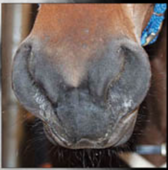
Respiratory Diseases of the Horse



A problem-oriented approach to diagnosis & management

Laurent Couëtil
Jan Hawkins

MANSON PUBLISHING

Respiratory Diseases of the Horse

A problem-oriented approach to diagnosis & management

LAURENT L COUËTIL DVM, PhD, DACVIM

Professor, Department of Veterinary Clinical Sciences
Director, Equine Research Programs and Equine Sports Medicine Center
College of Veterinary Medicine, Purdue University,
West Lafayette, Indiana, USA

JAN F HAWKINS DVM, DACVS

Associate Professor, Department of Veterinary Clinical Sciences
College of Veterinary Medicine, Purdue University,
West Lafayette, Indiana, USA

MANSON PUBLISHING/THE VETERINARY PRESS

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Version Date: 20141208

International Standard Book Number-13: 978-1-84076-647-9 (eBook - PDF)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

CONTENTS

PREFACE

THIS BOOK is the result of the career-long interests of the two authors in diseases of the equine respiratory tract, from both medical (LC) and surgical (JH) perspectives. The equine respiratory tract presents unique questions and challenges that equine practitioners struggle with daily. For example: Where is the abnormal breathing sound coming from? Why does this horse have a nasal discharge? Why is this horse not performing up to expectations?

This book attempts to provide a framework to help equine practitioners systematically evaluate, diagnose, and treat the most common (and some not so common) disorders of the equine respiratory tract. It is organized in a way that emulates the approach that a clinician would use to assess a horse with a suspected respiratory abnormality. Hence, the book starts with a detailed description of anatomic features and pulmonary function, followed by an in-depth discussion of clinical examination methods and the use of appropriate diagnostic tests to help arrive at a clinical diagnosis. A novel *modus operandi* taken by the authors is the use of a problem-oriented approach to the diagnosis of equine respiratory diseases. With this in mind, there are chapters dedicated to the evaluation of a horse presenting with a complaint of coughing, nasal discharge, increased respiratory effort, abnormal respiratory noise, or congenital respiratory abnormalities. Each starts by discussing the pathophysiology of a particular respiratory disease manifestation and then suggests an approach to reaching a diagnosis. Once a presumptive diagnosis is obtained, the reader can refer to the comprehensive discussion of each particular respiratory disease, including medical and/or surgical therapy.

LAURENT COUËTIL
JAN HAWKINS

ABBREVIATIONS

$A\text{–}aD_{O_2}$	alveolar–arterial oxygen tension difference
ABG	arterial blood gas
ACTH	adrenocorticotropic hormone
AHR	airway hyperresponsiveness
BAL	bronchoalveolar lavage
CAD	cricoarytenoideus dorsalis (muscle)
CAJ	cricoarytenoid joint
C_{aO_2}	oxygen content of arterial blood
CCA	common carotid artery
C_{dyn}	dynamic lung compliance
CFC	chlorofluorocarbon
CMS	caudal maxillary sinus
CN	cranial nerve
CNS	central nervous system
CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
CRI	constant rate infusion
CT	computed tomography
DDSP	dorsal displacement of the soft palate
DMSO	dimethylsulfoxide
2,3-DPG	2,3-diphosphoglycerate
DTPA	diethylene triamine pentaacetic acid
EE	epiglottic entrapment
EHV	equine herpesvirus
EIPH	exercise-induced pulmonary hemorrhage
EPM	equine protozoal encephalomyelitis
EVA	equine viral arteritis
F_A	fractional concentration of a gas in alveolar air
F_{ACO_2}	fractional concentration of carbon dioxide in alveolar air
F_{AO_2}	fractional concentration of oxygen in alveolar air
FE	forced expiration
FEF	forced expiratory flow
FEV_1	forced expiratory volume during 1 second
F_I	concentration of a gas in inspired air
F_{ICO_2}	fraction of inspired carbon dioxide
F_{IO_2}	fraction of inspired oxygen
FOM	forced oscillatory mechanics
FRC	functional residual capacity
FVC	forced vital capacity
GP	guttural pouch
GPE	guttural pouch empyema
GPM	guttural pouch mycosis
H	hemagglutinin
Hb	hemoglobin
HFA	hydrofluoroalkane
HYPP	hyperkalemic periodic paralysis
IAD	inflammatory airway disease
IFNα	interferon alpha
IM	intramuscular/intramuscularly
IV	intravenous/intravenously
LAP	left atrial pressure
LRT	lower respiratory tract
MMAD	mass median aerodynamic diameter
N	neuraminidase
NSAID	non-steroidal anti-inflammatory drug
O_2	oxygen

ΔP	pressure gradient
ΔP_{plmax}	maximal change in transpulmonary pressure
P_{aCO_2}	partial arterial pressure of carbon dioxide
P_{ACO_2}	partial alveolar pressure of carbon dioxide
PAM	pulmonary alveolar macrophage
P_{aO_2}	partial arterial pressure of oxygen
P_{AO_2}	partial alveolar pressure of oxygen
PAP	pulmonary artery pressure
Pb	barometric pressure
P_{CO_2}	partial pressure of carbon dioxide
PCR	polymerase chain reaction
PCV	packed cell volume
Pet_{CO_2}	end-tidal partial pressure of carbon dioxide
P_{ICO_2}	partial pressure of inspired carbon dioxide
P_{IO_2}	partial pressure of inspired oxygen
pMDI	pressurized metered-dose inhaler
PO	per os
P_{O_2}	partial pressure of oxygen
PRT	proximal respiratory tract
P_{tp}	transpulmonary pressure
P_{vCO_2}	partial venous pressure of carbon dioxide
$\dot{Q}$	perfusion
RAO	recurrent airway obstruction
R_{aw}	flow resistance through the airways
RBC	red blood cell
R_{cw}	chest wall resistance
RDPA	rostral displacement of the palato-pharyngeal arch
R_L	pulmonary resistance
RMS	rostral maxillary sinus
RR	respiratory rate
R_{rs}	resistive component of the respiratory system
R_{ti}	lung tissue resistance
RV	residual volume
S_{aO_2}	oxygen saturation of hemoglobin in arterial blood
SC	subcutaneous
SCC	squamous cell carcinoma
TLC	total lung capacity
TW	tracheal wash
URT	upper respiratory tract
$\dot{V}$	ventilation or airflow (volume of gas per minute)
V_A	alveolar volume
$\dot{V}_A$	alveolar ventilation (per minute)
VC	vital capacity
$\dot{V}_{CO_2}$	carbon dioxide produced per minute by metabolism
V_D	physiologic dead space
$\dot{V}_D$	physiologic dead space ventilation (per minute)
$\dot{V}_E$	expired minute ventilation (expired volume per minute)
$\dot{V}_{O_2}$	oxygen consumed per minute by metabolism
$\dot{V}_{O_2max}$	maximal oxygen consumption or maximal aerobic capacity
$\dot{V}/\dot{Q}$	ventilation–perfusion (ratio)
V_T	tidal volume
WBC	white blood cell
Zrs	impedance of the respiratory system

CHAPTER 1

ANATOMY OF THE EQUINE RESPIRATORY TRACT

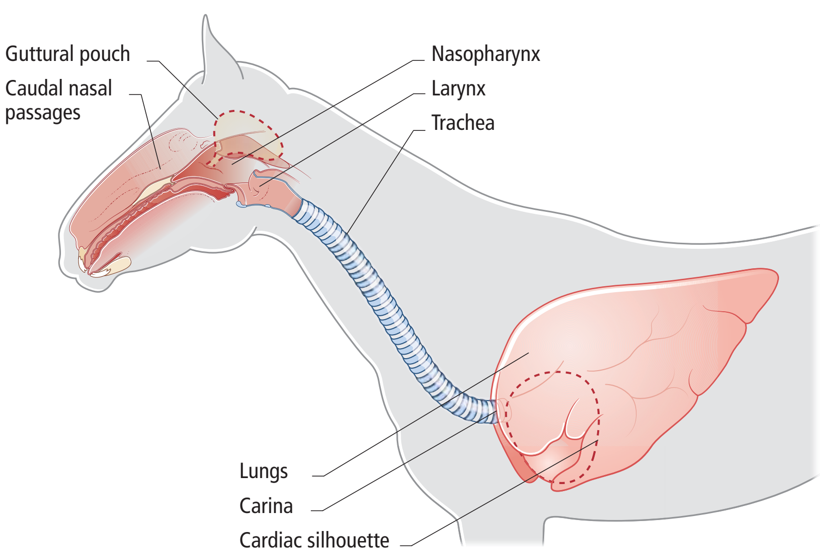
INTRODUCTION

The anatomy of the respiratory tract greatly influences its function (**1**). Additional factors, such as exercise, will result in further adaptation of the respiratory tract anatomy by increasing contraction of the accessory respiratory muscles to accommodate the increase in ventilation or exercise-induced hyperpnea. From a functional standpoint, it is helpful to separate the respiratory tract into the extrathoracic airways and the intrathoracic airways, with the former extending from the nose to the extrathoracic portion of the trachea.

EXTRATHORACIC AIRWAYS

Overview

The main role of the airways is to act as a conduit for air flow between the nasal opening and the gas-exchanging areas of the lung. To accommodate convection of air, the extrathoracic airways, and in particular the nasal passages, modify the air by adjusting its temperature nearer to normal body temperature, increasing the relative humidity closer to full saturation, and by filtering larger particles. The total cross-sectional area of the proximal respiratory tract is minimal compared with the vast surface area of the distal airways (bronchioles) and alveolar spaces. Any disease resulting in a decrease in airway patency will impair airflow and, ultimately, pulmonary function; however, a decrease in airway diameter will have maximum impact if located along the proximal airways, since all air travels through this bottleneck. In contrast, diseases involving the distal airways in the lung have to be severe and extensive to cause flow limitation. At rest, horses use only a small portion of their vital respiratory capacity (approximately 10%), so diseases resulting in airway obstruction have to be severe in order to impair pulmonary function. During strenuous exercise, horses utilize 100% of their respiratory capacity and mild airway obstruction that would not normally affect pulmonary function at rest may greatly interfere with gas exchanges during exercise.



◀ 1 Anatomy of the equine respiratory tract, with anatomic regions corresponding to endoscopic views in the following figures: caudal nasal passages (6); guttural pouch (15); nasopharynx (19); larynx (20); trachea (37); carina (41).

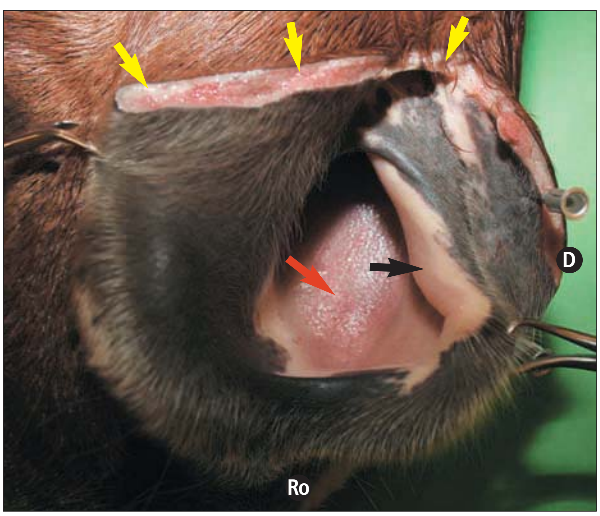
Assessment of diseases of the extrathoracic airways requires a full understanding of the unique anatomic features of the equine proximal respiratory tract (PRT). Knowledge of the gross and endoscopic anatomy of the PRT is crucial to arriving at a working diagnosis in a horse with clinical signs of respiratory noise and exercise intolerance. The normal anatomy of the structures (nares and rostral nasal passages, nasal septum, conchae and paranasal sinuses, guttural pouches (GPs), nasopharynx, hard and soft palate, epiglottis, larynx, and cervical portion of the trachea) that make up the equine PRT are described below.

Nares and rostral nasal passages

Airflow from the left and right nares should be equal and easily palpable or visualized by movement of soft cotton or condensation on a mirror (**2**).

The nares consist of the nasal opening, alar folds, nasal diverticulum, and the rostral aspect of the nasal septum (**3**).

◀ **2 Subjective evaluation of palpable airflow from each nasal passage. Clinical assessment of airflow can be enhanced by the use of a rebreathing bag.**



▲ **3 Gross postmortem photograph illustrating the cut edge of the nasal diverticulum (yellow arrows), alar fold (black arrow), and rostral nasal septum (red arrow). (D) dorsal; (Ro) rostral.**

▲ **4 Manual palpation of the rostral nasal septum.**

The false nostrils should be capable of full and symmetrical opening. The alar fold should be thin, pliable, and not edematous. The nasal diverticulum is located dorsal to the alar fold. The rostral aspect of the nasal septum is palpated manually with the index fingers (**4**). The normal rostral nasal septum is bilaterally symmetrical and the mucosa should be smooth and have no appreciable pitting edema.

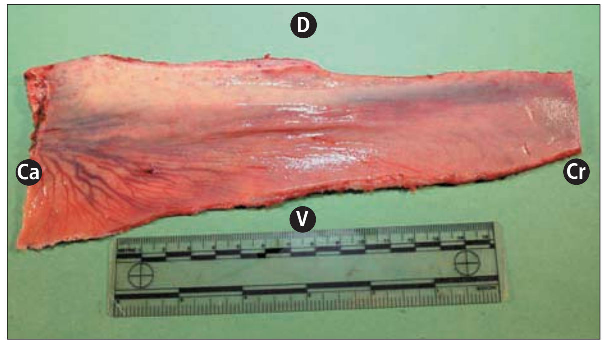
Nasal septum

The equine nasal septum consists predominantly of fibrocartilage (**5**). The ventral aspect of the nasal septum is attached to the vomer bone. A normal nasal septum should be straight and not deviated towards either nasal passage. It is covered by nasal mucosa.

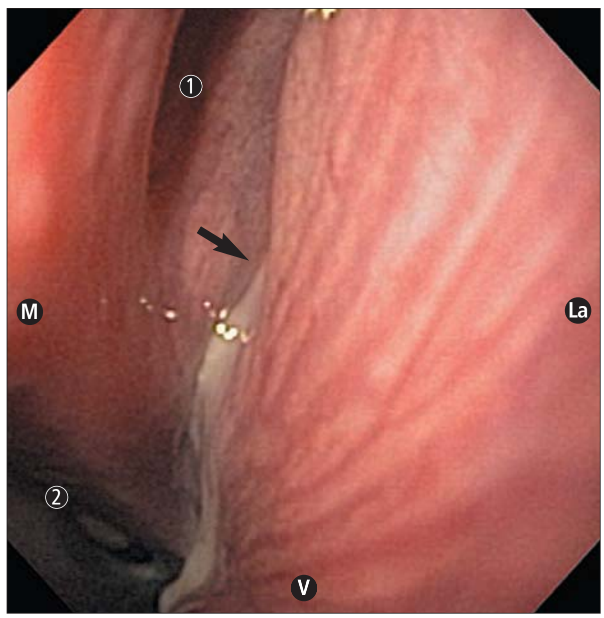
The nasal cavities are lined with a richly vascularized mucosa to allow warming and humidification of inhaled air. Vasomotor tone is under the control of the autonomic nervous system, with excitation of sympathetic and parasympathetic nerves leading to nasal vasoconstriction and vasodilation, respectively. Exercise is associated with sympathetic excitation and increased nasal volume. Despite these mechanisms, which are designed to increase airway patency during exercise, the nasal passages still represent one of the bottleneck regions of the equine respiratory tract.

Conchae and paranasal sinuses

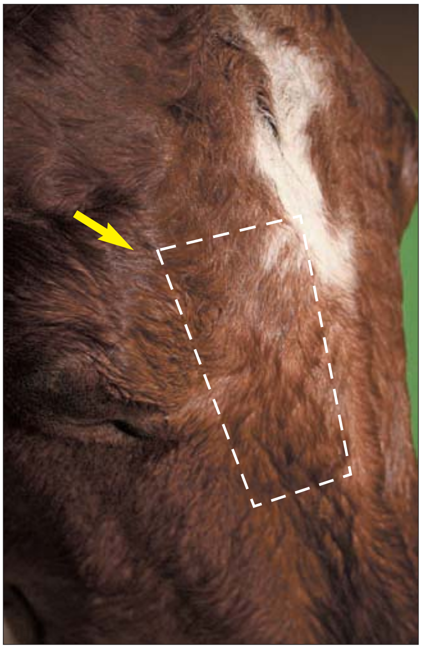
The horse has seven paranasal sinuses on each side of the skull. These are the dorsal, middle, and ventral conchal sinuses, the rostral and caudal maxillary sinuses, the frontal sinus, and the sphenopalatine sinus. The conchae and sinuses communicate through multiple natural openings. The dorsal and middle conchal, sphenopalatine, and frontal sinuses communicate with the caudal maxillary sinus. The ventral conchal sinus communicates with the rostral maxillary sinus. The nasomaxillary opening is the communication between the nasal passage and the maxillary sinus (**6**). It is located in the middle meatus in the area of the ethmoid turbinate and it can be visualized with an endoscope.



▲ 5 **Gross postmortem appearance of a normal nasal septum. Note the prominent vascular pattern on the caudal and ventral aspect of the septum. (Ca) caudal; (Cr) cranial; (D) dorsal; (V) ventral.**

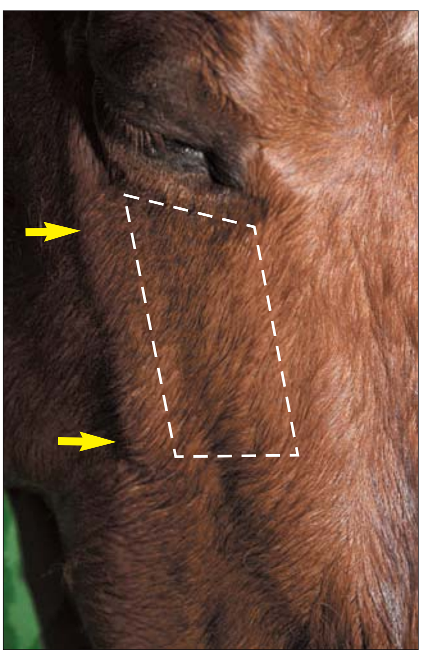


▲ 6 **Endoscopic view of the left nasomaxillary opening (arrow) with purulent exudate exiting the maxillary sinus. (1) ethmoid turbinates; (2) nasopharynx; (La) lateral; (M) medial; (V) ventral.**



▲ **7 Gross postmortem appearance of the surgical limits of the frontal sinus (dotted line). Arrow, supraorbital foramen.**

▼ **8 Gross postmortem photograph illustrating the boundaries of the maxillary sinus (dotted line). Arrow, facial crest.**

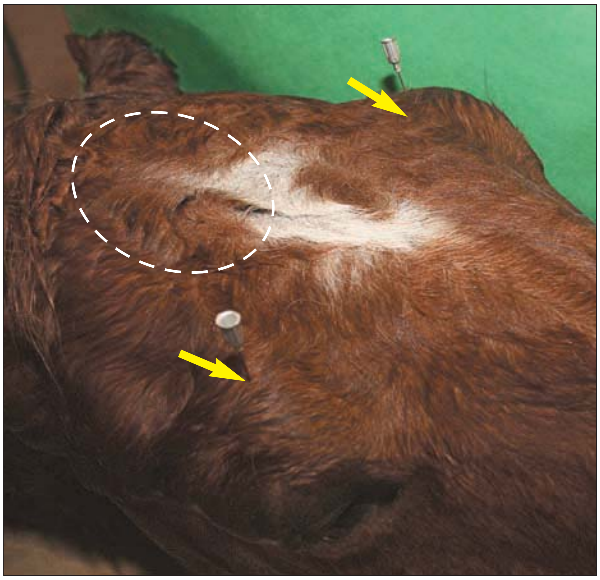


Along with an understanding of the natural openings between the sinuses, the surgical limits of the frontal and maxillary sinuses should also be known. The surgical limits of the frontal sinus are: medially, the midline of the forehead; caudally, a line joining the right and left supraorbital foramina; rostrally, a line approximately 8–10 cm rostral, or a line perpendicular to the facial crest, half-way between the medial canthus and the infraorbital foramen; and laterally, a line drawn from the medial canthus of the eye to the nasoincisive notch (**7**).

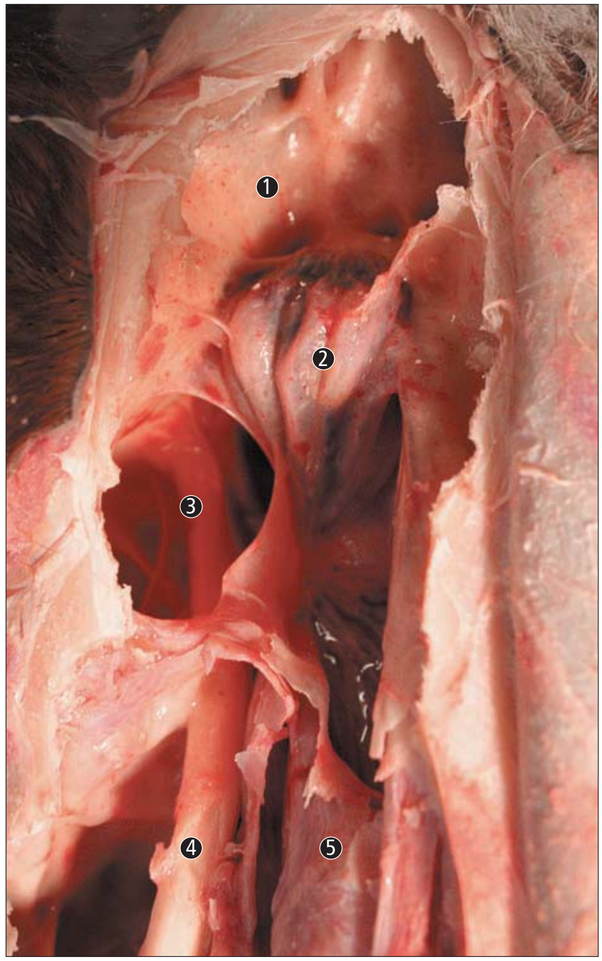
The surgical limits of the maxillary sinus are: dorsally, a line from the medial canthus of the eye to the infraorbital foramen; caudally, a line from the medial canthus to the facial crest; rostrally, a line from the infraorbital foramen to the facial crest; and ventrally, the facial crest (**8**).

Other important anatomic features of the frontal and maxillary sinuses include the following:

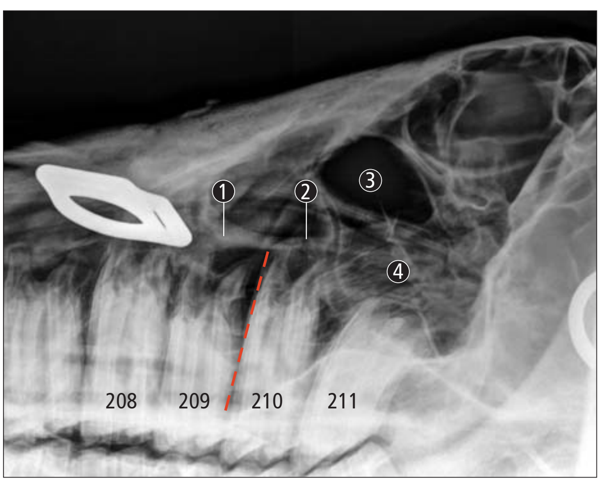
- The rostral limit of the frontal sinus is 2–3 cm from where the nasal bones diverge and the calvarium is close to the caudal limit of the sinus (**9**). Therefore, it is very important not to go beyond the supraorbital foraminae when surgically opening the frontal sinus.
- At the rostral end of the frontal sinus there is a large medial and ventral communication with the dorsal conchal sinus (**10**). At this point the common area between the two is called the conchofrontal sinus. The ethmoidal labyrinth is located on the floor of this sinus between the two orbits. Finally, the frontal sinus communicates with the maxillary sinus via the frontomaxillary opening.
- The rostral and caudal maxillary sinuses are separated by an incomplete bony septum. The floor of the rostral maxillary sinus contains the roots of the 3rd (4th premolar; 108, 208) and 4th (1st molar; 109, 209) cheek teeth (**11**). The floor of the caudal maxillary sinus contains the roots of the 5th (2nd molar; 110, 210) and 6th (3rd molar; 111, 211) cheek teeth.



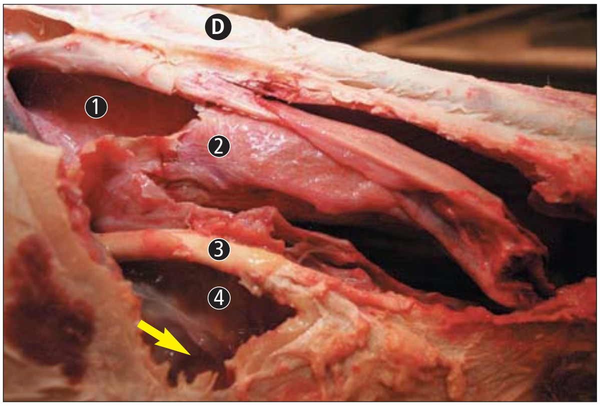
▲ **9** **Gross postmortem photograph illustrating the relationship between the caudal aspect of the frontal sinus and the calvarium (circle). Arrows, supraorbital foramina.**



▶ **10** **Gross postmortem photograph detailing the relationship between the right frontal sinus (1), the ethmoid turbinates (2), the frontomaxillary opening (3), the infraorbital canal (4), and the dorsal nasal conchae (5).**



◀ **11** **Digital oblique radiographic view of the left maxillary and frontal sinus of an 11-year-old Thoroughbred gelding. This view demonstrates the location of cheek teeth 208 and 209 in the rostral maxillary sinus (RMS [1]) and cheek teeth 210 and 211 in the caudal maxillary sinus (CMS [2]). The dotted red line represents the bony septum between the RMS and the CMS. (3) frontal sinus; (4) ethmoid turbinates.**

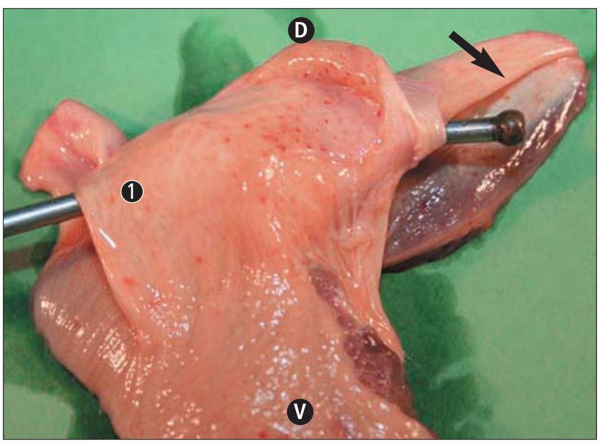


▲ **12 Gross postmortem photograph demonstrating the relationship between the right caudal nasal septum (1), the nasal conchae (2), the infraorbital canal (3), the rostral maxillary sinus (4), and the teeth roots (arrow) within the rostral maxillary sinus. (D) dorsal.**

- The infraorbital nerve within the infraorbital canal and the lacrimal canal is located along the medial wall of the maxillary sinus, with the lacrimal canal located dorsal to the infraorbital canal (**12**). The volume of the maxillary sinus increases with age as the reserve crowns of the cheek teeth become smaller with use. There is a large opening into the sphenopalatine sinus caudal and medial to the infraorbital canal and a small opening medially into the middle conchal sinus. The maxillary sinus communicates with the nasal passage via the nasomaxillary opening.

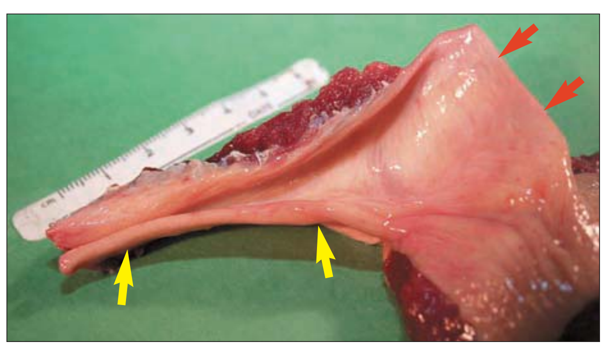
Guttural pouches

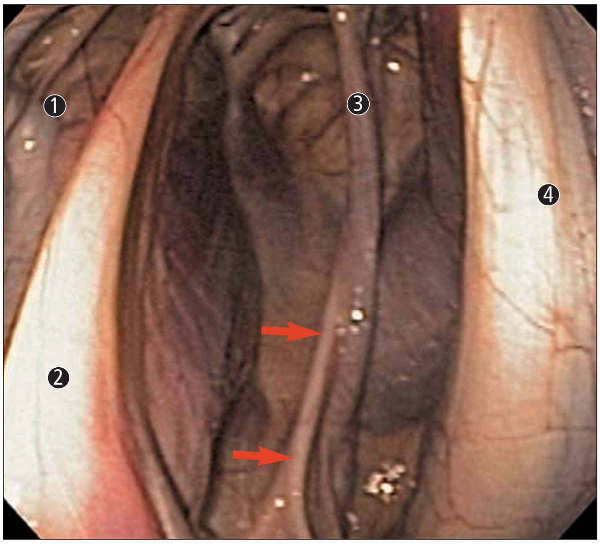
The GPs are anatomic structures unique to the horse among all domestic species. Each pouch is a diverticulum of the eustachian tube. The function of the GPs is unknown, though one report has suggested that it is to aid cooling of blood within the carotid and maxillary arteries during exercise. The GPs are paired structures divided by a medial septum. Each pouch has a capacity of approximately 300 ml, although it can accommodate up to 1 liter of fluid due to the distensible nature of the walls. The right and left pouches are separated caudally by the rectus capitus ventralis and longus capitus muscles and rostrally by a thin median septum, formed by the right and left pouch mucosal lining. Each GP communicates with the pharynx through the pharyngeal orifice. A fibrocartilaginous flap closes over the orifice (**13**). The free edge of this flap slopes caudally and ventrally along the wall of the pharynx. The pharyngeal orifice is shaped like a funnel with the mouth of the funnel located rostrally and the end of the funnel



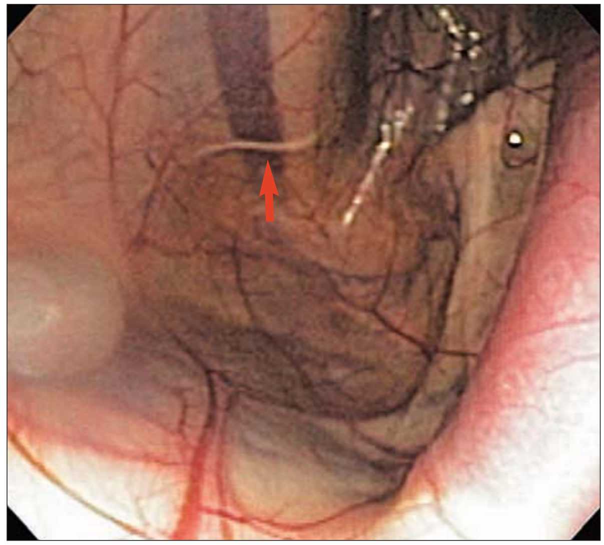
▲ **13 This specimen portrays the right cartilaginous flap (1) of the guttural pouch and the plica salphingopharyngea (arrow) dissected away from the guttural pouch. A Chambers catheter is being used to elevate the flap. (D) dorsal; (V) ventral.**

▶ **14 Gross postmortem photograph detailing the right medial aspect of the guttural pouch cartilaginous flap (red arrows) and the plica salphingopharyngea (yellow arrows).**





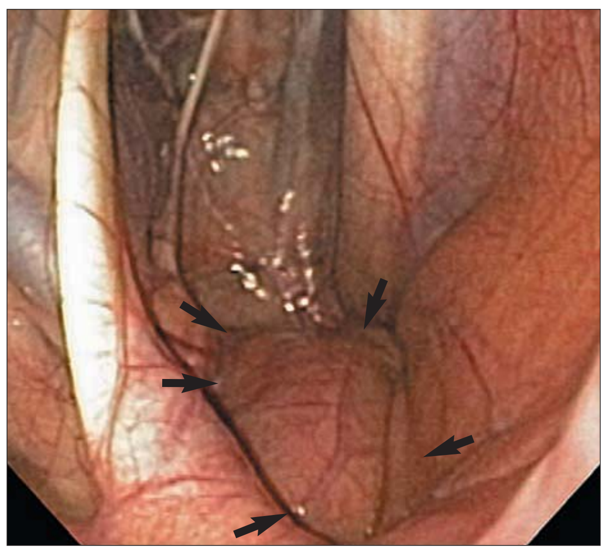
▲ **15** **Endoscopic view of the interior of the medial compartment of the right guttural pouch. (1) maxillary artery; (2) stylohyoid bone; (3) internal carotid artery; (4) longus capitus muscle; arrows, glossopharyngeal and hypoglossal nerves.**



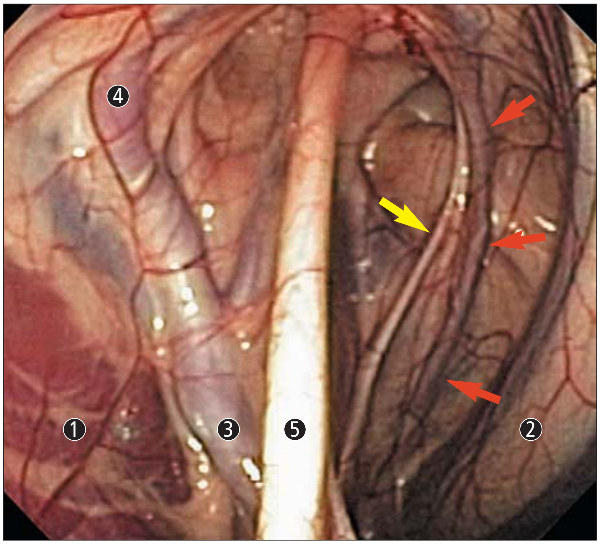
▲ **16** **Endoscopic view of the interior of the left medial compartment of the guttural pouch. The ventral branch of the vagus nerve is visible (arrow).**

located caudally. The caudal narrowing is due to a transverse fold of mucous membrane (plica salpingopharyngea) on the floor of the opening that connects the medial lamina (flap) with the lateral wall of the pharynx (**14**). The stylohyoid bone separates the interior of each pouch into medial and lateral compartments (**15**). The medial compartment is approximately twice the size of the lateral compartment. It contains the internal carotid artery, the cranial cervical ganglion, the cervical sympathetic trunk, the vagus nerve (CN X), the glossopharyngeal nerve (CN IX), the hypoglossal nerve (CN XII), and the spinal accessory nerve (CN XI) along the roof of the guttural pouch and traversing the caudal wall.

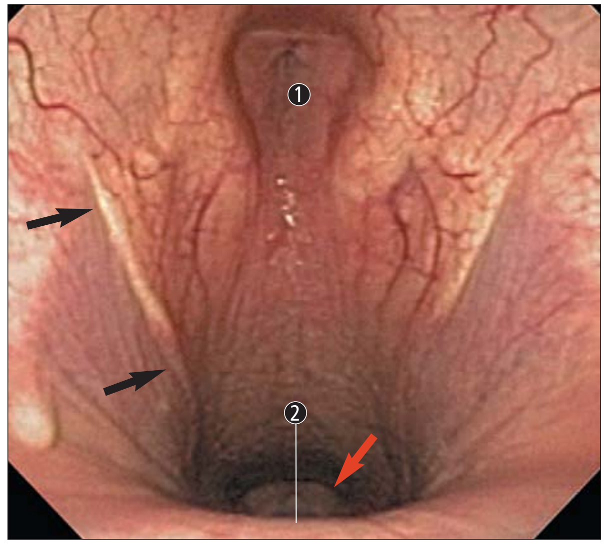
The pharyngeal branch of the vagus nerve (**16**), the cranial laryngeal nerve, and the medial retropharyngeal lymph nodes lie beneath the mucosa on the floor of the medial compartment (**17**).



▲ **17** **Endoscopic view of the right guttural pouch of a horse. Note the enlargement of the retropharyngeal lymph nodes (arrows) on the floor of the medial compartment of the pouch.**



▲ **18 Endoscopic photograph illustrating the structures within the lateral (1) and medial compartments (2) of the right guttural pouch. (3) external carotid artery; (4) maxillary artery; (5) stylohyoid bone; red arrows, internal carotid artery; yellow arrow, glossopharyngeal and hypoglossal nerves.**



▲ **19 Endoscopic view of the normal nasopharynx. (1) dorsal pharyngeal recess; (2) soft palate; black arrows, pharyngeal openings into the guttural pouch; red arrow, corniculate processes of the arytenoid cartilages.**

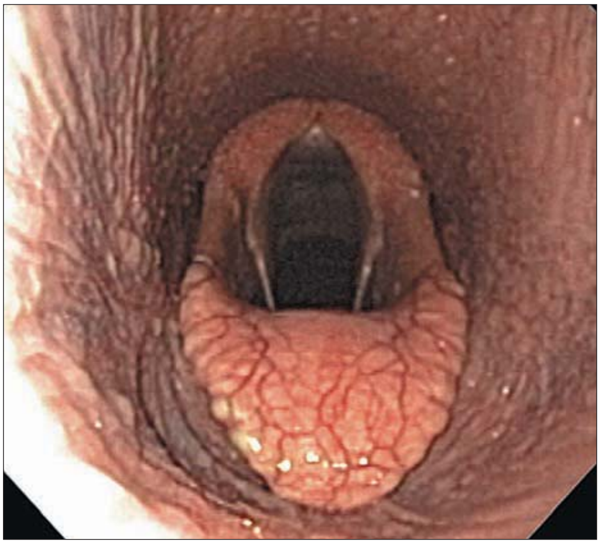
The lateral compartment contains the external carotid artery along the ventral surface, where it is in close association with the glossopharyngeal and hypoglossal nerves (**18**). Dorsally, the external carotid artery continues as the maxillary artery. Also within this compartment is the maxillary vein, the chorda tympani nerve, and branches of the mandibular nerve. The facial nerve (CN VII) courses over the caudal dorsal aspect.

Nasopharynx

The nasopharynx contains the guttural pouch openings, dorsal pharyngeal recess, soft palate, palatopharyngeal arch, larynx, and esophageal opening (**19**).

The mucosa of the nasopharynx is comprised of a pseudostratified columnar epithelium sprinkled with goblet cells and lymphoid tissue, below which lie elastic connective tissue and muscle. In young horses the lymphoid tissue is active and this can lead to the visual appearance of pharyngeal lymphoid hyperplasia, which may be graded from 1 to 4:

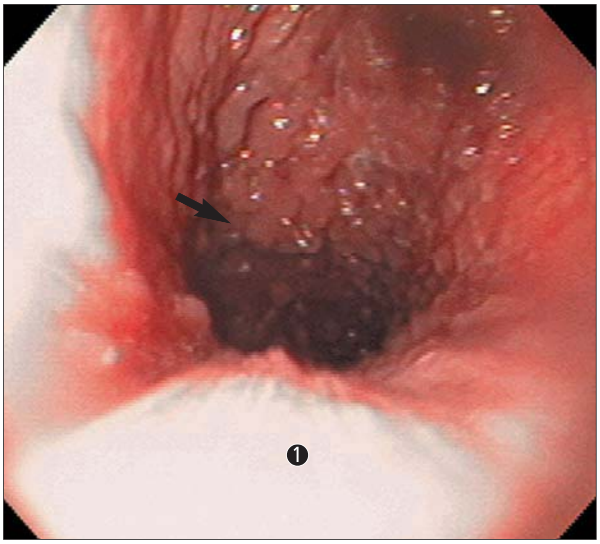
- **Grade 1** is present when there is a small number of white follicles in multiple positions over the dorsal pharyngeal wall (**20**).
- **Grade 2** is present when there are many small, white, lymphoid follicles located over the dorsal and lateral walls of the pharynx, to the level of the guttural pouch openings (**21**). Among the scattered white follicles are numerous follicles that are pink and glistening. Pink or red edematous follicles are considered to be immunologically active.
- **Grade 3** is present when there are many large, coalescing follicles covering the lateral and dorsal pharyngeal wall (**22**). Some of the follicles may spread across the surface of the soft palate.
- **Grade 4** is present when active, pink, glistening follicles cover the pharynx and include the dorsal surface of the soft palate and, occasionally, the surface of the epiglottis and the lining of the guttural pouches (**23**). Some of the follicles coalesce into larger masses.



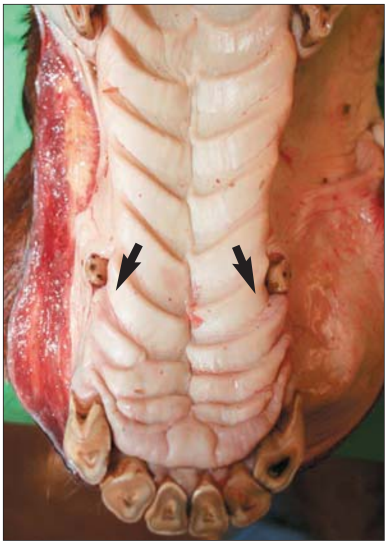
▲ **20 Endoscopic view of a horse with grade 1 pharyngeal lymphoid hyperplasia.**

▲ **21 Endoscopic view of a horse with grade 2 pharyngeal lymphoid hyperplasia.**

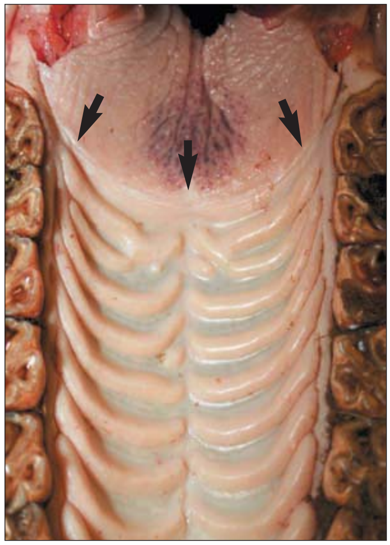
▲ **22 Endoscopic view of a horse with grade 3 pharyngeal lymphoid hyperplasia (arrows).**



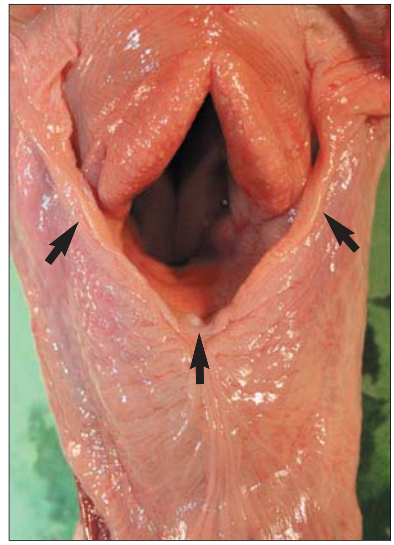
▲ **23 Endoscopic view of a horse with grade 4 pharyngeal lymphoid hyperplasia. The arrow indicates coalescing lymphoid follicles, extending onto the soft palate (1), characteristic of grade 4 pharyngeal lymphoid hyperplasia.**



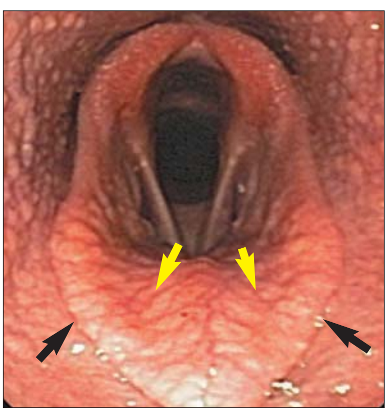
▲ 24 Gross postmortem photograph illustrating a normal hard palate. Note the prominent rugae of the hard palate and the location of the palatine arteries (arrowed) adjacent to the canine teeth.



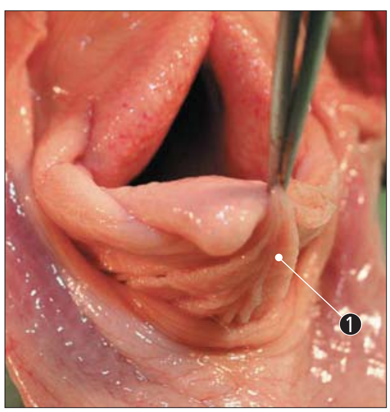
▲ 25 Gross postmortem photograph detailing the junction between the hard and the soft palate (arrows).



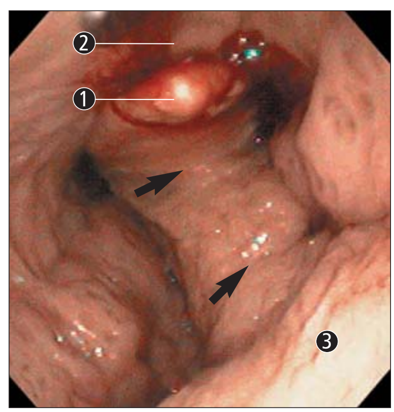
▲ 26 Gross postmortem photograph of normal soft palate. The epiglottis has been deflected ventral to the soft palate to allow visualization of the caudal edge. The arrows indicate the caudal aspect of the soft palate with the edges becoming part of the palatopharyngeal arch.



▲ 27 Endoscopic view of a normal epiglottis. The black arrows identify the serrated edge of the epiglottis and the yellow arrows identify the normal vascular pattern on its dorsal surface.



▲ 28 Gross postmortem photograph illustrating the redundant nature of the aryepiglottic fold (1).



▲ 29 Endoscopic view of the epiglottis (1) in the oral cavity. The soft palate (2) is dorsal to the epiglottis. (3) base of the tongue; arrows, location of the hyoepiglotticus muscle. An epiglottic hook is located dorsal to the epiglottis.

Hard and soft palate

The hard palate begins rostrally at the maxillary incisors and ends caudally approximately at the level of the last caudal cheek tooth (**24**). At this level it intersects with the soft palate. Within the hard palate is the incisive bone. The oral surface of the hard palate consists of mucosal ridges. The major palatine arteries encircle the hard palate and lie in close approximation to the lingual aspect of the canine and cheek teeth.

The soft palate begins rostrally at its intersection with the hard palate and ends caudally as palatopharyngeal arches, which encircle the larynx (**25**). The soft palate at this level has a 'button-hole' appearance with the larynx acting as the 'button' (**26**). The soft palate consists of a mucosal lining of pseudostratified columnar epithelium with underlying muscle and fat. Normally, the soft palate rests beneath the epiglottis. This anatomic feature makes the horse an obligate nose breather.

Epiglottis

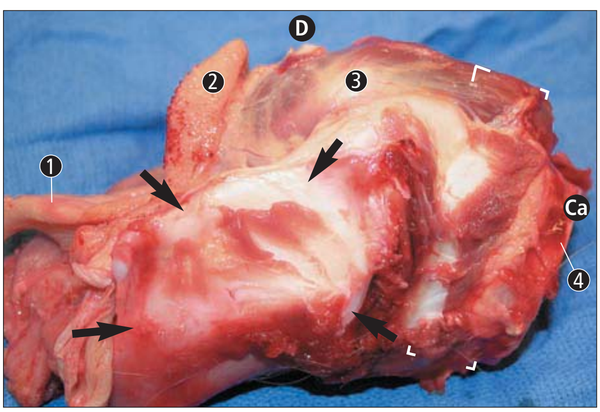
The epiglottis makes up a portion of the larynx. It has a leaf-like appearance (**27**) and several important anatomic features. The edges of the epiglottis appear serrated and there is a prominent vascular pattern on its surface. The epiglottis is attached to the arytenoid cartilages by the aryepiglottic fold (**28**), which originates from the lingual surface of the epiglottis.

The major muscle controlling dorsal and ventral positioning of the epiglottis is the hyoepiglotticus (**29**). Normally, the epiglottis rests dorsal to the soft palate except during deglutition, when it covers the rima glottitis.

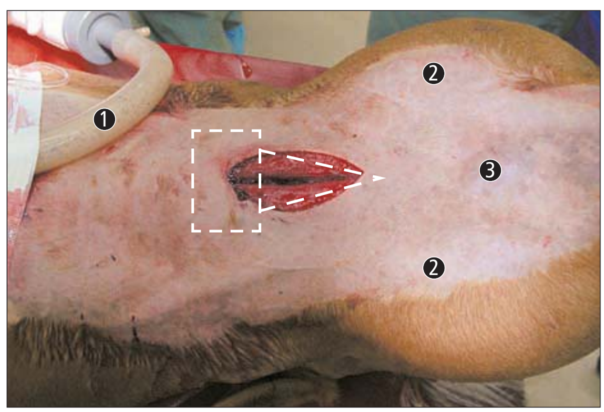
Larynx

The larynx consists of four cartilaginous structures: the epiglottic, thyroid, cricoid, and paired arytenoid cartilages (**30**).

The thyroid cartilage has a keel-like appearance and articulates with the cricoid cartilage via the cricothyroid joint. The cricoid cartilage has a signet ring appearance. The cricothyroid ligament spans the thyroid and cricoid cartilages on the ventral aspect of the larynx (**31**). The cricotracheal space is the junction between the cricoid cartilage and the trachea.



▲ 30 Gross postmortem photograph of a normal larynx (lateral view). (1) epiglottis; (2) arytenoid cartilage and its muscular process (3); (4) trachea; arrows, thyroid cartilage; dotted line, cricoid cartilage; (D) dorsal; (Ca) caudal.

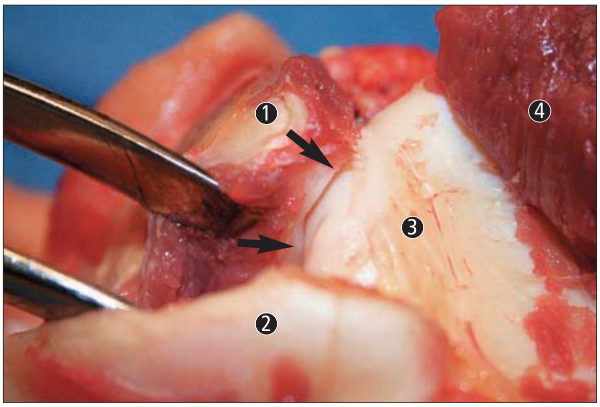


▲ 31 Intraoperative photograph of a horse in dorsal recumbency. The rectangular box represents the cricoid cartilage. The triangle represents the thyroid cartilage. The surgical incision incises the cricothyroid ligament. (1) endotracheal tube; (2) mandibular rami; (3) basihyoid bone.

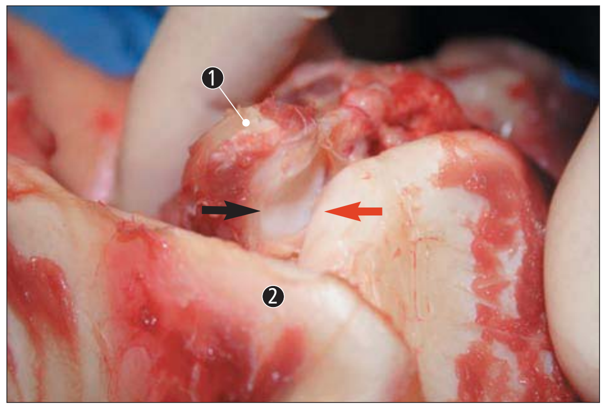
The cricoid cartilage articulates with the arytenoid cartilages via the right and left cricoarytenoid joints (**32**, **33**). This articulation is the major joint allowing movement of the arytenoid cartilages.

The arytenoid cartilages are paired structures. The arytenoid consists of the corniculate, vocal, and muscular processes (**34**). Between these processes is the body of the arytenoid. The vocal process is the insertion point for the vocal cord and the muscular process is the insertion point for the cricoarytenoideus dorsalis (CAD) muscle.

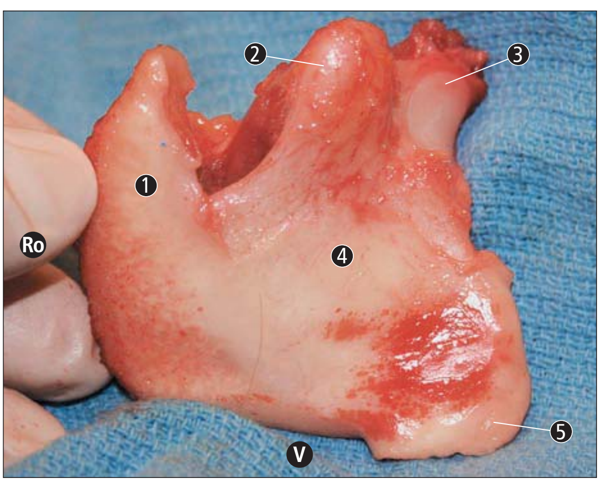
The CAD muscle is the major abductor of the arytenoid cartilage, and is innervated by the recurrent laryngeal nerve. The vocal cord is a fibroelastic



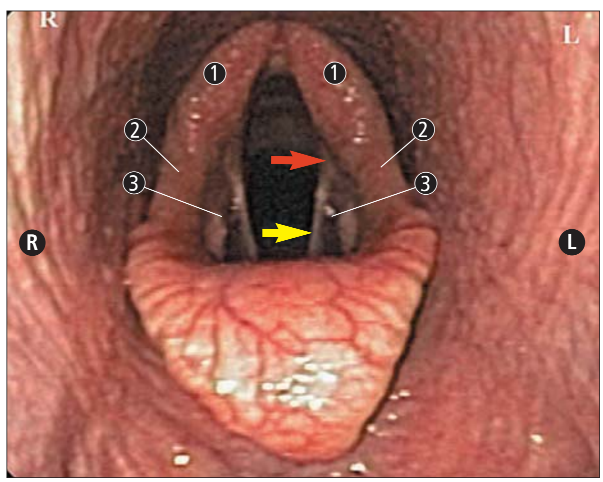
▲ 32 Gross postmortem photograph showing the left cricoarytenoid joint (arrows), the muscular process (1), the thyroid (2) and cricoid (3) cartilages, and the reflected cricoarytenoideus dorsalis muscle (4).



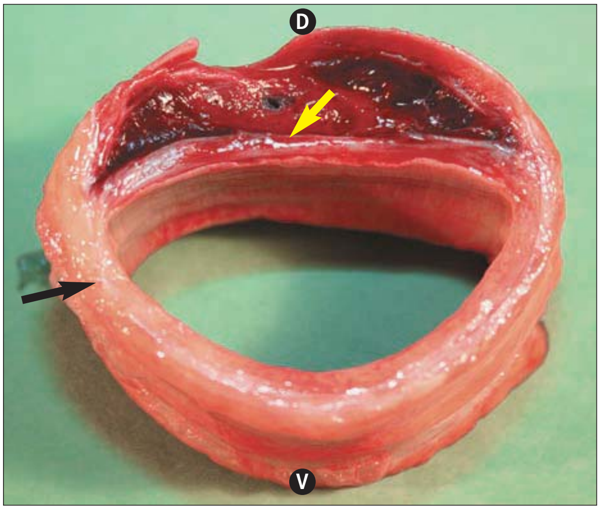
▲ 33 Gross postmortem photograph showing an opened cricoarytenoid joint. (1) muscular process; (2) thyroid; black arrow, arytenoid facet; red arrrow, cricoid facet.



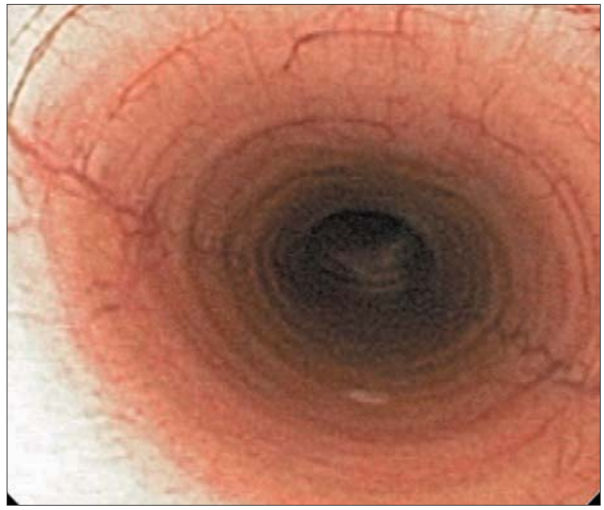
▲ 34 Complete left arytenoid cartilage dissected free of the remainder of the larynx. (1) corniculate process; (2) muscular process; (3) articular facet of cricoarytenoid joint; (4) body of the arytenoid; (5) vocal process; (Ro) rostral; (V) ventral.



▲ 35 Endoscopic view of a normal larynx at rest. (1) corniculate processes of the arytenoid cartilages; (2) aryepiglottic fold; (3) laryngeal ventricle; red arrow, vocal process of the left arytenoid cartilage; yellow arrow, vocal cord; (R) right; (L) left.



▲ **36** **Gross postmortem photograph of the divided cervical trachea. Black arrow, tracheal cartilage, which is incomplete dorsally; yellow arrow, dorsal tracheal ligament and trachealis muscle; (D) dorsal; (V) ventral.**



▲ **37** **Endoscopic view of a normal trachea.**

structure that originates on the ventral surface of the larynx and inserts on the vocal process of the arytenoid cartilage (**35**). Axial to the vocal cord is the laryngeal ventricle. The laryngeal ventricle is a blind-ended sac that extends caudally for approximately 3–4 cm.

Cervical trachea

The trachea is a flexible, non-collapsing tube that extends 70–80 cm (45–55 cm in ponies) from the cricoid cartilage of the larynx to the hilus of the lung. The trachea spans the distance from the first or second cervical vertebra to the sixth intercostal space. Distally, the trachea bifurcates into right and left principal bronchi. The cervical portion of the trachea extends from the larynx to the thoracic inlet and the thoracic portion extends from the thoracic inlet to the tracheal bifurcation. The thoracic portion of the trachea wall is subjected to pleural pressure, but the lumen is near atmospheric pressure. Proximally, the trachea is superficial and is covered ventrally by the cutaneous colli and sternothyrohyoideus muscles. Distally, towards the thoracic inlet, the trachea is covered ventrally by the sternocephalicus muscle.

The trachea of the horse has 48–60 concentric, incomplete hyaline cartilage rings. These rings are rigid and enclosed in a fibrous membrane, which prevents collapse. They also overlap dorsally to provide flexibility, and because of this the trachea can be collapsed laterally by manual pressure or pressure caused by enlarged external structures adjacent to the trachea (**36**). Dorsally, the trachealis muscle is attached to the inner surface of the tracheal rings and helps to maintain the patency of the tracheal lumen.

The tracheal lumen is lined by a mucous membrane consisting of ciliated pseudostratified columnar epithelial cells and mucus-producing goblet cells (**37**). A blanket of translucent mucus coats the respiratory mucosa, giving it a shiny, wet appearance. The mucus layer aids in removal of particulate foreign material from the respiratory tract. The submucosa, located below the mucous membrane lining, contains elastic tissue, which adds to the flexibility of the trachea.

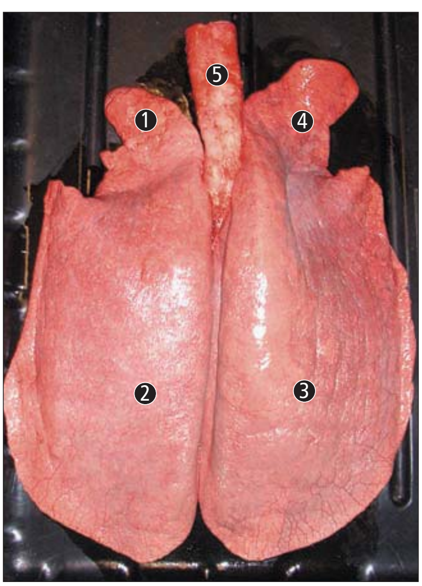
INTRATHORACIC AIRWAYS AND THE LUNGS

The external anatomy of the equine lung reveals no distinction between lobes except for the accessory lobe on the right side. The cardiac notch marks the separation between the cranial and caudal lobes (**38**).

Tracheobronchial tree

The ventral aspect of the trachea is lowest where it enters the thoracic inlet. As a result, excess mucus tends to pool at this level (**39**) and fluid infused during a tracheal wash will be easily aspirated by advancing the catheter tip in the tracheal puddle. The intrathoracic trachea is usually narrower proximal to the carina because the aorta pushes the left side of the tracheal wall inwards. The trachea ends above the heart base at the level of the left atrium, slightly right of midline. The trachea then gives way to the left and right principal bronchi at the carina (**40, 41**). After the carina, the airways are divided into lobar, segmental, and subsegmental bronchi, bronchioles, and, finally, terminal bronchioles. The right cranial lobar bronchus originates from the right principal bronchus at approximately the 10 o'clock position (**42**). The accessory lobar bronchus originates from the right principal bronchus at the 4 o'clock position, next to the first bronchus of the right caudal lung lobe at 7 o'clock. The right principal bronchus then becomes the right caudal lobar bronchus. The left principal bronchus becomes the left caudal lobar bronchus after supplying the left cranial lobar bronchus at the 2 o'clock position (**42**). Terminal bronchioles are the smallest conducting airways (i.e. without alveoli). Conducting airways do not participate in gas exchange, although diffusion may occur in terminal bronchioles since convective flow is near zero. Conducting airways constitute the anatomic dead space. The terminal bronchioles divide into respiratory bronchioles, then into alveolar ducts and end in alveolar sacs (**43**). Respiratory bronchioles are poorly developed in the horse but are the first airways with occasional alveoli protruding from their walls, whereas alveolar ducts and alveolar sacs are lined with alveoli. The distal airways containing alveoli constitute the respiratory zone.

▼ **38 Gross postmortem photograph of the costal surface of the lungs of a healthy horse showing the lack of interlobar fissures. (1) left cranial lobe; (2) left caudal lobe; (3) right caudal lobe; (4) right cranial lobe; (5) trachea.**



▼ **39 Endoscopic view of the trachea at the level of the thoracic inlet. White mucoid secretions may be seen accumulated on the floor of the trachea (arrow).**