up to date which would significantly reduce the risk of Equine Influenza Virus, but other viruses such as Equine Herpes Virus 1 and 4 and the virus of Equine Rhinitis A and B should be considered. Bacterial infection such as *Streptococcus equi subsp. zooepidemicus, Actinobacillus spp., Pasteurella spp., Bordetella bronchiseptica, Escherichia coli* and *Pseudomonas aeruginosa* are also possible causes for the clinical signs Herbie was displaying. However, as described above Herbie was bright and alert and had a normal temperature indicating a normal systemic status. A comprehensive laboratory panel including haematology and biochemistry could aid in the exclusion of an infectious process (i.e. changes in neutrophil count, decrease in serum protein concentration, as albumin is a negative inflammatory protein, or increase in serum amyloid A concentration). A TW cytology and culture would also be important in identifying potentially pathogenic bacteria and inflammatory cell changes such as presence of bacteria and toxic changes in neutrophils.

Upper airway diseases are unlikely in this case as they usually cause pronounced inspiratory effort and abnormal breathing sounds. However, they should be ruled out during endoscopic examination.

Cardiac disease causing pulmonary hypertension, such as mitral valve regurgitation and aortic regurgitation can seldom be a cause of respiratory disease, as lung function is impaired. Cardiac ultrasonography would have to be performed to rule out these diseases.

For the dermatological pathology, chorioptic mange caused by *Chorioptes bovis* and Equine Pastern Dermatitis (also known as Mud Fever) were the main differentials. The pastern dermatitis was probably secondary to the compromised skin barrier caused by the underlying mite infection combined with the potential environmental moisture.

As Severe Equine Asthma was our top differential upper airway endoscopy, BAL and TW were performed for fluid cytology.

10.2.3. Complementary Examination

For the safety of the horse and staff involved in the procedures, as well as minimizing contamination of samples, Herbie was sedated with Domidine® 10 mg/ml (detomidine 0.01 mg/kg IV) and Torphadine® 10 mg/ml (Butorphanol 0.01 mg/kg IV).

As it is a standardized practice at Pool House Equine Hospital, protocols for airway endoscopy and fluid collection for TW and BAL cytology are described in Dolly's case (case number 1).

Airway endoscopy showed no upper respiratory tract abnormalities. When inspecting the trachea and entrance of the bronchi, an increased amount of mucus was observed as an accumulation of clumps - grade 4 in the Gerber et al. (2004) scale. Increased hypersensitivity of the airways was also noted.

Both the TW and the BAL fluid Cytology were interpreted by a RCVS recognized specialist in veterinary pathology. The TW findings documented marked neutrophilic lower airway inflammatory

TRACHEAL WASH OR ASPIRATE CYTOLOGY REPORT

Appearance	Cloudy off white				
TNC	25.20 x 10^9/l	**EPITHELIAL CELLS:**			
RBC	0.04 x 10^12/l	**Tracheal/bronchial**	+/-	**Neutrophils: active**	3+
		Tracheal/bronchial (degen.)	-	**Neutrophils: degenerate**	-
Squames	+/-	**Bronchial**	-		
Mucus	3+	**Bronchial (degenerate)**	-	**Lymphocytes**	+/-
Debris	-	**Alveolar gps.**	-	**Eosinophils**	-
Oedema protein	-	**ALVEOLAR MACROPHAGES:**			
Fresh blood	-	**Dust (normal)**	+/-	**Fungi: hyphae**	-
		Vacuolated (activated)	1+	**Fungi: spores**	-
Key		**Haemosiderin**	-	**Bacteria**	-
- = none seen		**Degenerate**	-		
+/- = occasional		**Multinucleate**	+/-		
1+ = few					
2+ = moderate					
3+ = numerous					

Figure 4: Herbie's Tracheal Wash report (courtesy of Regina Pereira)

BRONCHO-ALVEOLAR LAVAGE CYTOLOGY REPORT

Appearance	Slightly cloudy off white				
		Differential Cell Count:			
TNC	0.40 x 10^9/l	**Neutrophils**	57 %	**Neutrophils: active**	2+
RBC	0.01 x 10^12/l	**Lymphocytes**	18 %	**Neutrophils: degenerate**	-
		Eosinophils	- %		
Squames	+/-	**Macrophages**	23 %	**Lymphocytes**	+/-
Mucus	+/-	**Mast Cells**	2 %	**Mast cells**	+/-
Debris	-	**Tracheobronchial epithelial cells**	+/-	**Eosinophils**	-
Oedema protein	-	**Alveolar macrophages:**			
Fresh blood	-	**Dust (normal)**	+/-	**Fungi: hyphae**	-
		Vacuolated (active)	1+	**Fungi: spores**	-
Key		**Haemosiderin**	-	**Bacteria**	-
- = none seen		**Degenerate**	-		
+/- = occasional		**Multinucleate**	+/-		
1+ = few					
2+ = moderate					
3+ = numerous					

Figure 5: Herbie's Bronchoalveolar lavage report (courtesy of Regina Pereira)

response and increased mucus within the sample. From a cytological perspective, the predominance of non-degenerate neutrophils strongly favoured an acute allergic/hypersensitivity response compatible to severe equine asthma rather than a bacterial infection. The BAL fluid cytology was compatible with the TW results. There was a marked increase in neutrophil percentage (57%) supporting an active airway inflammatory response compatible with an acute hypersensitivity response.

10.2.4 Diagnosis

Supported by clinical examination findings and interpretation of airway endoscopy, TW and BAL fluid cytology a diagnosis of Severe Equine Asthma was made.

10.2.5 Treatment

Environmental measures recommended for the management of SEA included soaking the hay for 15-45 minutes to decrease allergen exposure. It was also recommended to feed from ground level to reduce suspended particles and aid airway clearance. Pasture turnout on a dry lot full time was also recommended, reducing grass intake to minimize calories and sugar consumption. When stabling was necessary, opting for lower dust alternatives such as wood shavings. It was also advised to keep the neighbouring environment as dust free as possible, and to only clean when the horse was not stabled. Adequate ventilation is also essential to reduce possible irritants. It was also discussed that owner compliance and environmental changes are fundamental for an adequate treatment response and to only perform medical management wouldn't be enough.

In terms of medical management, at the time of consultation Herbie was showing clinical improvement under oral clenbuterol therapy. Pending cytological analysis results, 0.8 µ/kg Ventipulmin granules 16 µ/g (clenbuterol) PO BID and 0.3mg/kg of Sputolosin Oral Powder 5mg/g (dembrexine hydrochloride monohydrate) PO BID were given as a bronchodilator and a mucolytic agent respectively. The potential use of corticosteroids was discussed, always considering the potential risk for laminitis. Due to the increased risk of laminitis, a grazing muzzle to reduce carbohydrates intake and close monitoring to any potential signs was advised.

Concurrent dermatological conditions were also addressed.

After cytological confirmation of SEA, a targeted anti-inflammatory treatment plan was initiated. To avoid use of systemic corticosteroids, which are contraindicated when risk of laminitis is high due to previous history of laminitis, nebulized corticosteroids were selected.

Following cytological confirmation of a moderate to severe inflammatory airway disease consistent with equine asthma, a targeted anti-inflammatory treatment plan was initiated on 2 April 2026. Due to the contraindication of systemic corticosteroids, inhaled therapy was selected. Nebulization was performed using a Flexineb device, delivering 1.5 ml of 0.9% saline combined with 3 mg of dexamethasone solution (Rapidexon®) once daily in the morning, alongside an additional administration of 5 ml saline in the afternoon. This regimen was prescribed for a duration of three weeks, after which re-examination was planned. Adjunctive nutritional support included the addition of a small daily quantity of vegetable oil to the diet as they are a natural source of omega-3 and omega-6 supplementation. All in all, the therapeutic approach combined bronchodilation, targeted anti-inflammatory treatment, and environmental management, while carefully balancing the risk of laminitis associated with corticosteroid use.

10.2.6 Follow-up

After a week of treatment with nebulized injectable dexamethasone, Herbie's owners reported an episode of mild discomfort on all 4 feet. Since Herbie is at serious risk of developing laminitis, corticosteroid therapy was discontinued and he was advised to keep being nebulized with saline twice daily and to start 15 minute walking exercise every other day and see his reaction. After 2 days, the owner reported that Herbie was doing clinically well, only a small amount of serous nasal discharge was still present.

This reflects the importance of monitoring corticosteroid use, even when nebulized administration is used over the systemic route.

10.2.7 Prognosis

SEA carries a good prognosis if response to treatment (environmental and medical) is positive. In Herbie's case, response to treatment appears to be effective, so full recovery is to be expected. However, future medical management of SEA in Herbie's case can be challenging as laminitis presents a big risk so use of corticosteroids should be avoided, which increases difficulty in managing airway inflammation. As said in the previous case, owner compliance in keeping environmental risks controlled is fundamental in managing this case and avoiding possible flare-ups.

In terms of riding prognosis, if the condition is in remission, Herbie should be expected to be able to handle some low-level riding and hacking.

10.3 Case discussion

Both Dolly and Herbie were very standard cases of MEA and SEA, respectively. Both horses were older cob-type horse used for low-level exercise and presented to the hospital for respiratory abnormalities of different severities that were previously explained.

Regarding the diagnostic approach, laboratory analysis of BAL fluid cytology was diagnostic of both animal's pathologies as they agreed with history, clinical examination, endoscopic findings and TW results, supporting the importance of combining several diagnostic features. As supported by literature, Dolly had a mild increased neutrophil percentage (13% versus <5-10% in literature) with non-degenerate neutrophils which would support a MEA diagnosis. On the other hand, Herbie had a marked neutrophil percentage on BAL cytology (57%) supporting a SEA diagnosis [1,3,26].

Even with a straightforward diagnosis, management revealed to be complex and challenging. As described in both cases, Dolly had EMS and Herbie had history of laminitis which would classify them as having a higher risk of developing laminitis [156]. This meant systemic corticosteroid treatment should be avoided, and administration of nebulized formulations should be carefully monitored when selected [1,3, 26]. To address her insulin dysregulation Dolly was prescribed Levothyroxine at 0.1 mg/kg SID, a synthetic form of the thyroxine hormone, as it increased insulin sensitivity and calorie usage leading to weight loss by increasing basal metabolic rate. It is important to remember that pharmacological treatment will not substitute diet and exercise management strategies [156, 159].

In all asthma patients, long term environmental management is key to keep these horses healthy. Especially in horses where therapeutic options are limited, as it's Dolly and Herbie's cases. In both cases, environmental management was prioritized, with all the measures explained above being carefully explained to the owners during consultation so they could uptake all the information and clarify any doubts [3].

As mentioned before, studies show that nebulized injectable dexamethasone has no clinical efficacy in improving lung function and decreasing airway inflammation, so other options such as beclomethasone or fluticasone could have been used. Even though clinical improvement has happened in both cases, interpretation of dexamethasone efficacy should be cautious as many interventions were introduced simultaneously, including environmental modification, clenbuterol, nebulized therapy and dietary changes [3,115].

In Dolly's case, orthopaedic issues were noticed during her first consultation but only addressed once her MEA was under control and corticosteroid treatment was discontinued. It is worth mentioning that orthopaedic and respiratory pathology are the two main causes in poor performance in horses, so they can easily overlap when trying to reach the correct diagnosis. In terms of welfare, it is not advisable to perform a complete lameness evaluation respiratory function is impaired. Furthermore, when a horse is unable to undergo full dynamic evaluation due to respiratory compromise, orthopaedic assessment cannot be accurately interpreted [120].

In both cases, follow-up consultations suggested positive treatment results as clinical signs regarding respiratory pathology have improved significantly. This not only reflects correct medical management, but also good owner compliance in keeping up with the treatment plan established. Regarding EA, as long as management is maintained for the long-term Herbie and Dolly's prognosis is positive, with full recovery to be expected. However, it is important to consider that asthma is a lifelong chronic condition with potential for recurrence [1].

11. CRITICAL COMMENT AND CURRENT LIMITATIONS

Research on EA has evolved profoundly over the last few years. However, current scientific evidence is still limited by methodological and biological factors. Lack of randomised controlled trials and small sample sizes limit statistical power and generalisation of results.

A big barrier in research advances is lack of standard definitions, objective scoring systems and diagnostic cut-off values and the difference of tests used when diagnosing this condition (for example using BAL alone or using it with pulmonary function testing).

Monitoring lung function and certain serological tests are still commercially unavailable for most practitioners, making subclinical disease and remission very difficult to address.

As EA is a complex environmental disease and the way studies are conducted it is incredibly difficult to control different variables in research including housing, forage, weather, ventilation and owner compliance.

Much of the existing research is biased towards specific subpopulation, particularly when talking about MEA and its association with young racehorses and genetic studies on warmblood lineages.

Pharmacological therapies are where research is scarcer. When conducting systematic reviews or meta-analysis studies on medical treatment, biased is encountered with many smaller studies' results being overinterpreted. Furthermore, much of MEA asthma recommended drugs and dosages are still extrapolated from SEA studies. At the moment, there is still week evidence supporting the use of inhaled corticosteroids in reducing airway inflammation in MEA. The use of mucolytics remains mostly empirical, lacking randomised controlled evidence to back up their efficacy.

The ACVIM appeals for urgent need of more randomised blinded controlled trials regarding environmental and medical management.

12. CONCLUSION AND FUTURE PERSPECTIVES ON EQUINE ASTHMA

This work highlights EA as a clinically relevant condition that affects equine health, welfare and athletic performance on a worldwide scale. Its proximity to human asthma has contributed towards

uncovering the immunologic profile and cellular mechanisms behind its equine counterpart with research on endotypes and phenotypes focusing on making the treatment more individualised.

Despite many advances, the complexity of this disease makes it difficult to fully understand. Future research should focus on understanding genetic susceptibility and the relationship between exposure and individual pathophysiological response. New clinically available biomarkers, pulmonary function testing, multiomics research and regenerative therapies may improve early detection, accurate monitoring and new treatment strategies. As said before, longitudinal studies and randomised controlled trials are needed in environmental and medical management.

In conclusion, EA should be approached as a chronic inflammatory condition that needs continuous management and monitoring. Environmental management and owner compliance remain the foundation of long term successful control.

Shifting from a symptomatic approach towards a more personalised one is the future goal for this respiratory condition.

Bibliography

[1] Couëtil, L. L., Cardwell, J. M., Gerber, V., Lavoie, J.-P., Léguillette, R., & Richard, E. A. (2016). Inflammatory Airway Disease of Horses - Revised Consensus Statement. *Journal of Veterinary Internal Medicine*, *30*(2), 503–515.

[2] Couëtil, L., Cardwell, J. M., Leguillette, R., Mazan, M., Richard, E., Bienzle, D., Bullone, M., Gerber, V., Ivester, K., Lavoie, J.-P., Martin, J., Moran, G., Niedźwiedź, A., Pusterla, N., & Swiderski, C. (2020). Equine Asthma: Current Understanding and Future Directions. *Frontiers in Veterinary Science*, *7*, 450.

[3] Couëtil, L. L. (2024). Noninfectious Inflammatory Diseases of the Lower Airway of Athletic Horses (Including Equine Asthma). In *Equine Sports Medicine and Surgery* (pp. 720–752). Elsevier.

[4] Bond, S., Léguillette, R., Richard, E. A., Couetil, L., Lavoie, J.-P., Martin, J. G., & Pirie, R. S. (2018). Equine asthma: Integrative biologic relevance of a recently proposed nomenclature. *Journal of Veterinary Internal Medicine*, *32*(6), 2088–2098.

[5] Agache, I. (2019). Severe asthma phenotypes and endotypes. *Seminars in Immunology*, *46*, 101301.

[6] Leduc, L., Leclère, M., & Lavoie, J.-P. (2024). Towards personalized medicine for the treatment of equine asthma. *The Veterinary Journal*, *305*, 106125.

[7] Simões, J., Batista, M., & Tilley, P. (2022). The Immune Mechanisms of Severe Equine Asthma—Current Understanding and What Is Missing. *Animals*, *12*(6), 744.

[8] Klier, J., Lindner, D., Reese, S., Mueller, R. S., & Gehlen, H. (2021). Comparison of Four Different Allergy Tests in Equine Asthma Affected Horses and Allergen Inhalation Provocation Test. *Journal of Equine Veterinary Science*, *102*, 103433.

[9] White, S. J., Moore-Colyer, M., Marti, E., Hannant, D., Gerber, V., Coüetil, L., Richard, E. A., & Alcocer, M. (2019). Antigen array for serological diagnosis and novel allergen identification in severe equine asthma. *Scientific Reports*, *9*(1), 15170.

[10] Sage, S. E., Leeb, T., Jagannathan, V., & Gerber, V. (2024). Single-cell profiling of bronchoalveolar cells reveals a Th17 signature in neutrophilic severe equine asthma. *Immunology*, *171*(4), 549–565.

[11] Meiseberg, L. K., Delarocque, J., De Buhr, N., & Ohnesorge, B. (2024). Clinical variability of equine asthma phenotypes and analysis of diagnostic steps in phenotype differentiation. *Acta Veterinaria Scandinavica*, *66*(1), 51.

[12] Calzetta, L., Rogliani, P., Page, C., Roncada, P., Pistocchini, E., Soggiu, A., Piras, C., Urbani, A., & Matera, M. G. (2018). Clinical effect of corticosteroids in asthma-affected horses: A quantitative synthesis.

[13] Murcia, R. Y., Vargas, A., & Lavoie, J.-P. (2016). The Interleukin-17 Induced Activation and Increased Survival of Equine Neutrophils Is Insensitive to Glucocorticoids. *PLOS ONE*, *11*(5), e0154755.

[14] Kuruvilla, M. E., Lee, F. E.-H., & Lee, G. B. (2019). Understanding Asthma Phenotypes, Endotypes, and Mechanisms of Disease. *Clinical Reviews in Allergy & Immunology*, *56*(2), 219–233.

[15] Pacholewska, A., Jagannathan, V., Drögemüller, M., Klukowska-Rötzler, J., Lanz, S., Hamza, E., Dermitzakis, E. T., Marti, E., Leeb, T., & Gerber, V. (2015). Impaired Cell Cycle Regulation in a Natural Equine Model of Asthma. *PLOS ONE*, *10*(8), e0136103.

[16] Hulliger, M. F., Pacholewska, A., Vargas, A., Lavoie, J.-P., Leeb, T., Gerber, V., & Jagannathan, V. (2020). An Integrative miRNA-mRNA Expression Analysis Reveals Striking Transcriptomic Similarities between Severe Equine Asthma and Specific Asthma Endotypes in Humans. *Genes*, *11*(10), 1143.

[17] Pacholewska, A., Kraft, M., Gerber, V. (2017). Differential Expression of Serum MicroRNAs Supports CD4+ T Cell Differentiation into Th2/Th17 Cells in Severe Equine Asthma. *Genes*, *8*(12), 383.

[18] Lendl, L., & Barton, A. K. (2024). Equine Asthma Diagnostics: Review of Influencing Factors and Difficulties in Diagnosing Subclinical Disease. *Animals*, *14*(23), 3504.

[19] Mair, T. S. (1987). Value of tracheal aspirates in the diagnosis of chronic pulmonary diseases in the horse. *Equine Veterinary Journal*, *19*(5), 463–465.

[21] Ivester, K. M., Couëtil, L. L. , & Raskin, R. E. (2014). Environmental Exposures and Airway Inflammation in Young Thoroughbred Horses. *Journal of Veterinary Internal Medicine*, *28*(3), 918–924.

[22] Ivester, K. M., Couëtil, L. L. (2014). Investigating the Link between Particulate Exposure and Airway Inflammation in the Horse. *Journal of Veterinary Internal Medicine*, *28*(6), 1653–1665.

[23] Richard, E. A., Fortier, G. D., Pitel, P.-H., Dupuis, M.-C., Valette, J.-P., Art, T., Denoix, J.-M., Lekeux, P. M., & Erck, E. V. (2010). Sub-clinical diseases affecting performance in Standardbred trotters: Diagnostic methods and predictive parameters. *The Veterinary Journal*, *184*(3), 282–289.

[24] Nolen-Walston, R. D., Harris, M., Agnew, M. E., Martin, B. B., Reef, V. B., Boston, R. C., & Davidson, E. J. (2013). Clinical and diagnostic features of inflammatory airway disease subtypes in horses examined because of poor performance: 98 cases (2004–2010). *Journal of the American Veterinary Medical Association*, *242*(8), 1138–1145.

[25] Sheats, M. K., Davis, K. U., & Poole, J. A. (2019). Comparative Review of Asthma in Farmers and Horses. *Current Allergy and Asthma Reports*, *19*(11), 50.

[26] Morales, C. J., & Costa, L. R. R. (2024). Chronic Cough and Hyperpnea. *Veterinary Clinics of North America: Equine Practice*, *40*(2), e21–e39.

[27] Swinburne, J. E., Bogle, H., Klukowska-Rötzler, J., Drögemüller, M., Leeb, T., Temperton, E., Dolf, G., & Gerber, V. (2009). A whole-genome scan for recurrent airway obstruction in Warmblood sport horses indicates two positional candidate regions. *Mammalian Genome*, *20*(8), 504–515.

[28] Gerber, V. (2020). Genetics of Equine Respiratory Disease. *Veterinary Clinics of North America: Equine Practice*, *36*(2), 243–253.

[29] Costa, L. R. R., Johnson, J. R., Baur, M. E., & Beadle, R. E. (2006). Temporal clinical exacerbation of summer pasture-associated recurrent airway obstruction and relationship with climate and aeroallergens in horses. *American Journal of Veterinary Research*, *67*(9), 1635–1642.

[30] Seahorn, T. L., & Beadle, R. E. (1993). Summer pasture-associated obstructive pulmonary disease in horses: 21 cases (1983-1991). *Journal of the American Veterinary Medical Association*, *202*(5), 779–782.

[31] Diez De Castro, E., & Fernandez-Molina, J. M. (2024). Environmental Management of Equine Asthma. *Animals*, *14*(3), 446.

[32] Leclere, M., Lavoie-Lamoureux, A., & Lavoie, J. P. (2011). Heaves, an asthma-like disease of horses. *Respirology (Carlton, Vic.)*, *16*(7), 1027–1046.

[33] Thomas, S. J., de Solis, C. N., & Coleman, M. C. (2021). Case-Control Study of Risk Factors for Equine Asthma in Texas. *Journal of equine veterinary science*, *103*, 103644.

[34] Clements, J. M., & Pirie, R. S. (2007). Respirable dust concentrations in equine stables. Part 1: Validation of equipment and effect of various management systems. *Research in Veterinary Science, 83*(2), 256–262.
dor
[35] Clements, J. M., & Pirie, R. S. (2007). Respirable dust concentrations in equine stables. Part 2: The benefits of soaking hay and optimising the environment in a neighbouring stable. *Research in Veterinary Science, 83*(2), 263–268.

[36] Kirschvink, N., Di Silvestro, F., Sbaï, I., Vandenput, S., Art, T., Roberts, C., ... & Lekeux, P. (2002). The use of cardboard bedding material as part of an environmental control regime for heaves-affected horses: In vitro assessment of airborne dust and aeroallergen concentration and in vivo effects on lung function. *The Veterinary Journal, 163*(3), 319-325

[37] Vandenput, S., Istasse, L., Nicks, B., & Lekeux, P. (1997). Airborne dust and aeroallergen concentrations in different sources of feed and bedding for horses.*Veterinary Quarterly, 19*(4), 154-158.

[38] Wålinder, R., Riihimäki, M., Bohlin, S., Hogstedt, C., Nordquist, T., Raine, A., ... & Elfman, L. (2011). Installation of mechanical ventilation in a horse stable: Effects on air quality and human and equine airways. *Environmental Health and Preventive Medicine, 16*(4), 264–272.iv

[39] Ivester, K. M., Smith, K., Moore, G. E., Zimmerman, N. J., & Couëtil, L. L. (2012). Variability in particulate concentrations in a horse training barn over time. *Equine Veterinary Journal, 44*(S43), 51–56.

[40] Ivester, K. M., Couëtil, L. L., & Moore, G. E. (2018). An observational study of environmental exposures, airway cytology, and performance in racing thoroughbreds. *Journal of Veterinary Internal Medicine, 32*(5), 1754–1762.

[41] Pirie, R. S., Collie, D. D. S., Dixon, P. M., & McGorum, B. C. (2003). Inhaled endotoxin and organic dust particulates have synergistic proinflammatory effects in equine heaves (organic dust-induced asthma). *Clinical & Experimental Allergy, 33*(5), 676–683.

[42] Newton, J. R., Wood, J. L. N., & Chanter, N. (2003). A case control study of factors and infections associated with clinically apparent respiratory disease in UK Thoroughbred racehorses. *Preventive Veterinary Medicine, 60*(2), 107–132. https://doi.org/10.1016/S0167-5877(03)00115-4

[43] Gerber, V., Tessier, C., & Marti, E. (2015). Genetics of upper and lower airway diseases in the horse. *Equine Veterinary Journal, 47*(4), 390–397.

[44] Bindi, F., Vitale, V., Cingottini, D., Pasquini, A., Longini, M., Tagliaferri, G., Bonelli, F., Nocera, I., & Sgorbini, M. (2026). Differences in Redox Biomarkers in Bronchoalveolar Lavage Fluid of Leisure Horses With and Without Severe Equine Asthma: Preliminary Results. *Animals*, *16*(6), 882.

[45] Chapman, P. S., Green, C., Main, J. P. M., Taylor, P. M., Cunningham, F. M., Cook, A. J. C., & Marr, C. M. (2000). Retrospective study of the relationships between age, inflammation and the isolation of bacteria from the lower respiratory tract of thoroughbred horses. *Veterinary Record, 146*(4), 91–95.

[46] Christley, R. M., Hodgson, D. R., Rose, R. J., Wood, J. L. N., Reid, S. W. J., Whitear, K. G., & Hodgson, J. L. (2001). A case-control study of respiratory disease in Thoroughbred racehorses in Sydney, Australia. *Equine Veterinary Journal, 33*(3), 256–264.

[47] Wood, J. L. N., Chanter, N., & Mumford, J. A. (2005). Inflammatory airway disease, nasal discharge and respiratory infections in young British racehorses. *Equine Veterinary Journal, 37*(3), 236–242.

[48] Fortier, G., Pronost, S., Miszczak, F., Fortier, C., Leon, A., Richard, E., ... & Lekeux, P. (2008). Identification of equid herpesvirus-5 in respiratory liquids: A retrospective study of 785 samples taken in 2006–2007. *The Veterinary Journal*, *182*(3), 346-348.

[49] Fortier, G., van Erck, E., Fortier, C., Richard, E., Pottier, D., Pronost, S., ... & Lekeux, P. (2009). Herpesviruses in respiratory liquids of horses: Putative implication in airway inflammation and association with cytological features. *Veterinary Microbiology, 139*(1-2), 34–41.

[50] Houtsma, A., Bedenice, D., Pusterla, N., Pugliese, B., Mapes, S., Hoffman, A. M., ... & Mazan, M. R. (2015). Association between inflammatory airway disease of horses and exposure to respiratory viruses: A case control study. *Multidisciplinary Respiratory Medicine, 10*, 33.

[51] Pusterla, N., Mapes, S., Wademan, C., White, A., & Hodzic, E. (2013). Investigation of the role of lesser characterised respiratory viruses associated with upper respiratory tract infections in horses.

[52] Back, H., Penell, J., Pringle, J., Isaksson, M., Ronéus, N., Treiberg Berndtsson, L., & Ståhl, K. (2015). A longitudinal study of poor performance and subclinical respiratory viral activity in Standardbred trotters.

[53] Bond, S. L., Timsit, E., Workentine, M., Alexander, T., & Léguillette, R. (2017). Upper and lower respiratory tract microbiota in horses: Bacterial communities associated with health and mild asthma (inflammatory airway disease) and effects of dexamethasone. *BMC Microbiology, 17*(1), 184.

[54] Santos, R., Hunyadi, L., Sundman, E., Morales, L. M., Hyde, S. C., Fussell, M., ... & Trindade, F. (2024). Multi-Kingdom fecal microbiota alterations in horses with severe equine asthma. *Microorganisms, 12*(4), 484.

[55] Davis, M. S., Williams, C. C., Meinkoth, J. H., Malayer, J. R., Royer, C. M., Williamson, K. K., & McKenzie, E. C. (2007). Influx of neutrophils and persistence of cytokine expression in airways of horses after performing exercise while breathing cold air. *American Journal of Veterinary Research, 68*(2).

[56] Oikawa, M., Hobo, S., Oyamada, T., & Yoshikawa, H. (2005). Effects of orientation, intermittent rest and vehicle cleaning during transport on development of transport-related respiratory disease in horses. *Journal of Comparative Pathology, 132*(2-3), 153–168.

[57] Padalino, B., Raidal, S. L., Knight, P., Celi, P., Jeffcott, L., & Muscatello, G. (2018). Behaviour during transportation predicts stress response and lower airway contamination in horses.

[58] Sánchez, A., Couëtil, L. L., Ward, M. P., & Clark, S. P. (2005). Effect of airway disease on blood gas exchange in racehorses. *Journal of Veterinary Internal Medicine, 19*(1), 87–92.

[59] Stucchi, L., Alberti, E., Stancari, G., Conturba, B., Zucca, E., & Ferrucci, F. (2020). The relationship between lung inflammation and aerobic threshold in Standardbred racehorses with mild-moderate equine asthma. *Animals, 10*(8), 1278.

[60] Leclere, M., Lavoie-Lamoureux, A., Gélinas-Lymburner, E., David, F., Martin, J. G., & Lavoie, J. P. (2011). Effect of antigenic exposure on airway smooth muscle remodeling in an equine model of chronic asthma. *American Journal of Respiratory Cell and Molecular Biology, 45*(1), 181–187.

[61] Albornoz, A., Morales, B., Fernandez, V. B., Henriquez, C., Quiroga, J., Alarcón, P., Moran, G., & Burgos, R. A. (2025). Obesity-Associated Metabolomic and Functional Reprogramming in Neutrophils from Horses with Asthma. *Animals : an open access journal from MDPI*, *15*(13), 1992.

[62] Bullone, M., & Lavoie, J. P. (2015). Asthma "of horses and men"—How can equine heaves help us better understand human asthma immunopathology and its functional consequences? *Molecular Immunology, 66*(1), 97–105.

[63] Höglund, N., Rossi, H., Javela, H. M., Oikari, S., Nieminen, P., Mustonen, A. M., Airas, N., Kärjä, V., & Mykkänen, A. (2024). The amount of hyaluronic acid and airway remodelling increase with the severity of inflammation in neutrophilic equine asthma. *BMC Veterinary Research, 20*(1), 273.

[64] Dlugopolska, D., Siwinska, N., & Noszczyk-Nowak, A. (2025). Equine Asthma in a Comparative Perspective: Cardiovascular and Neurological Manifestations of Asthma Across Different Species. *Animals : an open access journal from MDPI*.

[65] Bedenice, D., Mazan, M. R., & Hoffman, A. M. (2008). Association between cough and cytology of bronchoalveolar lavage fluid and pulmonary function in horses diagnosed with inflammatory airway disease. *Journal of Veterinary Internal Medicine.*

[66] Wasko, A. J., Barkema, H. W., Nicol, J., Fernandez, N., Logie, N., & Léguillette, R. (2011). Evaluation of a risk-screening questionnaire to detect equine lung inflammation: Results of a large field study. *Equine Veterinary Journal, 43*(2), 145–152.

[67] Bosshard, S., & Gerber, V. (2014). Evaluation of coughing and nasal discharge as early indicators for an increased risk to develop equine recurrent airway obstruction (RAO). *Journal of Veterinary Internal Medicine, 28*(2), 618–623.

[68] Rettmer, H., Hoffman, A. M., Lanz, S., Oertly, M., & Gerber, V. (2015). Owner-reported coughing and nasal discharge are associated with clinical findings, arterial oxygen tension, mucus score and

bronchoprovocation in horses with recurrent airway obstruction in a field setting. *Equine Veterinary Journal, 47*(3), 291–295.

[69] Dixon, P. M., Railton, D. I., & McGorum, B. C. (1995). Equine pulmonary disease: A case control study of 300 referred cases. Part 2: Details of animals and of historical and clinical findings. *Equine Veterinary Journal, 27*(6), 422–427.

[70] Robinson, N. E., Berney, C., Eberhart, S., deFeijter-Rupp, H. L., Jefcoat, A. M., Cornelisse, C. J., Gerber, V. M., & Derksen, F. J. (2003). Coughing, mucus accumulation, airway obstruction, and airway inflammation in control horses and horses affected with recurrent airway obstruction. *American Journal of Veterinary Research, 64*(5), 550–557.

[71] Gerber, V., Straub, R., Marti, E., Hauptman, J., Herholz, C., King, M., Imhof, A., Tahon, L., & Robinson, N. E. (2004). Endoscopic scoring of mucus quantity and quality: Observer and horse variance and relationship to inflammation, mucus viscoelasticity and volume. *Equine Veterinary Journal, 36*(7), 576–582.

[72] Laumen, E., Doherr, M. G., & Gerber, V. (2010). Relationship of horse owner assessed respiratory signs index to characteristics of recurrent airway obstruction in two Warmblood families. *Equine Veterinary Journal, 42*(2), 142–148.

[73] Decloedt, A., De Clercq, D., Ven, S., van der Vekens, N., Chiers, K., & van Loon, G. (2017). Right ventricular function during acute exacerbation of severe equine asthma. *Equine Veterinary Journal, 49*, 1-6.

[74] Sage, A. M., Valberg, S., Hayden, D. W., Firshman, A. M., & Jacob, K. (2006). Echocardiography in a horse with cor pulmonale from recurrent airway obstruction. *Journal of Veterinary Internal Medicine, 20*(3), 694–696.

[75] Simões, J., & Tilley, P. (2023). Decision making in severe equine asthma—Diagnosis and monitoring. *Animals, 13*(24), 3872.

[76] Jocelyn, N. A., Wylie, C. E., Lean, M., Barrelet, A., & Foote, A. K. (2018). Association of neutrophil morphology with bacterial isolates in equine tracheal wash samples. *Equine Veterinary Journal, 50*(6), 752–758.

[77] Hughes, K. J., Malikides, N., Hodgson, D. R., & Hodgson, J. L. (2003). Comparison of tracheal aspirates and bronchoalveolar lavage in racehorses 1. Evaluation of cytological stains and the percentage of mast cells and eosinophils. *Australian Veterinary Journal, 81*(11), 681–684.

[78] Malikides, N., Hughes, K. J., Hodgson, D. R., & Hodgson, J. L. (2003). Comparison of tracheal aspirates and bronchoalveolar lavage in racehorses 2. Evaluation of the diagnostic significance of neutrophil percentage. *Australian Veterinary Journal, 81*(11), 685–687.

[79] Christley, R. M., Hodgson, D. R., Rose, R. J., Reid, S. W. J., & Hodgson, J. L. (1999). Comparison of bacteriology and cytology of tracheal fluid samples collected by percutaneous transtracheal aspiration or via an endoscope using a plugged, guarded catheter. *Equine Veterinary Journal, 31*(3), 197–202.

[80] Depecker, M., Richard, E. A., Pitel, P. H., Fortier, G., Leleu, C., & Couroucé-Malblanc, A. (2014). Bronchoalveolar lavage fluid in Standardbred racehorses: Influence of unilateral/bilateral profiles and cut-off values on lower airway disease diagnosis. *The Veterinary Journal, 199*(1), 150–156.

[81] Walston, R. D., Harris, M., Agnew, M. E., Martin, B. B., Reef, V. B., Boston, R. C., & Davidson, E. J. (2013). Clinical and diagnostic features of inflammatory airway disease subtypes in horses examined because of poor performance: 98 cases (2004-2010). *Journal of the American Veterinary Medical Association, 242*(8), 1138–1145.

[82] Hoffman, A. M. (2008). Bronchoalveolar lavage: Sampling technique and guidelines for cytologic preparation and interpretation. *Veterinary Clinics of North America: Equine Practice, 24*(2), 423–435.

[83] Rossi, H., Virtala, A.-M., Raekallio, M., Rahkonen, E., Rajamäki, M. M., & Mykkänen, A. (2018). Comparison of tracheal wash and bronchoalveolar lavage cytology in 154 horses with and without respiratory signs in a referral hospital over 2009-2015. *Frontiers in Veterinary Science, 5*, 61.

[84] Sweeney, C. R., Rossier, Y., Ziemer, E. L., & Lindborg, S. (1992). Effects of lung site and fluid volume on results of bronchoalveolar lavage fluid analysis in horses. *American Journal of Veterinary Research, 53*(8), 1376–1379.

[85] Pickles, K., Pirie, R. S., Rhind, S., Dixon, P. M., & McGorum, B. C. (2002). Cytological analysis of equine bronchoalveolar lavage fluid. Part 2: Comparison of smear and cytocentrifuged preparations. *Equine Veterinary Journal.*

[86] Hughes, K. J., Malikides, N., Hodgson, D. R., & Hodgson, J. L. (2003). Comparison of tracheal aspirates and bronchoalveolar lavage in racehorses 1. Evaluation of cytological stains and the percentage of mast cells and eosinophils. *Australian Veterinary Journal, 81*(11), 681–684.

[87] Wichtel, M., Gomez, D., Burton, S., Wichtel, J., & Hoffman, A. (2016). Relationships between equine airway reactivity measured by flowmetric plethysmography and specific indicators of airway inflammation in horses with suspected inflammatory airway disease. *Equine Veterinary Journal, 48*(4), 466–471.

[88] Couëtil, L., Hammer, J., Miskovic Feutz, M., Nogradi, N., Perez-Moreno, C., & Ivester, K. (2012). Effects of N-butylscopolammonium bromide on lung function in horses with recurrent airway obstruction. *Journal of Veterinary Internal Medicine, 26*(6), 1433–1438.

[89] Robinson, N. E., Olszewski, M. A., Boehler, D., Berney, C., Hakala, J., Matson, C., & Derksen, F. J. (2000). Relationship between clinical signs and lung function in horses with recurrent airway obstruction (heaves) during a bronchodilator trial. *Equine Veterinary Journal, 32*(5), 393–400.

[90] Nolen-Walston, R. D., Kuehn, H., Boston, R. C., Mazan, M. R., Wilkins, P. A., Bruns, S., & Hoffman, A. M. (2009). Reproducibility of airway responsiveness in horses using flowmetric plethysmography and histamine bronchoprovocation.

[91] Miskovic, M., Couëtil, L. L., & Thompson, C. A. (2007). Lung function and airway cytologic profiles in horses with recurrent airway obstruction maintained in low-dust environments. *Journal of Veterinary Internal Medicine, 21*(5), 1060–1066.

[92] Art, T., Duvivier, D. H., Votion, D., Anciaux, N., Vandenput, S., Bayly, W. M., & Lekeux, P. (1998). Does an acute COPD crisis modify the cardiorespiratory and ventilatory adjustments to exercise in horses? *Journal of Applied Physiology, 84*(3), 845–852.

[93] Kozłowska, N., Wierzbicka, M., Jasiński, T., & Domino, M. (2022). Advances in the diagnosis of equine respiratory diseases: A review of novel imaging and functional techniques. *Animals, 12*(3), 381.

[94] Secombe, C., Waldmann, A. D., Hosgood, G., & Mosing, M. (2020). Evaluation of histamine-provoked changes in airflow using electrical impedance tomography in horses. *Equine Veterinary Journal, 52*(4), 556–563.

[95] Herteman, N., Mosing, M., Waldmann, A. D., Gerber, V., & Schoster, A. (2021). Exercise-induced airflow changes in horses with asthma measured by electrical impedance tomography. *Journal of Veterinary Internal Medicine, 35*(5), 2500–2510.

[96] Stucchi, L., Ferrucci, F., Bullone, M., Dellacà, R. L., & Lavoie, J.-P. (2022). Within-breath oscillatory mechanics in horses affected by severe equine asthma in exacerbation and in remission of the disease. *Animals, 12*(1), 4.

[97] Richard, E. A., Fortier, G. D., Denoix, J.-M., Art, T., Lekeux, P. M., & Van Erck, E. (2009). Influence of subclinical inflammatory airway disease on equine respiratory function evaluated by impulse oscillometry. *Equine Veterinary Journal, 41*(4), 384–389.

[98] Lo Feudo, C. M., Stucchi, L., Bizzotto, D., Dellacà, R., Lavoie, J.-P., & Ferrucci, F. (2024). Respiratory oscillometry testing in relation to exercise in healthy and asthmatic Thoroughbreds. *Equine Veterinary Journal*.

[99] Gy, C., Leclere, M., Vargas, A., Grimes, C., & Lavoie, J.-P. (2019). Investigation of blood biomarkers for the diagnosis of mild to moderate asthma in horses. *Journal of Veterinary Internal Medicine, 33*(4), 1789–1795.

[100] Bullone, M., de Lagarde, M., Vargas, A., & Lavoie, J.-P. (2015). Serum surfactant protein D and haptoglobin as potential biomarkers for inflammatory airway disease in horses. *Journal of Veterinary Internal Medicine, 29*(6), 1707–1711.

[101] Cooper, B. L., Hobbs, K. J., Bayless, R., Stinson-Miller, A., Gruber, E., Hepworth-Warren, K., Lavoie, J.-P., & Sheats, M. K. (2025). A portable fluorometer detects significantly elevated cell-free DNA in tracheal wash and bronchoalveolar lavage fluid in horses with severe asthma. *Animals, 15*, 3483.

[102] Janssen, P., Tosi, I., Hego, A., Maréchal, P., Marichal, T., & Radermecker, C. (2022). Neutrophil extracellular traps are found in bronchoalveolar lavage fluids of horses with severe asthma and correlate with asthma severity. *Frontiers in Immunology,* 13, 921077.

[103] Symoens, A., Westerfeld, R., Vives, B. M., André, V., Moulon, L., Collomb, M., Richard, H., Juette, T., Bédard, C., & Leclère, M. (2025). Steamed hay and alfalfa pellets for the management of severe equine asthma. *Equine Veterinary Journal, 57*(3), 756–765.

[104] Westerfeld, R., Payette, F., Dubuc, V., Manguin, E., Picotte, K., Beauchamp, G., Bédard, C., & Leclere, M. (2024). Effects of soaked hay on lung function and airway inflammation in horses with severe asthma. *Journal of Veterinary Internal Medicine, 38*(1), 469–476.

[105] Moore-Colyer, M. J. S., Taylor, J. L. E., & James, R. (2016). The effect of steaming and soaking on the respirable particle, bacteria, mould, and nutrient content in hay for horses. *Journal of Equine Veterinary Science, 39*, 62–68.

[106] Orard, M., Hue, E., Couroucé, A., Bizon-Mercier, C., Toquet, M.-P., Moore-Colyer, M., Couëtil, L., Pronost, S., Paillot, R., Demoor, M., & Richard, E. A. (2018). The influence of hay steaming on clinical signs and airway immune response in severe asthmatic horses. *BMC Veterinary Research, 14*(1), 345.

[107] Olave, C. J., Ivester, K. M., Couetil, L. L., Burgess, J., Park, J. H., & Mukhopadhyay, A. (2023). Effects of low-dust forages on dust exposure, airway cytology, and plasma omega-3 concentrations in Thoroughbred racehorses: A randomized clinical trial. *Journal of Veterinary Internal Medicine, 37*(1), 338–348.

[108] Woods, P. S. A., Robinson, N. E., Swanson, M. C., Reed, C. E., Broadstone, R. V., & Derksen, F. J. (1993). Airborne dust and aeroallergen concentration in a horse stable under two different management systems. *Equine Veterinary Journal, 25*(3), 208–213.

[109] McGorum, B. C., Ellison, J., & Cullen, R. T. (1998). Total and respirable airborne dust endotoxin concentrations in three equine management systems. *Equine Veterinary Journal, 30*(5), 430–434.

[110] Bullone, M., & Lavoie, J.-P. (2020). The equine asthma model of airway remodeling: From a veterinary to a human perspective. *Cell and Tissue Research, 380*(2), 223–236.

[111] Boivin, R., Pilon, F., Lavoie, J.-P., & Leclere, M. (2018). Adherence to treatment recommendations in horses with mild asthma. *Equine Veterinary Journal, 50*(3), 294–300.

[112] Léguillette, R., Tohver, T., Bond, S. L., Nicol, J. A., & McDonald, K. J. (2017). Effect of dexamethasone and fluticasone on airway hyperresponsiveness in horses with inflammatory airway disease. *Journal of Veterinary Internal Medicine, 31*(4), 1193–1201.

[113] Pistocchini, E., Carrillo Heredero, A. M., Mazan, M., Couëtil, L., Bertini, S., & Calzetta, L. (2025). Clinical efficacy of inhaled corticosteroids in equine asthma: A meta-analysis and number needed to treat. *Pulmonary Pharmacology & Therapeutics, 88*, 102342.

[114] Pirie, R. S., Mueller, H.-W., Engel, O., Albrecht, B., & von Salis-Soglio, M. (2021). Inhaled ciclesonide is efficacious and well tolerated in the treatment of severe equine asthma in a large prospective European clinical trial. *Equine Veterinary Journal, 53*(6), 1094–1104.

[115] de Wasseige, S., Picotte, K., & Lavoie, J.-P. (2021). Nebulized dexamethasone sodium phosphate in the treatment of horses with severe asthma.

[116] Sanz, M. G., Jellen, G., Cody, L., Jones, L. R., Lemos, K. R., & Leguillette, R. (2025). Use of inhaled ciclesonide for treatment of moderate asthma in Thoroughbred racehorses. *Journal of Veterinary Internal Medicine, 39*(2), e17267.

[117] Arroyo, M. G., Couëtil, L. L., Nogradi, N., Kamarudin, M. M., & Ivester, K. M. (2016). Efficacy of inhaled levalbuterol compared to albuterol in horses with recurrent airway obstruction. *Journal of Veterinary Internal Medicine, 30*(4), 1333–1337.

[118] Davis, E., & Rush, B. R. (2002). Equine recurrent airway obstruction: Pathogenesis, diagnosis, and patient management. *Veterinary Clinics of North America: Equine Practice, 18*(3), 453–467.

[119] Cornelisse, C. J., Robinson, N. E., Berney, C. E. A., Kobe, C. A., Boruta, D. T., & Derksen, F. J. (2004). Efficacy of oral and intravenous dexamethasone in horses with recurrent airway obstruction. *Equine Veterinary Journal, 36*(5), 426–430.

[120] Bessonnat, A., Picotte, K., & Lavoie, J.-P. (2020). Intra-articular triamcinolone acetonide improves lung function in horses with severe asthma. *Equine Veterinary Journal, 52*(1), 131–135.

[121] Millares-Ramirez, E. M., Picotte, K., & Lavoie, J.-P. (2021). Pulmonary response of severely asthmatic horses after intra-articular administration of methylprednisolone. *Equine Veterinary Journal, 53*(1), 78–84.

[122] Cha, M. L., & Costa, L. R. R. (2017). Inhalation therapy in horses. *Veterinary Clinics of North America: Equine Practice.*

[123] Trevisiol, S., Moulard, Y., Kaabia, Z., Lejeune, D., Popot, M.-A., Bonnaire, Y., & Bailly-Chouriberry, L. (2022). LC-HRMS/MS study of the prodrug ciclesonide and its active metabolite desisobutyryl-ciclesonide in plasma after an inhalative administration to horses for doping control purposes. *Drug Testing and Analysis, 14*(2), 252–261.

[124] Robinson, N. E., Berney, C., Behan, A., & Derksen, F. J. (2009). Fluticasone propionate aerosol is more effective for prevention than treatment of recurrent airway obstruction. *Journal of Veterinary Internal Medicine, 23*(6), 1247–1253.

[125] Bullone, M., Vargas, A., Elce, Y., Martin, J. G., & Lavoie, J.-P. (2017). Fluticasone/salmeterol reduces remodeling and neutrophilic inflammation in severe equine asthma. *Scientific Reports, 7*(1), 8843.

[126] Rush, B. R., Raub, E. S., Thomsen, M. M., Davis, E. G., Matson, C. J., & Hakala, J. E. (2000). Pulmonary function and adrenal gland suppression with incremental doses of aerosolized beclomethasone dipropionate in horses with recurrent airway obstruction. *Journal of the American Veterinary Medical Association, 217*(3), 359–364.

[127] Lavoie, J.-P., Leclere, M., Rodrigues, N., Lemos, K. R., Bourzac, C., Lefebvre-Lavoie, J., Beauchamp, G., & Albrecht, B. (2019). Efficacy of inhaled budesonide for the treatment of severe equine asthma. *Equine Veterinary Journal, 51*(3), 401–407.

[128] Broadstone, R. V., Scott, J. S., Derksen, F. J., & Robinson, N. E. (1988). Effects of atropine in ponies with recurrent airway obstruction. *Journal of applied physiology (Bethesda, Md. : 1985)*, *65*(6), 2720–2725.

[129] Ducharme, N. G., & Fubini, S. L. (1983). Gastrointestinal complications associated with the use of atropine in horses. *Journal of the American Veterinary Medical Association*, *182*(3), 229–231

[130] Robinson, N. E., Derksen, F. J., Berney, C., & Goossens, L. (1993). The airway response of horses with recurrent airway obstruction (heaves) to aerosol administration of ipratropium bromide. *Equine Veterinary Journal, 25*(4), 299–303.

[131] de Lagarde, M., Rodrigues, N., Chevigny, M., Beauchamp, G., Albrecht, B., & Lavoie, J.-P. (2014). N-butylscopolammonium bromide causes fewer side effects than atropine when assessing bronchoconstriction reversibility in horses with heaves. *Equine Veterinary Journal, 46*(4), 474–478.

[132] Erichsen, D. F., Aviad, A. D., Schultz, R. H., & Kennedy, T. J. (1994). Clinical efficacy and safety of clenbuterol HCl when administered to effect in horses with chronic obstructive pulmonary disease (COPD). *Equine veterinary journal*, *26*(4), 331–336.

[133] Read, J. R., Boston, R. C., Abraham, G., Bauquier, S. H., Soma, L. R., & Nolen-Walston, R. D. (2012). Effect of prolonged administration of clenbuterol on airway reactivity and sweating in horses with inflammatory airway disease. *American Journal of Veterinary Research, 73*(1), 140–145.

[134] Ayres, J. W., et al. (1985). Theophylline and dyphylline pharmacokinetics in the horse. *American Journal of Veterinary Research, 46*(12), 2505–2511.

[135] McKiernan, B. C., & Koritz, G. D. (1990). Plasma theophylline concentration and lung function in ponies with recurrent obstructive lung disease. *Equine Veterinary Journal, 22*(3), 194–197.

[136] Broadstone, R. V., Robinson, N. E., Gray, P. R., Woods, P. S. A., & Derksen, F. J. (1991). Effects of furosemide on ponies with recurrent airway obstruction. *Pulmonary Pharmacology, 4*(4), 203–208.

[137] Tanquerel, L., Fillion-Bertrand, G., Lavoie, J.-P., & Leclere, M. (2018). Effects of magnesium sulfate infusion on clinical signs and lung function of horses with severe asthma. *American Journal of Veterinary Research, 79*(6), 664–673.

[138] Derksen, F. J., Olszewski, M. A., Robinson, N. E., Berney, C., Hakala, J. E., Matson, C. J., & Ruth, D. T. (1999). Aerosolized albuterol sulfate used as a bronchodilator in horses with recurrent airway obstruction. *American Journal of Veterinary Research, 60*(6), 689–693.

[139] Rush, B. R., Hoskinson, J. J., Davis, E. G., Matson, C. J., & Hakala, J. E. (1999). Pulmonary distribution of aerosolized technetium Tc 99m pentetate after administration of a single dose of aerosolized albuterol sulfate in horses with recurrent airway obstruction. *American Journal of Veterinary Research, 60*(6), 764–769.

[140] Tesarowski, D. B., Viel, L., McDonell, W. N., & Newhouse, M. T. (1994). The rapid and effective administration of a beta 2-agonist to horses with heaves using a compact inhalation device and metered-dose inhalers. *The Canadian Veterinary Journal, 35*(3), 170–173.

[141] Derksen, F. J., Olszewski, M. A., Robinson, N. E., Berney, C., Lloyd, J. W., Hakala, J., Matson, C., & Ruth, D. T. (1996). Use of a hand-held, metered-dose aerosol delivery device to administer pirbuterol acetate to horses with 'heaves'. *Equine Veterinary Journal, 28*(4), 306–310.

[142] Henrikson, S. L., & Rush, B. R. (2001). Efficacy of salmeterol xinafoate in horses with recurrent airway obstruction. *Journal of the American Veterinary Medical Association, 218*(12), 1961–1965.

[143] Pirie, R. S., & McGorum, B. C. (2017). Inhalation therapy for equine lower respiratory tract disease. *Practice, 39*(10), 317–327.

[144] Duvivier, D. H., Bayly, W. M., Votion, D., Vandenput, S., Art, T., & Lekeux, P. (1999). Effects of inhaled dry powder ipratropium bromide on recovery from exercise of horses with COPD. *Equine Veterinary Journal, 31*(1), 20–24.

[145] Tavanaeimanesh, H., Alinia, Z., Sadeghian Chaleshtori, S., Moosavian, H., Mohebi, Z., & Daneshi, M. (2024). The efficacy of N-acetylcysteine in decreasing airway inflammation and mucus accumulation in horses with 18 hours of head confinement. *Journal of Veterinary Internal Medicine, 38*(2), 1224-1231.

[146] Léguillette, R. (2003). Recurrent airway obstruction-heaves. *Veterinary Clinics of North America: Equine Practice.*

[147] Bond, S., & Léguillette, R. (2024). A CONSORT-guided, randomized controlled clinical trial of nebulized administration of dexamethasone and saline on lower airway cytokine mRNA expression in horses with moderate asthma. *Journal of Veterinary Internal Medicine, 38*(2), 1214–1223.

[148] Condor, M., Macovei, I., Dumitrescu, I., & Ionescu, C. (2022). The effect of dry saline aerosol therapy on arterial blood gas parameters in horses with mild equine asthma. *Scientific Works. Series C. Veterinary Medicine, 68*(2), 51–58.

[149] Votion, D., Ghafir, Y., Munsters, K., Art, T., & Lekeux, P. (1997). Aerosol deposition in equine lungs following ultrasonic nebulisation versus jet aerosol delivery system. *Equine Veterinary Journal, 29*(5), 388–393.

[150] Nogradi, N., Couëtil, L. L., Messick, J., Stochelski, M. A., & Burgess, J. R. (2015). Omega-3 fatty acid supplementation provides an additional benefit to a low-dust diet in the management of horses with chronic lower airway inflammatory disease. *Journal of Veterinary Internal Medicine, 29*(1), 299–306.

[151] Klier, J., Bartl, C., Geuder, S., Geh, K. J., Reese, S., Goehring, L. S., Winter, G., & Gehlen, H. (2019). Immunomodulatory asthma therapy in the equine animal model: A dose-response study and evaluation of a long-term effect. *Immunity, Inflammation and Disease, 7*(3), 130–149.

[152] Barussi, F. C. M., Bastos, F. Z., Leite, L. M. B., Fragoso, F. Y. I., Senegaglia, A. C., Brofman, P. R. S., & Michelotto Jr, P. V. (2016). Intratracheal therapy with autologous bone marrow-derived mononuclear cells reduces airway inflammation in horses with recurrent airway obstruction. *Respiratory Physiology & Neurobiology, 232*, 35–42.

[153] Mainguy-Seers, S., Picotte, K., & Lavoie, J.-P. (2018). Efficacy of tamoxifen for the treatment of severe equine asthma. *Journal of Veterinary Internal Medicine, 32*(5), 1748-1753.

[154] Mainguy-Seers, S., Vargas, A., Labrecque, O., Bédard, C., Hélie, P., & Lavoie, J.-P. (2019). Randomised study of the immunomodulatory effects of azithromycin in severely asthmatic horses. *Veterinary Record, 185*(5), 143.nol

[155] Aviza, G. A., Ainsworth, D. M., Eicker, S. W., Santiago, M. A., Divers, T. J., & Perkins, G. A. (2001). Outcome of horses diagnosed with and treated for heaves (recurrent airway obstruction). *Equine Veterinary Education*, *13*(5), 243–246.

[156] Durham, A. E., Frank, N., McGowan, C. M., Menzies-Gow, N. J., Roelfsema, E., Vervuert, I., Feige, K., & Fey, K. (2019). ECEIM consensus statement on equine metabolic syndrome. *Journal of veterinary internal medicine*, *33*(2), 335–349.

[157] Glatter, M., Bochnia, M., Wensch-Dorendorf, M., Greef, J. M., & Zeyner, A. (2021). Feed Intake Parameters of Horses Fed Soaked or Steamed Hay and Hygienic Quality of Hay Stored following Treatment. *Animals : an open access journal from MDPI*, *11*(9), 2729.

[158] Pratt-Phillips, S., & Munjizun, A. (2023). Impacts of Adiposity on Exercise Performance in Horses. *Animals : an open access journal from MDPI*, *13*(4), 666.

[159] Frank N. (2011). Equine metabolic syndrome. *The Veterinary clinics of North America. Equine practice*, *27*(1), 73–92.

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