OCCLUSION OF THE INTERNAL CAROTID ARTERY OF HORSES: EVALUATION OF A TECHNIQUE DESIGNED TO PREVENT EPISTAXIS CAUSED BY GUTTURAL POUCH MYCOSIS

by

Hoyt Stephen Cheramie

Thesis submitted to the faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Veterinary Medical Sciences

Approved:

R. Scott Pleasant, Chairman

John L. Robertson H. David Moll Colin B. Carrig

August 1998
Blacksburg, Virginia

Key Words: Embolization, Equine, Fungal Infection

Copyright 1998. Hoyt Stephen Cheramie

OCCLUSION OF THE INTERNAL CAROTID ARTERY OF HORSES: EVALUATION OF A TECHNIQUE DESIGNED TO PREVENT EPISTAXIS CAUSED BY GUTTURAL POUCH MYCOSIS

by

Hoyt Stephen Cheramie

R. Scott Pleasant, Committee Chairman

Department of Large Animal Clinical Sciences

(ABSTRACT)

In six, healthy, adult horses, the origin of the left internal carotid artery was isolated via a modified hyovertebrotomy approach. Normograde blood flow was occluded by placement of a tourniquet on the artery near its origin. Lumenal access was gained through placement of a distally directed introducer sheath and retrograde blood flow from the cerebral arterial circle was confirmed. An 8.5 mm diameter detachable latex balloon loaded onto a carrier catheter and placed within a guiding catheter was introduced into the internal carotid artery through the introducer sheath and advanced to the target occlusion site (the proximal curve of the sigmoid flexure of the internal carotid artery). The balloon was inflated with 0.5 ml of a radiopaque solution. Correct placement and inflation of the balloon were confirmed by intraoperative radiography. The balloon was then released and the guiding and carrier

catheters withdrawn. Immediate embolization of the distal internal carotid artery was determined by lack of retrograde blood flow through the introducer sheath. The introducer sheath was withdrawn from the vessel and the proximal tourniquet was replaced with two ligatures. Horses were euthanized on day 30 and detailed gross and histopathologic examinations were performed.

The balloons were easily placed into the target site and produced immediate occlusion of retrograde flow from the cerebral arterial circle. All balloons remained inflated in their original position throughout the study period. Mature thrombus formation and absence of clinically significant inflammation were consistent findings in all occluded internal carotid arteries at gross necropsy and histologic examination.

To Lesley for her unending patience, understanding, and love,

to my parents, for their continuous

encouragement, support, and faith,

AND

to the horse,

whose free spirit has inspired me

ACKNOWLEDGMENTS

This project was made possible through the generous financial support of both the Virginia Veterinary Medical Association and the United States Department of Agriculture, Animal Health and Disease Fund.

I would like to specifically thank Dr. R. Scott Pleasant, my graduate studies and residency program advisor, for his guidance, patience, and especially his encouragement throughout my graduate program.

My thanks are also extended to the members of my graduate committee, Drs. H. David Moll, John L. Robertson, and Colin B. Carrig, for their support of and contribution to this work. Drs. Mary E. Jensen and Jacques E. Dion are greatly appreciated for their time and assistance in furthering my understanding of interventional radiology and the use of detachable balloons. Additional thanks are due Dr. Francois Elvinger, Dr. Clint Coakley and James David Barfield for their assistance in the statistical analysis of data and Terry Lawrence for his excellent artwork.

A special thanks to Michael Higgins, Julie Zurfluh, Shannon McCourt, Lynne Johnson and Michael “Tony” Huffman for their meticulous care of the horses.

This study was conducted at the Harry T. Peters, Jr. Large Animal Clinic of the Veterinary Medical Teaching Hospital, Virginia-Maryland Regional College of Veterinary Medicine, and the support of its technical staff is greatly appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Erosion of the internal carotid artery and accompanying hemorrhage is common in horses with guttural pouch mycosis. The first known reference to guttural pouch mycosis appeared in **Medico Veterinario** in 1868 in an article written by Rivolta (cited by Cook et al. 1968). Rivolta described an unfamiliar fungal infection of the guttural pouch in a horse that eventually died of gangrenous aspiration pneumonia. Rivolta named the fungus *Gutturomyces equi*. However, in a report of a second case in 1873, Rivolta (cited by Buer 1942) concluded from the appearance of the fungus and the type of lesion that the organism was an *Aspergillus* species, but his attempts to culture and isolate the organism were unsuccessful.

Guttural pouch mycosis was described sporadically over the next seventy years (Buer 1942). Affected horses in these reports died of fatal hemorrhage or aspiration pneumonia. The first attempt to treat the disease surgically was reported in 1942 by Buer. In a horse with unilateral epistaxis, the internal carotid artery on the affected side was surgically occluded at its origin with a ligature. Nevertheless, the horse died 8 days later from gangrenous aspiration pneumonia. However, the horse did not experience any further hemorrhage prior to its death. When the horse was necropsied, the internal carotid artery was found to be completely thrombosed. More recently, Cook published

extensively on the clinical signs, pathology and presumptive etiology of guttural pouch mycosis in a series of papers (Cook 1966; Cook 1968; Cook et al. 1968).

High mortality rates are associated with erosion of the internal carotid artery and ensuing hemorrhage in horses with guttural pouch mycosis. It is recommended that the artery be occluded as soon as possible after the problem is recognized to prevent fatal epistaxis (Lane 1989; Freeman 1992). Ligation of the internal carotid artery at its origin (proximal to the mycotic lesion) has been shown to be effective in reducing the risk of hemorrhage (Church et al. 1986; Greet 1987). However, severe and fatal hemorrhages, attributed to retrograde flow from the cerebral arterial circle, have occurred after this procedure.

Concerns about the continued risk of hemorrhage after proximal ligation led to the development of a balloon-catheter technique to occlude the internal carotid artery (Freeman and Donawick 1980a; Freeman and Donawick 1980b). The procedure involves placing the balloon of a balloon-tipped catheter distal to the area of infection and a ligature at the origin of the internal carotid artery. This technique has been highly effective in preventing hemorrhage. However, postoperative complications, including wound infection and foreign body reaction have occurred (Freeman and Donawick 1980a; Caron et al. 1987). These complications are thought to be related to the presence of the catheter within the internal carotid artery at the site of the mycotic lesion or the need to bury redundant portions of the catheter within the surgical wound. The

development of postoperative complications usually necessitates a second surgical procedure to address the problems adequately.

Detachable intravascular balloons are used in human medicine for safe, immediate and permanent occlusion of vessels, intracranial aneurysms and arteriovenous fistulas (White et al. 1980; Debrun 1992; Higashida et al. 1992; Lownie et al. 1992; Matsumoto et al. 1992; Chaloupka and Putman 1995). These balloons are placed through introducer systems either directly into the target vessel or into a distant, more easily accessible vessel and “driven” to the target vessel under fluoroscopic guidance. Once positioned appropriately, the balloons are inflated and released, and the carrier and guiding catheters withdrawn. The detached balloon immediately occludes the vessel and a thrombus forms in the occluded vessel.

The use of a detachable balloon to occlude the internal carotid artery distal to a mycotic lesion in the horse would seem to be a reasonable modification of the balloon-tipped catheter technique. Retrograde hemorrhage from the cerebral arterial circle would be prevented. Additionally, the need to leave an in-dwelling catheter within the lumen of the artery at the site of the mycotic lesion or buried within the surgical wound would be eliminated. The objective of this study was to evaluate a technique to occlude the internal carotid artery of the horse using an intravascular, detachable latex balloon distally and ligatures proximally.

REVIEW OF LITERATURE

Guttural Pouch and Vascular Anatomy

The guttural pouches are paired, air-filled, ventral diverticula of the auditory tubes, which connect the pharynx to the tympanic cavity of the ear in the horse (Sisson 1975). These diverticulations are peculiar to some members of the order Perissodactyla including the horse and other equids (Dyce et al. 1996), the tapir (Turner 1850), the rhinoceros (Brandt 1863), the South American forest mouse (Hinchcliffe and Pye 1969), and six species of insectivorous bats (Valdivieso 1979).

The anatomic relationships between the guttural pouches and surrounding tissues are numerous and quite complex in the horse. The pouches communicate with the pharynx through the rostral portion of the auditory tube, which begins as the pharyngeal opening (*ostium pharyngeum tubae auditive*). The pouches do not communicate with each other. They are separated by the rectus capitis ventralis and longus capitis muscles dorsally, and meet ventrally, forming a thin median septum (Dyce et al. 1996). Several vascular and neural structures as well as muscles, bones, glands, and lymph nodes are intimately related to the guttural pouches. The shape, size and contour of the guttural pouches are determined by their anatomic relationships with surrounding structures. The pouches are bound dorsally by the sphenoid, occipital and petrous temporal bones and caudo-dorsally by the atlanto-occipital joint and

atlas (Sisson 1975). The pharynx, larynx, cricopharyngeus muscle and origin of the esophagus make up the ventral boundary of the pouches (Dyce et al. 1996). The lateral margins are determined by the pterygoideus, levator veli palatini, tensor veli palatini, stylohyoideus, occipitohyoideus and caudal belly of the digastricus muscles, the parotid and mandibular salivary glands, the caudal border of the mandible and skin (Sisson 1975). Each guttural pouch is partially divided ventrally and caudally into a large medial and a small lateral compartment by the stylohyoid bone. The guttural pouches in adult horses each have a capacity of approximately 300 - 500 ml (Dyce et al. 1996).

The guttural pouches are delicate, loosely attached mucous membranes lined with ciliated epithelium (Sisson 1975). A variety of seromucinous glands are found in the membranes. Numerous lymph nodules may also be present in young horses. A fold of mucous membrane protruding into the pouch contains the internal carotid artery, and glossopharyngeal, vagal, and hypoglossal cranial nerves as these structures course along the caudal wall of the medial compartment (Dyce et al. 1996). The cranial cervical ganglion, cervical sympathetic trunk, and accessory cranial nerve also course along the caudal wall of the medial compartment. The cranial branch of the laryngeal nerve, pharyngeal branch of the vagal nerve, pharyngeal branch of the glossopharyngeal nerve and retropharyngeal lymph nodes lie beneath the caudal ventral floor of the medial compartment (Sisson 1975). The facial nerve has a limited contact with the dorsal part of the pouch as it exits the skull (Dyce

et al. 1996). The external carotid and linguofacial arteries are in apposition with the pouch ventrally. The external carotid artery courses along the floor of the medial compartment then passes ventral to the stylohyoid bone and continues along the floor of the lateral compartment before branching into the maxillary and superficial temporal arteries which course in a dorsal direction along the lateral wall of the lateral compartment (Sisson 1975).

The internal carotid artery originates as the first terminating branch of the common carotid artery just proximal to the origin of the occipital artery (Nanda 1975). Not uncommonly it arises with the occipital artery as a common trunk of variable length (Nanda 1975). The internal carotid artery courses in a rostrodorsad direction axial to the occipital artery for a short distance then becomes contained within a membranous fold of the caudal wall of the medial compartment as it approaches the foramen lacerum (Nanda 1975) (Figure 1). As the internal carotid artery leaves its apposition with the guttural pouch, it enters the venous cavernous sinus and forms a sigmoid flexure (Nanda 1975). Just distal to the flexure, it enters the foramen lacerum and is connected with the opposite internal carotid artery by the caudal intercarotid artery which courses caudal to the hypophysis (Nanda 1975). The internal carotid artery perforates the dura mater and gives off the caudal communicating artery and continues rostrally for a short distance to terminate as the rostral and middle cerebral arteries (Nanda 1975). The caudal communicating artery joins the basilar artery and the rostral cerebral artery joins the corresponding branch of

the other side, thus forming the cerebral arterial circle (Nanda 1975). Therefore, in the horse, there is complete collateral circulation between the left and right internal carotid arteries and basilar artery to supply blood to the brain (Figure 2).

Guttural Pouch Function

A variety of functions have been suggested for the guttural pouches, but none have been proven to date. One theory is that the pouches fill with warmed air during expiration; and that before or during inspiration, this warmed air flows from the pouch into the nasopharynx and mixes with the inspired cool air (Fish 1910). Another theory of guttural pouch function is that they influence internal carotid artery blood pressure. The air pressure within the pouches is known to fluctuate with the phase and forcefulness of respiration. Because of the internal carotid artery's significant exposure within the pouch, it is thought to be affected by these pressure changes.

A third theory put forward more recently is that the guttural pouches serve as a brain-cooling mechanism when core body temperature is elevated (Baptiste et al. 1993). Experiments using cadaver heads in which the internal carotid arteries were perfused with fluid at temperatures and flow rates approximating those of life, showed that the fluid temperature reaching the cerebrum could be reduced several degrees when vigorous respiration was simulated. Although the methods used by Baptiste et al. (1993) were artificial simulations, the findings do lend substantial support to this theory which is thought to occur in a variety of other species which have developed similar vascular specializations

and arterial retes (Baker and Chapman 1977; Khamas and Ghoshal 1982; McConaghy et al. 1995).

Guttural Pouch Mycosis

Guttural pouch mycosis is an important and often fatal disease of horses. The disease was first described by Rivolta in 1868 (cited by Cook et al. 1968). Rivolta reported the disease to be caused by a fungus he termed *Gutturomyces equi*. In a subsequent description of a second case in 1873, Rivolta classified the fungus as an *Aspergillus* species based on the appearance of the fungus and the type of lesion produced (cited by Buer 1942). Other early reports of guttural pouch mycosis are found sporadically in the literature. Buer (1942) described three cases and reviewed nine cases previously reported by six authors between 1881 and 1931. Recently, several reviews have been published describing guttural pouch mycosis in horses. Cook (1968) and Cook et al. (1968) reported thirty-two cases, Church et al. (1986) reported seventeen cases, Greet (1987) reported thirty-five cases, and Caron et al. (1987) reported thirteen cases. Including several single and small group case reports, one-hundred ninety-three cases of guttural pouch mycosis cases have been identified in the literature. The clinical signs, pathological findings and treatments of guttural pouch mycosis detailed in the following pages are based on these reports.

The usual presentation of the disease is a unilateral fungal infection located in the caudo-dorsal aspect of the guttural pouch, caudal and medial to the

articulation of the stylohyoid bone with the petrous portion of the temporal bone (Cook et al. 1968; Greet 1987; Dyce et al. 1996). No age, sex, breed, or geographic predisposition to this disease has been determined, although it is suggested to occur more frequently in horses stabled during the warmer months (Cook 1968). Based on the number of cases reported in the United Kingdom (Cook et al. 1968; Church et al. 1986; Greet 1987; Lane 1989), the disease may be more common there than in other parts of the world.

The fungal infection often results in inflammation and erosion of vascular and neural structures intimately associated with the guttural pouch membrane producing a variety of clinical signs (Cook et al. 1968). Important structures which are commonly affected include the internal carotid artery, glossopharyngeal, vagal, hypoglossal and accessory nerves, the cranial cervical ganglion and the cervical sympathetic trunk. The external carotid artery, maxillary artery and facial nerve are less commonly affected.

The characteristic lesion, a fungal plaque, appears as a diptheritic membrane, irregular in contour and closely attached to the underlying tissue (Cook et al. 1968) (Figure 3). It can be brown, yellow, green, black, white or a combination of colors and can range in size from a discrete nodule of a few millimeters to an expansive plaque covering the entire roof of the pouch (Cook et al. 1968). Fungal mycelia, a variety of bacteria, and necrotic tissue and debris make up the diptheritic membrane (Cook et al. 1968) (Figure 4). Several fungi have been identified in the lesion including *Aspergillus* spp (Rivolta, 1873;

Buer, 1942; Cook et al. 1968; Johnson et al. 1973; Nation 1978; Rawlinson and Jones 1978; Owen and McKelvey 1979), *Penicillium* spp (Buer, 1942), *Acaulium* sp (Buer, 1942) and *Corallium* sp (Buer, 1942). Microscopically, the fungal elements can be seen invading the underlying tissues including arteries and nerve fibers (Cook et al. 1968). Arterial association may stimulate development (Cook et al. 1968), perhaps serving as a nutrient supply for fungal growth. Moderate to severe local inflammation of the surrounding mucous membrane and underlying tissue is common.

Risk factors for the development of guttural pouch mycosis are poorly understood. Early authors considered the condition to be a primary mycotic infection. Nevertheless, Buer (1942) was unable to produce the disease by introduction of solutions containing a *Penicillium* sp (which he had isolated from a clinical case) in combination with hay and oat dust, saline, or serum into the guttural pouches of healthy horses. This lead him to suggest that fungal infection occurs after some initial insult. Buer (1942) found that damaging the mucosal lining by prior instillation of phenol or alcohol into the pouches did not facilitate experimental fungal infection. Suggestions that mycosis is preceded by strangles (Buer 1942) or guttural pouch empyema (Hutyra et al. 1949) have not been substantiated in the more recent reviews (Cook 1966; Cook et al. 1968; Church et al. 1986; Greet 1987). The fungi found in the mycotic plaque are thought to be unlikely primary pathogens (Buer 1942; Cook et al. 1968; Johnson et al. 1973), since they can often be recovered in washings from

guttural pouches as well as other parts of the upper respiratory tract of healthy horses (Cook 1966; Cook et al. 1968).

The most common and striking clinical sign of guttural pouch mycosis is spontaneous epistaxis (Cook 1966; Cook 1968; Cook et al. 1968; Church et al. 1986; Caron et al. 1987; Greet 1987; Lane 1989). This is due to the erosion of the wall of the affected artery by the invading fungal mycelia and associated inflammatory cells (Cook 1966; Cook et al. 1968; Lingard et al. 1974; Greet 1987). Repeated bouts of epistaxis, over a period of days to weeks prior to a fatal hemorrhage, are common (Cook 1966; Cook 1968; Lingard et al. 1974; Nation 1978; Rawlinson and Jones 1978). However, Cook (1968), Nation (1978) and Church et al. (1986) each report a case of a fatal hemorrhage occurring during the first identified bout of epistaxis.

In the case reported by Nation (1968), a mare which was observed to be normal by the owner the night before the episode and which had no previous signs of illness or epistaxis was found dead in her paddock, as a result of severe epistaxis. Necropsy demonstrated a rupture of the right external carotid artery at the site of a necrotic plaque containing fungal mycelia. In the case reported by Church et al. (1986), a horse experienced a fatal hemorrhage during an examination for abnormal head carriage, submandibular swelling and unilateral mucopurulent nasal discharge. A mycotic plaque was identified involving the left internal carotid artery at necropsy.

Because of the predilection of the lesion to occur in the caudal dorsal area of the medial compartment, the internal carotid artery is the most commonly affected vascular structure (Cook 1968; Cook et al. 1968; Church et al. 1986; Caron et al. 1987; Greet 1987). Lesions affecting the external carotid and maxillary arteries have also been reported (Cook 1966; Cook 1968; Smith and Barber 1984; Caron et al. 1987; Freeman et al. 1989), but at least 120 of the 125 cases of guttural pouch mycosis reported between 1966 and 1987 involved the internal carotid artery (Lane 1989).

Several other clinical signs seen with guttural pouch mycosis can be related to cranial nerve damage by the mycotic plaque. Histopathologic lesions of affected neural structures described by Cook et al. (1968) ranged from slight swelling of myelin sheaths and Schwann cells and dilation of intraneural vessels to deep mycelial penetration of nerve fibers with extensive inflammatory cell infiltration.

Pharyngeal hemiplegia is the most common neuropathy diagnosed in horses with guttural pouch mycosis (Lane 1989) and is related to involvement of the pharyngeal branches of the vagal and glossopharyngeal nerves (Cook 1966; Cook 1968) and the cranial laryngeal nerve (Freeman 1991). Clinical manifestations of pharyngeal hemiplegia include dysphagia, coughing, displacement of the palatopharyngeal arch, and the presence of saliva and ingesta in the nasopharynx (Figure 5) and nares (Cook 1968; Lane 1989). In

severely affected horses, aspiration pneumonia has been reported (Buer 1942; Cook 1968; Lane 1989).

Laryngeal hemiplegia on the ipsilateral side of the lesion has also been reported (Cook 1966; Greet 1987) (Figure 6). Since the recurrent laryngeal nerve does not traverse the guttural pouch, this is likely due to damage of the components of the vagus nerve that will become the recurrent laryngeal nerve as the vagus nerve courses through the pouch (Cook 1966).

Other less common clinical signs seen with guttural pouch mycosis include parotid pain, nasal discharge, abnormal head posture, Horner's syndrome, colic, sweating, corneal ulcers, and head shyness (Cook 1966; Cook 1968; Lane 1989; Freeman 1991). Sequelae related to guttural pouch mycosis include atlanto-occipital arthropathy (Walmsley 1988), atlanto-occipital joint infection (Dixon and Rowlands 1981), mycotic encephalitis (Wagner et al. 1978), middle ear infection (Dixon and Rowlands 1981), blindness (Hatziolos et al. 1975), necrosis of the stylohyoid and petrous temporal bones (Dixon and Rowlands 1981), facial paralysis (Hilbert et al. 1981), guttural pouch-pharyngeal fistula (Jacobs and Fretz 1982), and lingual hemiplegia (Kipar and Frese 1993).

Treatment of guttural pouch mycosis is aimed at prevention of hemorrhage, resolution of the mycotic plaque and symptomatic support of other clinical signs. The success of medical treatment of guttural pouch mycosis is low. Church et al. (1986) and Greet (1997) report less than half of the horses treated medically

responded to treatment. Topical application of antifungal agents is technically difficult (Church et al. 1986; Speirs et al. 1995) and has an unpredictable efficacy. Systemic treatment is complicated by the high cost of antifungal drugs, lack of information on their pharmacodynamics in horses, and the high toxicity of some of the compounds. Most importantly, the response to medical therapy, if any, is usually too slow to reduce the risk of fatal hemorrhage (Freeman 1991). In 12 confirmed cases of guttural pouch mycosis reported prior to 1966, 7 horses died from fatal epistaxis. In a series of 32 horses with guttural pouch mycosis, Cook (1968) reported that 9 of 23 horses with a history of epistaxis died of fatal hemorrhage.

Due to the high mortality associated with hemorrhage of the internal carotid artery caused by guttural pouch mycosis, occlusion of the artery as soon as the problem is recognized has been recommended. The first reported attempt at surgical management of hemorrhage related to guttural pouch mycosis was by Buer (1942). In a horse with unilateral epistaxis, the origin of the affected internal carotid artery (proximal to the mycotic lesion) was surgically occluded by ligation. The long term success of the technique could not be determined because the horse died of gangrenous aspiration pneumonia 8 days after the surgical procedure. Nonetheless, the horse did not experience any further epistaxis prior to death. At necropsy, a mycotic plaque in the caudal medial guttural pouch affecting the internal carotid artery was identified. The occluded

internal carotid artery contained an organized thrombus extending from the ligature to a point distal to the eroded portion of the artery.

Ligation of the origin of the internal carotid artery has been used recently to reduce the risk of hemorrhage in cases of guttural pouch mycosis (Owen 1974; Church et al. 1986; Greet 1987) (Figure 7). Although reported to be successful in most cases, severe and fatal hemorrhages have occurred after this procedure (Owen 1974; McIlwraith 1978; Church et al. 1986; Greet 1987). Church et al. (1986) reported an overall 20% post-ligation hemorrhage rate with 1 (6%) fatal hemorrhage. Greet (1987) reported an overall 17 % post-ligation hemorrhage rate with 1 (3%) fatal hemorrhage. The hemorrhages were attributed to retrograde flow from the cerebral arterial circle.

The clinical success of this technique is based on the formation of a thrombus distal to the mycotic lesion at some time after surgery. It is unknown how long an occluding thrombus takes to form. The horse reported by Owen (1974) hemorrhaged on days 7, 8 and 10 after surgical ligation. Consequently, horses treated with this technique continue to be at risk for hemorrhage until the artery thromboses distal to the site of the mycotic lesion. Freeman et al. (Freeman et al. 1994) demonstrated that ligation of the origin of the internal carotid artery in horses does not decrease blood pressure within the artery distal to the ligature over a three-day period. This result further emphasizes the continued risk of hemorrhage in horses treated by proximal ligation alone until adequate thrombus formation has occurred.

Placement of an additional ligature distal to the mycotic lesion to eliminate retrograde flow is usually not possible because the site is difficult to reach surgically and is usually obscured by the blood clot filling the pouch, the mycotic plaque or a submucosal hematoma (McIlwraith 1978; Lane 1989). The surgical approach may also risk iatrogenic nerve damage (Freeman 1992). In one report in which proximal and distal ligation were performed, the horse developed Horner's syndrome due to the inadvertent incorporation of the sympathetic trunk within the ligature (Owen 1974).

Concerns about the continued risk of hemorrhage after proximal ligation alone led to the development of a balloon-tipped catheter technique to occlude the internal carotid artery (Freeman and Donawick 1980b). This procedure involves catheterizing the affected internal carotid artery, just distal to its origin, with a balloon-tipped catheter. The catheter is advanced distally within the artery until the balloon is distal to the site of the mycotic lesion and between the proximal and distal curves of the sigmoid flexure. The balloon is inflated to occlude retrograde flow from the cerebral arterial circle (Figure 8). Normograde flow is occluded by ligation of the internal carotid artery proximal to the site of catheterization. The exposed portion of the catheter is shortened, occluded and buried within the surgical wound. This technique has been reported to be very effective in preventing hemorrhage (Freeman and Donawick 1980a; Caron et al. 1987; Speirs et al. 1995). However, postoperative complications such as moderate to severe inflammation at the surgical wound, draining wounds,

ascending infections and abscess formation were cited. These complications were attributed to the presence of the catheter within the internal carotid artery at the site of the mycotic lesion, leading to infection, or the need to bury the redundant portions of the catheter within the surgical wound, leading to inflammation and foreign body reactions. These complications often necessitate a second surgical procedure to remove the catheter or provide adequate wound drainage (Freeman and Donawick 1980a; Caron et al. 1987; Lane 1989). The balloon-tipped catheter technique has also been used for occlusion of the external carotid and maxillary arteries in cases of guttural pouch mycosis affecting these vessels (Freeman et al. 1989).

Resolution of the mycotic plaque occurs after occlusion of the affected artery (Caron et al. 1987; Speirs et al. 1995). The spontaneous regression of the mycotic plaque after arterial occlusion (without any other therapy) supports the theory put forth by Cook et al. (1968) that the affected artery may be the nutrient source of the fungal infection. It appears that once the nutrient source is eliminated by arterial occlusion, the infection is no longer able to sustain itself and the mycotic plaque regresses without further treatment.

Embolization Techniques in Human Neurovascular Therapy

Permanent intravascular occlusion techniques are routinely used in humans for the treatment of numerous vascular accidents and anomalies, including hemorrhage, congenital vascular malformations, traumatic carotid cavernous fistulas, idiopathic and traumatic aneurysms and preoperative vascular

occlusion of large neoplasms in order to facilitate resection (Serbinenko 1974; Lasjaunias and Berenstein 1985; Dion 1992; Chaloupka and Putman 1995). The first known report of intravascular embolization to be employed in humans was in 1930 (Brooks 1930) and described the insertion of a piece of muscle into the carotid artery to embolize a carotid cavernous fistula. The procedure was improved over time and became more reliable. It was commonly used because it had the special advantage of avoiding intracranial operative procedures. The success of this technique lead to the development and use of artificial devices for intravascular occlusion (Serbinenko 1974; Debrun et al. 1975).

Early devices such as balloon-tipped catheters and silicone balls have evolved into highly advanced devices associated with decreased morbidity. Embolotherapuetic devices can be either general-use or site-specific. Examples of these devices include detachable latex and silicone balloons, expandable microcoils, fillable nylon sacs, gelatin sponges, polyvinyl alcohol foam, liquid adhesives, and occlusive stents (Greenfield 1980; Lasjaunias and Berenstein 1985; Dion 1992; Chaloupka and Putman 1995).

Of the techniques and devices available for vascular occlusion, detachable balloons have been reported to be superior over other embolic materials and devices for occluding large vessels (DeSouza and Reidy 1992; Matsumoto et al. 1992; Chaloupka and Putman 1995). The balloons are placed through introducer systems either directly into the target vessel or into a distant, more easily accessible vessel and “driven” to the target vessel by flow-directed or

coaxial steering systems under fluoroscopic guidance (Greenfield 1980; Scialfa et al. 1983; Lasjaunias and Berenstein 1985; Debrun 1992; Makita et al. 1992). Once positioned appropriately, the balloons are inflated and released, and the carrier and guiding catheters withdrawn. The detached balloon immediately occludes the vessel and a permanent thrombus forms in the occluded vessel.

Detachable balloons offer the distinct advantage of immediate and precise occlusion of large vessels and unlike any other embolization technique, the occlusion is reversible until the balloon is finally detached (White et al. 1980; Matsumoto et al. 1992). Occlusion reversibility offers the opportunity to assess the immediate local and systemic consequences of vascular occlusion at the chosen site. This benefit allows for precise and safe placement of the balloon using radiographic or fluoroscopic guidance before final detachment. Complication rates related to the balloons are low, with most complications associated with the inability to correctly position the balloon when using distant vessel access (DeSouza and Reidy 1992; Makita et al. 1992; Chaloupka and Putman 1995). Studies in swine have shown that if balloons placed in high flow vessels remained inflated more than 10 days, permanent occlusion occurred in >90% of arteries (Kaufman et al. 1979). Kaufman et al. (1979) also showed that if the balloons remained inflated for 3 weeks, permanent occlusion occurred in 100% of arteries.

Detachable Latex Balloons

Detachable latex balloons have several distinct advantages over detachable silicone balloons. Latex balloons are biologically inert, permeable to water, distensible (facilitates insertion of a large diameter balloon, when inflated, through a small access portal, when deflated), available in many shapes and sizes, and have good hysteresis properties (maintain shape and size despite multiple inflations and deflations) (Debrun 1992; Matsumoto et al. 1992). The properties of latex allow the balloons to be filled with hyperosmolar radiopaque solutions without fear of rupture or deflation, unlike silicone, as the osmolarity of the inflation solution has no effect on the long-term inflation of latex balloons (Tomsick 1985; Hawkins and Szaz 1987; Matsumoto et al. 1992). Detachable latex balloons have been shown to remain persistently inflated for weeks to months in a simulated arterial model (Pollak et al. 1993) and in clinical applications (Lasjaunias and Berenstein 1985). Detachable latex balloons have also been used successfully to treat secondary internal carotid artery aneurysm and rupture caused by local infection (Micheli et al. 1989; Hirai et al. 1996). In 2 cases, Hirai et al. (1996) were able to completely occlude the ruptured arteries without residual complications related to the presence of the balloons.

AIMS OF THE STUDY

The accepted methods of treating guttural pouch mycosis have markedly reduced the risk of death due to fatal hemorrhage. However, these techniques are not 100% successful in reducing the risk of hemorrhage or they carry an unacceptable postoperative complication rate. Treatment by proximal ligation alone continues to leave the patient at risk of severe or fatal hemorrhage for some unknown time after the surgical procedure until a complete thrombus forms within the internal carotid artery. The balloon-tipped catheter technique reduces the incidence of postoperative hemorrhage; however, complications related to the procedure are not uncommon, and often necessitate additional therapy or surgical intervention.

The use of balloon-tipped catheters was a rational step in using advanced human medical technology for treating animal patients. Continuing this logical process by using recently described detachable balloons in a similar fashion seems to be the next step. The aims of the study reported here were to:

1. subjectively evaluate the feasibility of placing a detachable balloon within the distal internal carotid artery in the horse,
2. qualitatively evaluate the ability of placing a detachable balloon distally and ligatures proximally to create complete, immediate and permanent occlusion of the internal carotid artery in the horse,

3. quantitatively study the local effects of the balloon on the internal carotid artery and surrounding tissues.

MATERIALS AND METHODS

General

Appropriate balloon size was determined by several measurements and subjective findings. Cross sectional measurements of the distal internal carotid artery at the site of proposed balloon deployment were made in fresh, adult, cadaver specimens. Non-detachable balloons were inflated to various measured diameters within the distal internal carotid artery in additional cadaver specimens. Balloon/vessel wall friction and vessel distention were assessed subjectively by manual traction on the balloons.

Six, healthy, adult horses (5 geldings, 1 mare) were used in this study. Identification numbers and signalment data are given in Appendix 1. After thorough historical evaluation, a complete physical examination, including endoscopic examination of the pharynx, larynx and left and right guttural pouches, was performed on each horse prior to selection for use in the study. Inclusion criteria established were:

1. no history of guttural pouch disease,
2. a normal physical examination, and
3. a normal endoscopic examination of both guttural pouches.

A normal guttural pouch examination was defined as findings of normal mucosal color, the presence of distinctly visible pulses of both the left and right internal and external carotid and maxillary arteries and the absence of obvious

signs of inflammation (redness and edema) within the guttural pouches (Figure 9).

Horses were housed in 12 x 12 foot stalls for at least 7 days prior to and for 30 days following the surgical occlusion of the left internal carotid artery. Horses were fed free choice grass hay and offered water ad lib. Procaine penicillin G (22,000 units/kg intramuscularly BID, Crystacillin® 300 A.S., Solvay, Mendota Heights, MN) and phenylbutazone (2.2 mg/kg intravenously BID, Equi-Phar™ Phenylbutazone Injection 20%, Vedco, St. Joseph, MO) were administered preoperatively and continued postoperatively for a total of 6 doses each.

For the surgical procedure, each horse was sedated with xylazine hydrochloride (0.4 mg/kg intravenously, Rompun®, Miles, Inc., Shawnee, KS) and general anesthesia was induced with guaifenesin (10% guaifenesin in 5% dextrose intravenously, to effect) and ketamine hydrochloride (2 mg/kg intravenously, KetaVed™, Vedco, St. Joseph, MO). After endotracheal intubation, anesthesia was maintained with halothane (Fluothane, Ayerest Laboratories, Inc., New York, NY) in oxygen. Lactated Ringers solution was administered intravenously at 10 ml/kg/hr during the surgical procedure.

The surgical procedures were carried out with routine aseptic techniques. One primary surgeon and two assistants participated in each procedure. Surgical times were recorded and the ease of the technique was evaluated in a subjective manner by the primary surgeon who participated in all surgeries.

Horses were observed for 30 days after the surgery for development of complications. Balloon inflation and position were evaluated postoperatively by radiographic examination on days 2, 5, 10, and 30 after surgery. Postoperative endoscopic examination of the left and right guttural pouches was performed on day 10 to evaluate the internal carotid arteries for color, consistency and presence of a pulse, and to assess the surrounding tissue for signs of inflammation and tissue viability.

Each horse was euthanatized with sodium pentobarbital (0.15 g/kg IV, Fatal Plus®, Vortech Pharmaceuticals, Dearborn, MI) 30 days postoperatively. A complete necropsy was performed on each horse. The left and right guttural pouches were examined grossly for signs of inflammation, including discoloration and thickening of the mucosal lining, and for tissue viability. Both the left and right internal carotid arteries and the cerebral arterial circle, along with portions of the left and right common carotid and external carotid arteries, were removed en bloc and examined grossly for inflammation and presence of a thrombus. Measurements of the distances from the origin of the internal carotid artery to the beginning of the thrombus and from the distal end of the thrombus to the caudal intercarotid artery were taken on the surgically occluded left side.

All tissues were placed in 10% neutral buffered formalin in preparation for histologic processing. Tissue samples were taken at predetermined sites (Figure 10) from both the left and right sides; common carotid artery (3 sites),

external carotid artery (2 sites), internal carotid artery (7 sites; 3 proximal to the balloon, 1 at the level of the balloon, 2 between the balloon and the caudal intercarotid artery, 1 distal to the caudal intercarotid artery), the caudal intercarotid artery (1 site), and the rostral cerebral artery (1 site). Tissue samples were embedded in paraffin, sectioned at 4 μm and stained with hematoxylin and eosin for histologic examination.

Tissue sections were examined and scored in a blinded manner. The presence or absence of a thrombus and stage of thrombus maturity were noted. Each section was scored in a semi-quantitative manner (based on the pathologist's experience) for degree and distribution of inflammation, fibrosis, endothelial proliferation, and vascular necrosis. The scoring system used was based on 0 = normal, 1 = mild, 2 = moderate, 3 = marked, and 4 = severe. Degree of inflammation, fibrosis, endothelial proliferation and vascular necrosis were compared between left and right sides using the McNemar test for paired data (Daniel 1990). Additionally, comparisons of the degree of inflammation between balloon sites and sites which contained a thrombus were made using a Fisher-Irwin Exact test. Results with *P* values less than 0.05 were considered significant.

Surgical Procedure

Each horse was placed in right lateral recumbency with the head extended and a padded roll placed under the parotid region to facilitate the surgical approach. The left parotid region was clipped and prepared for sterile surgery.

An 11 x 14 inch radiograph cassette was centered under the guttural pouch region prior to draping to expedite intraoperative radiographic examination.

A modified hyovertebrotomy approach (Freeman and Donawick 1980a) (Figure 11) was used to expose the proximal portion of the left internal carotid artery. The skin and subcutaneous tissue were incised. The parotid gland was dissected away from the wing of the atlas and reflected craniad. The loose areolar connective tissue beneath the parotid gland was dissected bluntly to expose the origins of the internal carotid and occipital arteries. Digital palpation and limited visualization were used to distinguish the internal carotid artery from the occipital and external carotid arteries at the terminal trifurcation of the common carotid artery. Once identified, the internal carotid artery was isolated by blunt dissection. A Rumel tourniquet composed of umbilical tape and polyethylene tubing was placed just distal (~ 2 cm) to the origin of the internal carotid artery to occlude normograde blood flow and to aid in exteriorization of the artery. A second Rumel tourniquet was placed approximately 3 cm distal to the first but in a fashion so as not to occlude the artery (Figure 12). The second tourniquet was used as an aid for exteriorization and stabilization of the artery. The surgical site was packed with saline-soaked sponges while the balloon delivery system was constructed.

The components of the balloon delivery system are depicted in Figure 13 and Figure 14. The system was constructed as follows. A Tuohy-Borst Adapter (Rotating Y Adapter, Medi-Tech, Natick, MA) was attached to an 8 Fr, 95 cm,

non-tapered, thin-walled guiding catheter (GC 8/95, Laboratoiries Nycomed S.A., Paris, France). A 2 Fr, 135 cm, balloon carrier microcatheter (Mini-Tourquer, CIFN 135, Laboratoiries Nycomed S.A., Paris, France) with stylet was placed through the adapter and guiding catheter. An 8.5 mm diameter, detachable latex balloon (GoldValve Balloon, GVB 17, Laboratoiries Nycomed S.A., Paris, France) (Figure 15) was inflated with 0.5 ml of a radiopaque solution of 1:1 physiologic saline and iothalamate sodium 66.8% (Conray 400, Mallinckrodt Medical, Inc., St. Louis, MO). The carrier microcatheter was primed with the same solution. The balloon was mounted onto the carrier microcatheter and the stylet removed, allowing the balloon to deflate. The carrier microcatheter was withdrawn into the guiding catheter so that the balloon was recessed 2 mm inside the guiding catheter and held in place by tightening the O-ring of the Tuohy-Borst Adapter attached to the end of the guiding catheter.

Vascular access was gained by placement of a distally directed 8 Fr introducer sheath (Pinnacle™ Introducer Sheath, Medi-tech, Natick, MA) between the two tourniquets, 5-10 mm distal to the proximal tourniquet. Several steps were involved in placement of the introducer sheath and are outlined as follows:

1. A 19 ga arterial access needle was inserted into the vessel (Figure 16).
2. A 0.035 inch guide wire was placed through the needle (Figure 17).

3. The needle was withdrawn over the wire and the introducer sheath with dilator in place was advanced over the wire into the vessel (Figure 18).
4. The introducer sheath was advanced 4 cm into the vessel and the dilator and wire were removed (Figure 19).

Retrograde blood flow from the cerebral arterial circle was confirmed by bleed-back through the ancillary fluid port of the introducer sheath. Continuous infusion of heparinized saline (4 U/ml, approximately 3 ml/min.) was then maintained through the introducer sheath and guide catheter. The balloon delivery system was introduced into the internal carotid artery through the flexible diaphragm of the introducer sheath and advanced within the vessel 13 cm or until resistance was met (Figure 20). The balloon was deployed by first advancing the carrier microcatheter 0.5-1.0 cm within the guiding catheter while retracting the guiding catheter 1 cm over the microcatheter (Figure 21). The balloon was then inflated with 0.5 ml of the radiopaque solution (Figure 22). Appropriate positioning and inflation of the balloon was confirmed by a single, lateral, intraoperative radiograph (Figure 23). Complete deployment was accomplished by detachment of the balloon using gentle traction on the carrier microcatheter and guiding catheter simultaneously. These catheters were withdrawn from the introducer sheath and immediate occlusion of the distal internal carotid artery was confirmed by lack of retrograde blood flow through the ancillary fluid port of the introducer sheath. The introducer sheath was then removed and the proximal Rumel tourniquet was replaced with 2 ligatures (0

Prolene®, Ethicon, Somerville, NJ) (Figure 24). Complete occlusion of the internal carotid artery was proven by lack of blood flow though the arterial puncture site. The subcutaneous tissues and skin were closed in routine fashion.

RESULTS

Surgical Procedure

The surgical procedure was technically straight-forward and readily accomplished. The internal carotid artery was correctly identified in all horses. A distinct decrease in surgical time was noted between the first two surgeries and the last 4 surgeries. The mean and median surgical times were 104.3 and 96 minutes respectively. Immediate occlusion of retrograde blood flow from the cerebral arterial circle was achieved after balloon inflation and deployment in all horses, as well as complete occlusion of the internal carotid artery after proximal ligation. Intraoperative complications were not encountered.

Postoperative Evaluation

No complications were noted over the 30 day postoperative observation period in any horse. All balloons remained inflated and in their original position throughout the study period as demonstrated by the sequential postoperative radiographic examinations (Figure 25). During endoscopic examination 10 days postoperatively, the left internal carotid arteries appeared smaller and more yellow-gray when compared to right side and to preoperative observations. No pulses were observed in the occluded arteries. The occluded arteries showed no distention of the distal segment within the guttural pouch. There was no discoloration of the mucosal lining nor any other gross

inflammation or necrosis within the guttural pouches at follow-up endoscopy or at the time of necropsy in any horse.

Gross and Histopathologic Findings

At necropsy, a distinct thrombus was noted within the left internal carotid artery in all horses extending from just distal (mean = 12 mm, median = 12.5 mm) to its origin to just proximal (mean = 7.8 mm, median = 8 mm) to the branching of the caudal intercarotid artery (Figure 26). The distances from the thrombus to the origin and first branch of the internal carotid artery in each horse are listed in Appendix 3. The right arterial tree was grossly normal in all horses.

Presence of a thrombus and degree of inflammation scores for the 14 sampled sites of the left and right arterial trees are presented in Appendices 4 - 10. Maturing to mature, organized thrombi, completely occluding the lumen, were seen histologically in all left internal carotid artery sections proximal to the caudal intercarotid artery (Figure 27). Neither gross nor histologic evidence of thrombi were detected in any of the left common and external carotid arteries or in any of the right common and external carotid arteries, or right internal carotid artery and its branches. The caudal intercarotid artery, left internal carotid artery distal to the caudal intercarotid artery, and the left rostral cerebral artery were grossly and histologically patent in all horses.

The left internal carotid artery at the site of the balloon was thin in all horses but there was no evidence of vascular breakdown seen in any specimen

(Figure 28). Inflammation was seen in 21 of the 168 histologic sections. Microscopically, inflammation was noted in the left internal carotid arteries at sites with thrombi (9 sections) and at balloon sites (4 sections) as well as the left common (2 sections) and external (5 sections) carotid arteries and right common carotid artery (1 section) (Appendix 4). Inflammation was generally mild and was characterized by focal neutrophilic infiltration of the media and adventitia (Figure 29). The degree of inflammation was significantly greater ($P < 0.001$) in the left arterial tree compared to the right arterial tree. There was no difference in degree of inflammation between sites containing thrombi and balloon sites ($P = 0.227$). Vascular necrosis was not seen in any section. Mild fibrosis was seen in 2 sections at balloon sites (Figure 30). Endothelial proliferation was seen in 2 sections from the same horse, 1 site containing a thrombus (mild) and 1 balloon site (marked) (Figure 31). Because of the absence of vascular necrosis and the low incidence of fibrosis and endothelial proliferation, no statistical comparisons were made for these parameters.

DISCUSSION

Familiarity with the balloons and catheter systems was easily mastered by bench tests before the surgical procedures were performed. The surgical procedure was technically straight-forward and readily accomplished within a time judged to be appropriate for the technical degree of the surgical procedure. The distinct decrease in surgical times between the first two and last four surgeries was related to an increased technical mastering of the procedure. The internal carotid artery was correctly identified in all horses. We did not encounter any common origins of the internal carotid and occipital arteries. All balloons were placed without intraoperative complications

Postoperative complications related to either occlusion of the internal carotid artery or presence of the balloons were not observed during the 30 day postoperative observation period. Complications relating to balloon use in human occlusion procedures are most commonly due to the inability to maneuver the balloon to the correct site when using distant vessel access (DeSouza and Reidy 1992; Makita et al. 1992; Chaloupka and Putman 1995). Other complications encountered during human procedures include premature detachment in high-flow situations and thrombosis of non-target arteries. Because the balloon occlusion technique evaluated in this study was performed directly within the target vessel in a zero-flow situation, the occurrence of these balloon-related complications would be unlikely.

The size of the balloon selected for use in this study was based on a combination of measurements and subjective findings. Cross-sectional lumenal measurements of the internal carotid artery were taken at the proposed site of balloon deployment in fresh cadavers. Non-detachable balloons were then inflated to various measured diameters within additional cadaver specimens. Balloon/vessel wall friction and vessel distention were assessed subjectively. Based on these measurements and subjective findings, an 8.5 mm diameter balloon with a volume of 0.5 ml was selected for use in this study.

Immediate occlusion of the internal carotid artery was obtained without compromise of the vessel wall in any horse in the study. This finding validates the techniques used to select the size of the balloon and also indicates that the 8.5 mm balloon would be appropriate for occluding the internal carotid artery of adult horses of most breeds.

The distance the balloons were inserted from the point of vascular access (13 cm or until resistance was met) was based on previously reported findings (Freeman and Donawick 1980a). It was our intention to place the balloons within the proximal bend or between the proximal and distal bends of the sigmoid flexure of the internal carotid artery. This site is beyond the guttural pouch, yet is a safe distance proximal to the cerebral arterial circle. All balloons were found to be located within the proximal bend of the sigmoid flexure at necropsy, thus further validating the reported distance for balloon insertion to occlude the distal internal carotid artery.

In this study, immediate occlusion of the distal internal carotid artery was apparent by lack of retrograde blood flow from the cerebral arterial circle in all horses after balloon deployment. Immediate occlusion of the internal carotid artery was accomplished without residual presence of a catheter within the lumen of the internal carotid artery or buried in the subcutaneous tissue. These findings suggest that the complications associated with ligation alone or the balloon-tipped catheter technique will be eliminated using the described technique of internal carotid artery occlusion.

All horses recovered without incident and showed no untoward effects attributable to the surgical procedure. No horses showed neurological defects which may have indicated compromise of cerebral circulation. None of the balloons were visible during follow-up endoscopic examination of the guttural pouch or during gross examination of the guttural pouches at necropsy, indicating that placement was in the desired location, distal to the site of a typical fungal plaque affecting the internal carotid artery. Sequential radiographic examinations showed all balloons to have remained inflated for 30 days with no balloon migration occurring.

At necropsy, thrombi were present in all surgically occluded internal carotid arteries. The thrombi did not extend into either the common carotid artery or the cerebral arterial circle.

The degree of inflammation in the left arterial tree was significantly greater than in the right arterial tree. The overall degree of inflammation was generally

mild and was comparable to previously reported findings at sites of thrombi in horses, (Freeman and Donawick 1980b) rats, (Quisling et al. 1985) and swine (Kaufman et al. 1979). The changes at the balloon sites appear to be less severe than previously reported for balloon-tipped catheter sites in horses (Freeman and Donawick 1980b). We consider the inflammatory changes, associated with the thrombi and latex balloons, observed in this study to be of no clinical significance. With the mild degree of inflammation and lack of complications seen in our study and the successful use of latex balloons in humans, we believe that long-term placement of latex balloons in horses will not cause untoward effects.

The study described was successful in answering the aims set forth at the onset of the project. The proposed technique is feasible in horses; placement of detachable balloons distally and ligatures proximally create immediate, complete and permanent occlusion of the internal carotid artery; and the local effects of the latex balloons are negligible. On the basis of this study, we believe occlusion of the internal carotid artery with a detachable latex balloon distally and ligatures proximally may have clinical application for the treatment of horses with guttural pouch mycosis and associated hemorrhage of the internal carotid artery. This technique needs to be evaluated in clinical cases to ultimately determine its efficacy. A modification of this procedure may also prove useful for occlusion of the external carotid and maxillary arteries in cases of guttural pouch mycosis affecting these vessels. Investigation of fluoroscopic

guided placement of balloons via the common carotid artery to treat horses with multiple affected arteries may also be warranted.

As of the writing of this thesis, we have used the described technique to treat two clinical cases of guttural pouch mycosis.

Case I

A five year-old, Thoroughbred gelding presented for severe left-sided epistaxis. A history of multiple episodes of unilateral, left sided epistaxis over the previous 3 weeks was established by the owner. Endoscopic examination revealed a blood coagulum at the entrance to the left guttural pouch. A large, fresh blood clot filled the entire left guttural pouch. Although a mycotic plaque had not been visualized, it was decided between the clinicians and owner to occlude the left internal carotid artery using the described technique based on the history and clinical findings. The technique was modified to use fluoroscopic guided balloon placement. After distal balloon placement, an aberrant vessel arising between the origin of the internal carotid artery and the suspected site of the lesion was identified. A second balloon was placed under fluoroscopic guidance between the aberrant vessel and the suspected lesion site. No intraoperative or postoperative complications were noted. Postoperative endoscopy confirmed the presence of a mycotic plaque over the internal carotid artery in the caudo-dorsal aspect of the left guttural pouch. Postoperative radiographs taken the day after surgery and over the next five

months showed the balloons to have remained inflated in their original sites. Follow-up endoscopy demonstrated resolution of the lesion without further treatment. At one year follow-up, the horse had no further bleeding, has shown no complications and has resumed competitive endeavors.

Case II

A four year-old, American Saddlebred mare presented for bilateral nasal discharge and coughing while eating. Physical examination revealed feed material present in the nares and dysphagia when eating and drinking. Endoscopic examination revealed food material within the nasopharynx and grade IV right laryngeal hemiplegia. Mild generalized pharyngeal collapse and paresis were also noted. A mycotic plaque affecting the caudo-dorsal wall of the guttural pouch adjacent to the internal carotid artery was identified during endoscopic examination of the right guttural pouch. Although there was no history of epistaxis, the owner opted for surgical occlusion of the internal carotid artery to prevent hemorrhage and to treat the lesion. A normal arterial tree was identified by angiography during the surgical procedure and one balloon was placed distal to the lesion and the origin of the artery was ligated. Correct balloon placement was confirmed by intraoperative radiography. Postoperative radiographs demonstrated the balloon to be inflated and in the original position. No intraoperative or postoperative complications were noted. On follow-up examination 6 weeks after surgery, the mycotic plaque had completely

resolved. Radiographically, the balloon was still inflated and had not migrated. No hemorrhage was ever detected and a mild improvement in the dysphagia was noted. The owner was happy with the outcome at this point. However, a seven month follow-up revealed the horse had died six months postoperative due to aspiration pneumonia which was probably related to the unresolved dysphagia.

The successful use of detachable latex balloons distally and ligatures proximally in preventing fatal hemorrhage from the internal carotid artery and subsequent resolution of the mycotic plaque in these two clinical cases suggests that this method will be safe and effective in other clinical cases. Further evaluation is still warranted however, to completely endorse the described technique.

LITERATURE CITED

Baker MA, Chapman LW: Rapid brain cooling in exercising dogs. Science 195:781-783, 1977

Baptiste K, Grandage J, Johnson K: Is the guttural pouch of the horse a brain-cooling device? J Anat 183:174, 1993

Brandt JF: Bericht uber eine abhandlung, untersuchung der gattung hyrax in anotomischer und verwandtschaftlicher beziehung. Bull Acad Imp Sci (St Petersburg) 5:508-510, 1863

Brooks B: The treatment of traumatic arteriovenous fistula. South Med J 23:100-106, 1930

Buer AW: Über luftsackmykose beim pferd. Skand VetTidskr 32:593-609, 1942

Caron JP, Fretz PB, Bailey JV, et al.: Balloon-tipped catheter arterial occlusion for prevention of hemorrhage caused by guttural pouch mycosis: 13 cases (1982-1985). J Am Vet Med Assoc 191:345-349, 1987

Chaloupka JC, Putman CM: Endovascular therapy for surgical diseases of the cranial base. Clin Plast Surg 22:417-450, 1995

Church S, Wyn-Jones G, Park AH, Ritchie HE: Treatment of guttural pouch mycosis. Equine Vet J 18:362-365, 1986

Cook WR: Observations on the aetiology of epistaxis and cranial nerve paralysis in the horse. Vet Rec 78:396-406, 1966

Cook WR: The clinical features of guttural pouch mycosis in the horse. Vet Rec 83:336-345, 1968

Cook WR, Campbell RSF, Dawson C: The pathology and aetiology of guttural pouch mycosis in the horse. Vet Rec 83:422-428, 1968

Daniel WW: Applied Nonparametric Statistics (ed 2). Boston, PWS-KENT Publishing Company, 1990, pp 163-168

Debrun G: Management of traumatic carotid-cavernous fistulas, in F. Viñuela, V. V. Halbach and J. Dion (eds): Interventional Neuroradiology: Endovascular Therapy of the Central Nervous System. New York, Raven Press, 1992, pp 107-112

Debrun G, Lacour P, Caron J, et al.: Experimental approach to the treatment of carotid cavernous fistulas with an inflatable and isolated balloon. Neuroradiology 9:9-12, 1975

DeSouza NM, Reidy JF: Embolization with detachable balloons - applications outside the head. Clin Radiol 46:170-175, 1992

Dion JE: Principles and methodology, in F. Viñuela, V. V. Halbach and J. Dion (eds): Interventional Neuroradiology: Endovascular Therapy of the Central Nervous System. New York, Raven Press, 1992, pp 1-16

Dixon PM, Rowlands AC: Atlanto-occipital joint infection associated with guttural pouch mycosis in a horse. Equine Vet J 13:260-262, 1981

Dyce KM, Sack WO, Wensing CJG: Textbook of Veterinary Anatomy (ed 2). Philadelphia, W.B. Saunders Company, 1996, pp 501-504

Fish PA: The exchange of air in the eustachian or guttural pouches of the horse. Am J Physiol 27:229-232, 1910

Freeman DE: Guttural pouches, in J. Beech (ed): Equine Respiratory Disorders. Philadelphia, PA, Lea and Febiger, 1991, pp 305-330

Freeman DE: Guttural pouch, in J. Auer (ed): Equine Surgery. Philadelphia, PA, W. B. Saunders Company, 1992, pp 480-488

Freeman DE, Donawick WJ: Occlusion of the internal carotid artery in the horse by means of a balloon-tipped catheter: clinical use of a method to prevent epistaxis caused by guttural pouch mycosis. J Am Vet Med Assoc 176:236-240, 1980a

Freeman DE, Donawick WJ: Occlusion of the internal carotid artery in the horse by means of a balloon-tipped catheter: evaluation of a method designed to prevent epistaxis caused by guttural pouch mycosis. J Am Vet Med Assoc 176:232-235, 1980b

Freeman DE, Donawick WJ, Klein LV: Effect of ligation on internal carotid artery blood pressure in horses. Vet Surg 23:250-256, 1994

Freeman DE, Ross MW, Donawick WJ, Hamir AN: Occlusion of the external carotid and maxillary arteries in the horse to prevent hemorrhage from guttural pouch mycosis. Vet Surg 18:39-47, 1989

Greenfield AJ: Transcatheter vessel occlusion: selection of methods and materials. Cardiovasc Intervent Radiol 3:222-228, 1980

Greet RC: Outcome of treatment in 35 cases of guttural pouch mycosis. Equine Vet J 19:483-487, 1987

Hatziolos BC, Sass B, Albert TF, Stevenson MC: Ocular changes in a horse with gutturomycosis. J Am Vet Med Assoc 167:51-54, 1975

Hawkins TD, Szaz KF: The permeability of detachable latex rubber balloons, an in vitro study. Invest Radiol 22:969-972, 1987

Higashida RT, Halbach VV, Hieshima GB: Endovascular therapy of intracranial aneurysms, in F. Viñuela, V. V. Halbach and J. Dion (eds): Interventional Neuroradiology: Endovascular Therapy of the Central Nervous System. New York, Raven Press, 1992, pp 51-62

Hilbert BJ, Huxtable CR, Brighton AJ: Erosion of the internal carotid artery and cranial nerve damage caused by guttural pouch mycosis in a horse. Aust Vet J 57:346-347, 1981

Hinchcliffe R, Pye A: Variations in the middle ear of the mammalia. J Zool 157:277-288, 1969

Hirai T, Korogi Y, Sakamoto Y, et al.: Emergency balloon embolization for carotid artery rupture secondary to postoperative infection. Cardiovasc Intervent Radiol 19:50-52, 1996

Hutyra F, Marek J, Manninger R: Special Pathology and Therapeutics of the Diseases of Domestic Animals (ed 5th). London, BalléireTindall and Cox, 1949

Jacobs KA, Fretz PB: Fistula between the guttural pouches and the dorsal pharyngeal recess as a sequela to guttural pouch mycosis in the horse. Can Vet J 23:117-118, 1982

Johnson JH, Merriam JG, Attleberger M: A case of guttural pouch mycosis caused by *Aspergilus nidulans*. VM/SAC 68:771-774, 1973

Kaufman SL, Strandberg JD, Barth KH, et al.: Therapeutic embolization with detachable silicone balloons: long-term effects in swine. Invest Radiol 14:156-161, 1979

Khamas WA, Ghoshal NG: Blood supply to the nasal cavity of sheep (*Ovis aries*) and its significance to brain temperature regulation. Anat Anz 151:14-28, 1982

Kipar A, Frese K: Hypogolossal neuritis with associated lingual hemiplegia secondary to guttural pouch mycosis. Vet Pathol 30:574-576, 1993

Lane JG: The management of guttural pouch mycosis. Equine Vet J 21:321-324, 1989

Lasjaunias P, Berenstein A: Endovascular Treatment of Craniofacial Lesions, in (eds): Surgical Neuroangiography, vol 2. Berlin-Heidelberg, Springer-Verlag, 1985

Lingard DR, Gosser HS, Monfort TN: Acute epistaxis associated with guttural pouch mycosis in two horses. J Am Vet Med Assoc 164:1038-1040, 1974

Lownie SP, Duckwiler GR, Fox AJ, Drake CG: Endovascular therapy of nongalenic cerebral arteriovenous fistulas, in F. Viñuela, V. V. Halbach and J. Dion (eds): Interventional Neuroradiology: Endovascular Therapy of the Central Nervous System. New York, Raven Press, 1992, pp 87-106

Makita K, Furui S, Tsuchiya K, et al.: Guide-wire directed detachable balloon: clinical application in treatment of varicoceles. Radiology 183:575-577, 1992

Matsumoto AH, Selby JB Jr, Tegtmeyer CJ: Detachable balloons as peripheral vascular embolic agents. Semin Interv Radiol 9:62-71, 1992

McConaghy FF, Hales JR, Rose RJ, Hodgson DR: Selective brain cooling in the horse during exercise and environmental heat stress. J Appl Physiol 79:1849-1854, 1995

McIlwraith CW: Surgical treatment of acute epistaxis associated with guttural pouch mycosis. VM/SAC 73:67-69, 1978

Micheli F, Schteinschnaider A, Plaghos LL, et al.: Bacterial cavernous sinus aneurysm treated by detachable balloon technique. Stroke 20:1751-1754, 1989

Nanda BS: Blood supply to the brain, in R. Getty (ed): Sisson and Grossman's The Anatomy of the Domestic Animals (ed 5). Philadelphia, PA, W.B. Saunders Company, 1975, pp 578-584

Nation PN: Epistaxis of guttural pouch origin in horses: pathology of three cases. Can Vet J 19:194-197, 1978

Owen R ap R: Epistaxis prevented by ligation of the internal carotid artery in the guttural pouch. Equine Vet J 6:143-149, 1974

Owen R ap R, McKelvey WAC: Ligation of the internal carotid artery to prevent epistaxis due to guttural pouch mycosis. Vet Rec 104:100-101, 1979

Pollak JS, Lee GK, White RI Jr, Dormandy B: Comparison of the mechanical properties of detachable balloons for embolotherapy. J Vasc Interv Radiol 4:91-95, 1993

Quisling RG, Mickle JP, Ballinger WJ: Latex vascular occlusion balloons: histopathologic evaluation in a high-flow aortocaval fistula model. AJNR 6:583-587, 1985

Rawlinson RJ, Jones RT: Guttural pouch mycosis in two horses. Aust Vet J 54:135-138, 1978

Scialfa G, Valsecchi F, Scotti G: Treatment of vascular lesions with balloon catheters. Am J Neuroradiol 4:395-398, 1983

Serbinenko FA: Balloon catheterization and occlusion of major cerebral vessels. J Neurosurg 41:125-145, 1974

Sisson S: The ear, in R. Getty (ed): Sisson and Grossman's The Anatomy of the Domestic Animals (ed 5). Philadelphia, PA, W.B. Saunders Company, 1975, pp 723-725

Smith KM, Barber SM: Guttural pouch hemorrhage associated with lesions of the maxillary artery in two horses. Can Vet J 25:239-242, 1984

Speirs VC, Harrison IW, van Veenendaal JC, et al.: Is specific antifungal therapy necessary for the treatment of guttural pouch mycosis in horses? Equine Vet J 27:151-152, 1995

Tomsick TA: Osmotic effects upon long term inflation of latex detachable balloons. Neurosurgery 17:952-954, 1985

Turner HN: Contributions to anatomy of the tapir. Proc Zool Soc (London), 102-106, 1850

Valdivieso D: Morphology of the basisphenoid pits and related structures of the bat *Otomops martiensseni* . Toronto, Royal Ontario Museum, 1979

Wagner PC, Miller RA, Gallina AM, Grant BD: Mycotic encephalitis associated with a guttural pouch mycosis. J Equine Med Surg 2:355-359, 1978

Walmsley JP: A case of atlanto-occipital arthropathy following guttural pouch mycosis in a horse. The use of radioisotope bone scanning as an aid to diagnosis. Equine Vet J 20:219-220, 1988

White RI Jr, Barth KH, Kaufman SL, et al.: Therapeutic embolization with detachable balloons. Cardiovasc Intervent Radiol 3:229-241, 1980

FIGURES

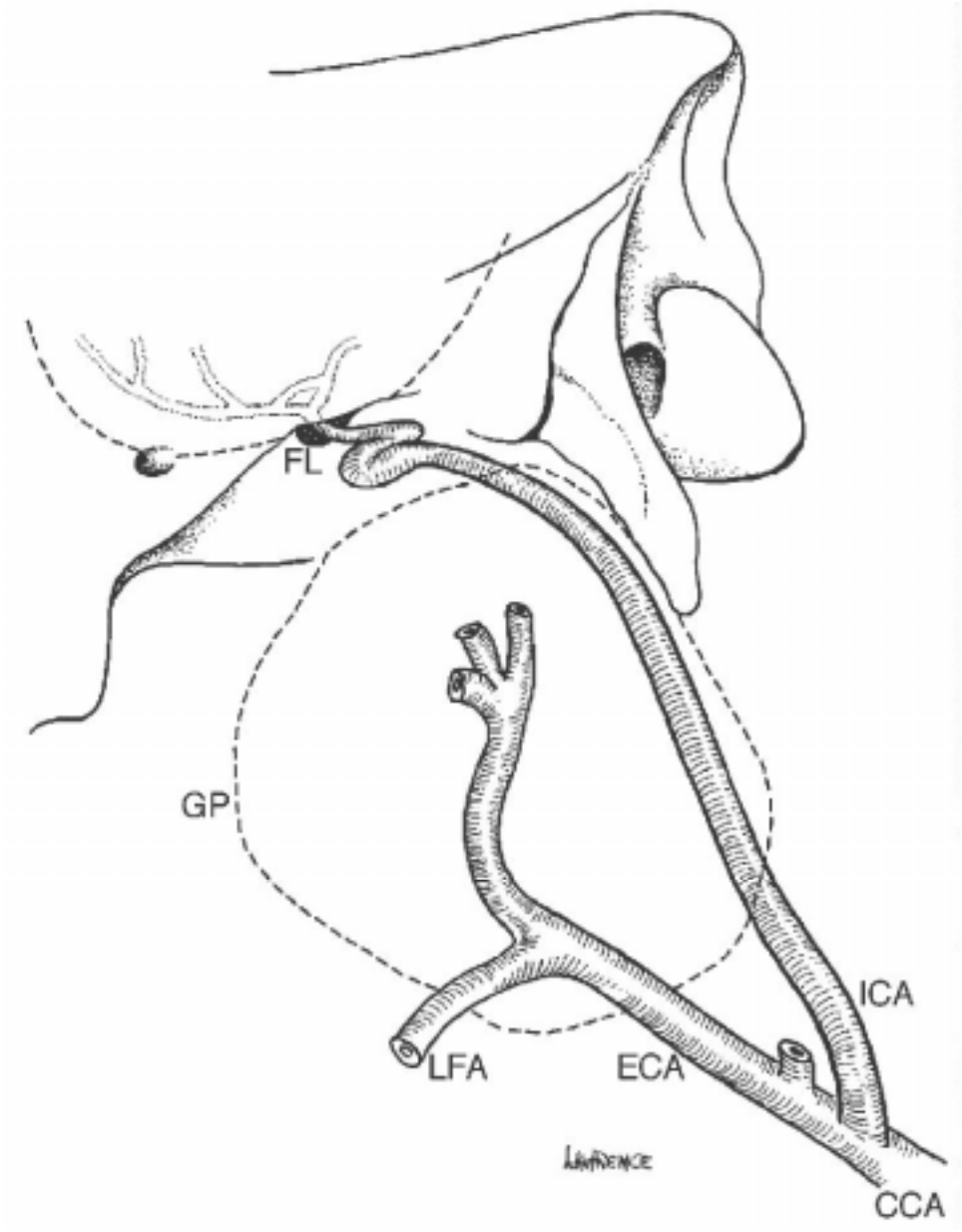

Figure 1. The internal carotid artery. The internal carotid artery is the first of the three terminating branches of the common carotid artery. It enters the calvarium at the foramen lacerum. CCA = common carotid artery, ICA = internal carotid artery, ECA = external carotid artery, LF = linguofacial artery, FL = foramen lacerum, GP = guttural pouch outline.

Back

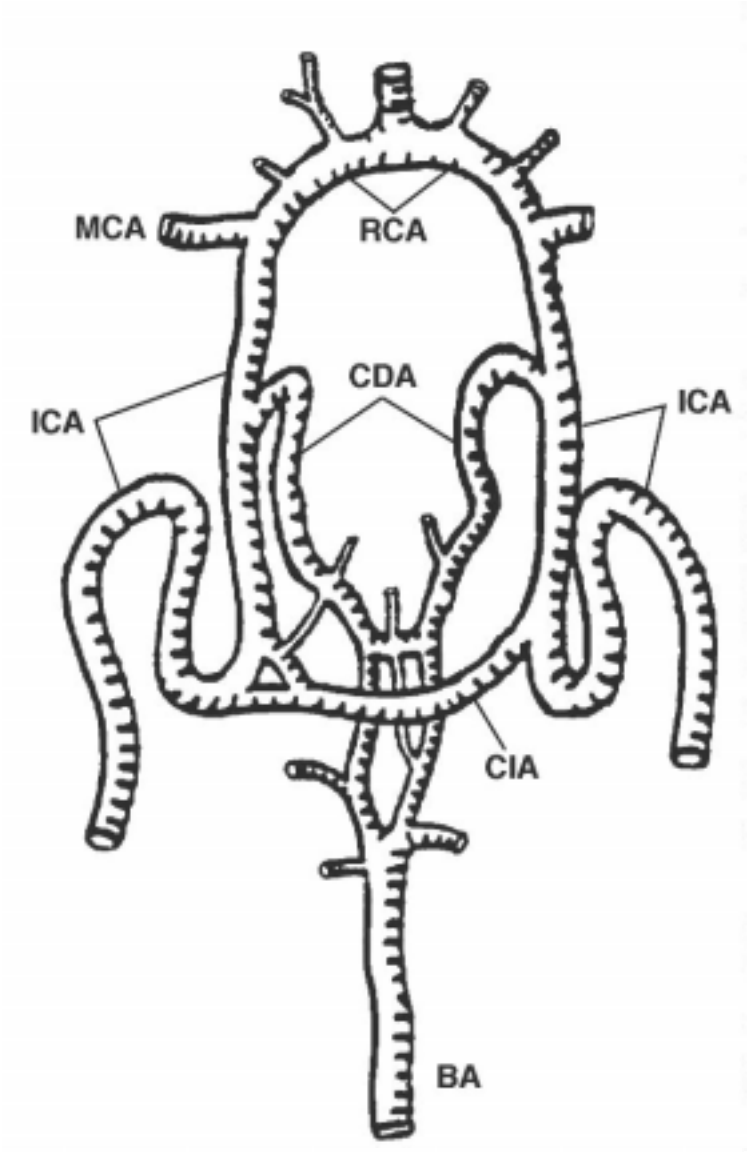

Figure 2. Cerebral arterial circle. Ventral view of the cerebral arterial circle. ICA = internal carotid artery, CIA = caudal intercarotid artery, CDA = caudal communicating artery, MCA = middle cerebral artery, RCA = rostral cerebral artery, BA = basilar artery.

Back

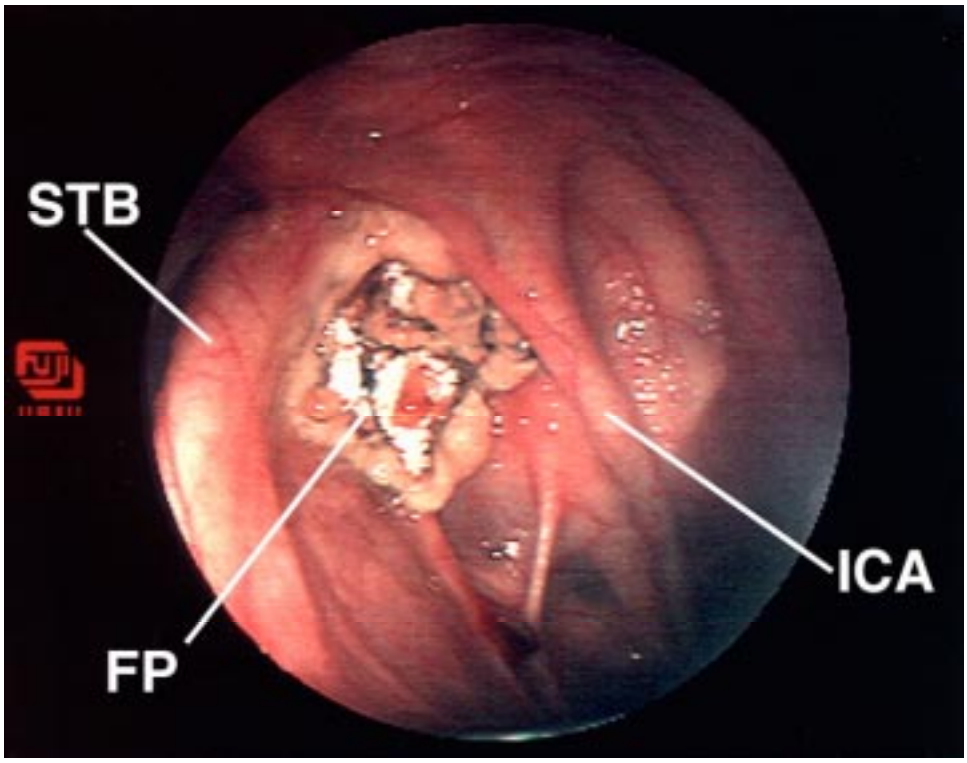

Figure 3. Fungal plaque. Endoscopic view of a mycotic plaque affecting the caudodorsal aspect of the medial compartment of the guttural pouch. STB = stylohyoid bone, FP = fungal plaque, ICA = internal carotid artery.

Back

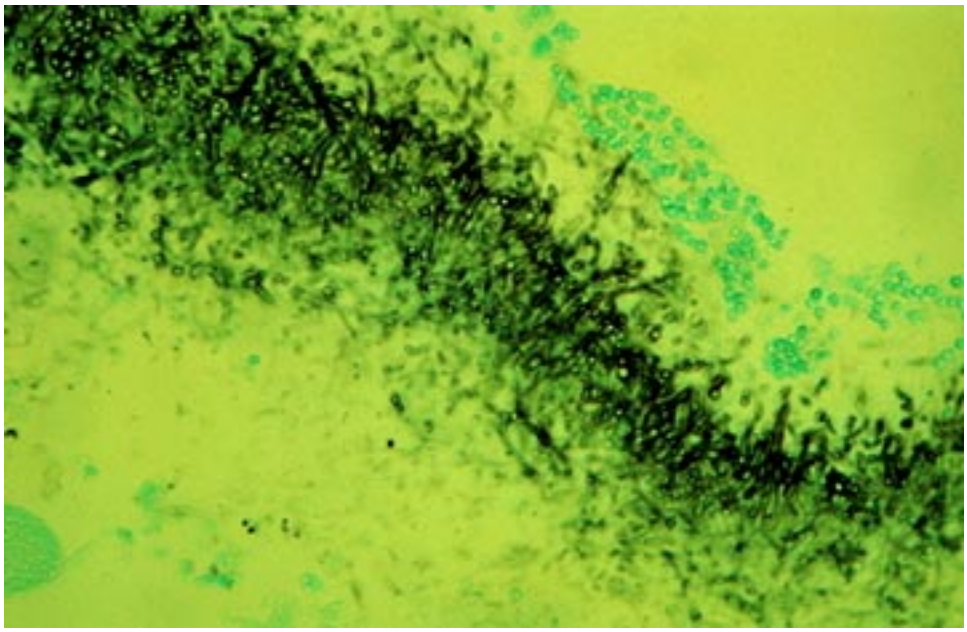

Figure 4. Mycotic plaque. Histologic appearance of a mycotic plaque. The fungal mycelia are easily observed using Gomori Methenamine Silver stain (original magnification = 25x). Back

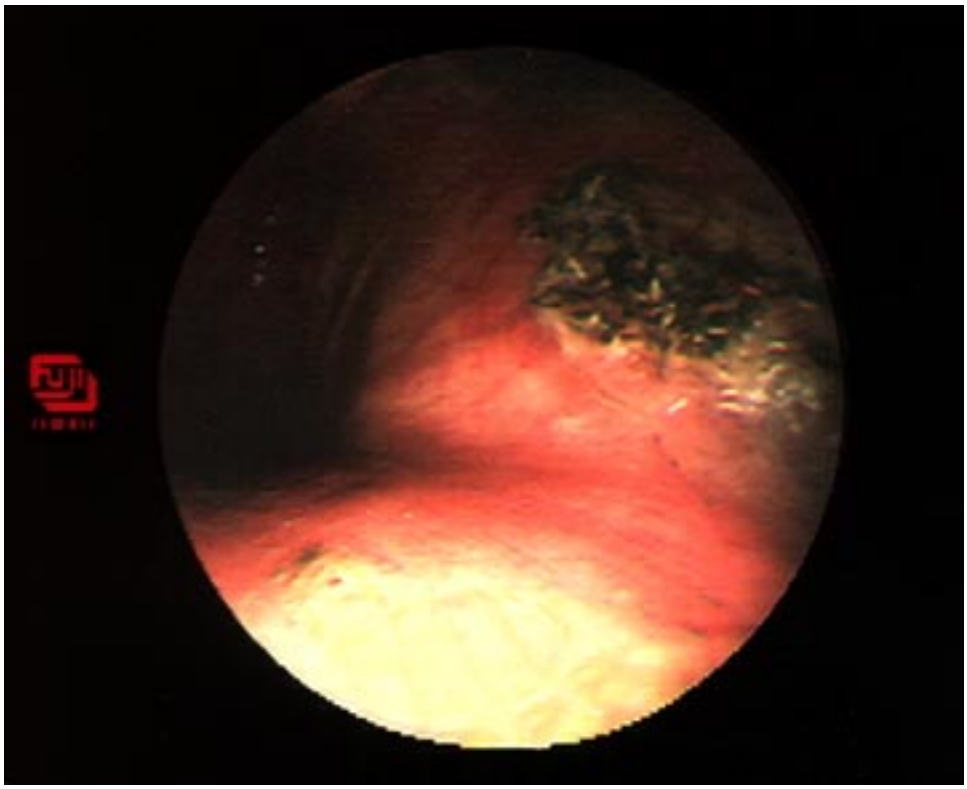

Figure 5. Dysphagia. Endoscopic view of the floor and lateral wall of the nasopharynx of a horse with dysphagia secondary to guttural pouch mycosis. Saliva and ingesta are noted on the floor and wall.

Back

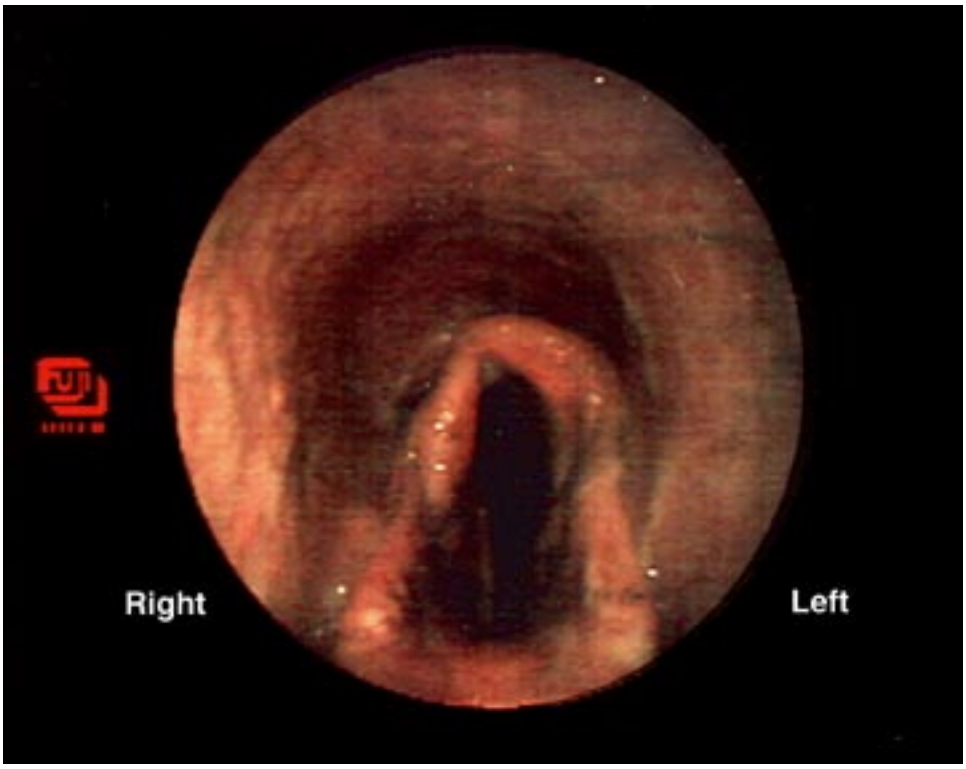

Figure 6. Laryngeal hemiplegia. Endoscopic view of the larynx of a horse with right laryngeal hemiplegia secondary to guttural pouch mycosis. The right arytenoid cartilage has “fallen” inward and did not move during observation.

Back

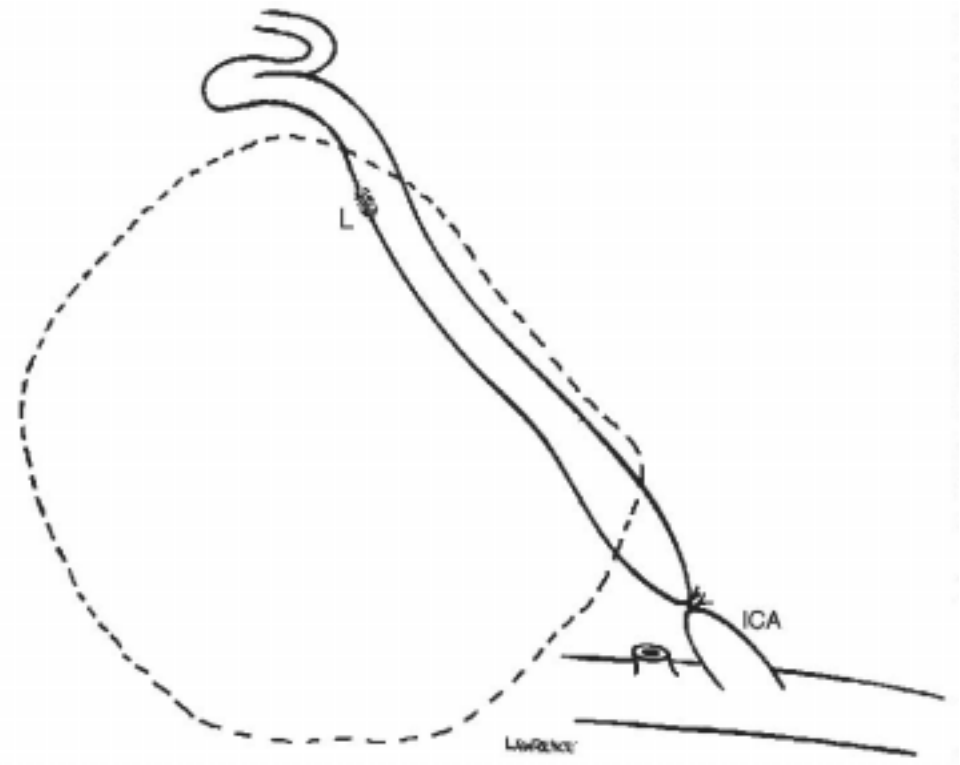

Figure 7. Proximal ligation. Illustration demonstrating simple ligation of the origin of the internal carotid artery. L = vascular lesion, ICA = internal carotid artery.

Back

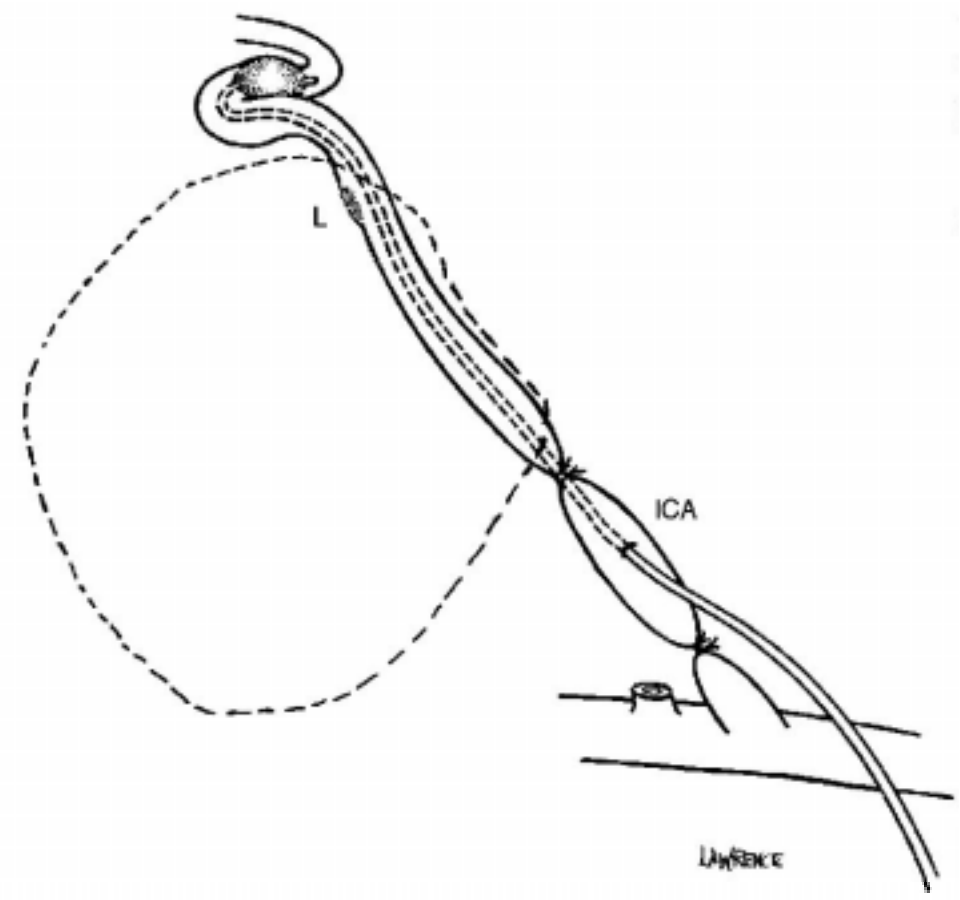

Figure 8. Balloon-tipped catheter. Illustration demonstrating placement of a balloon-tipped catheter. L = vascular lesion, ICA = internal carotid artery.

Back

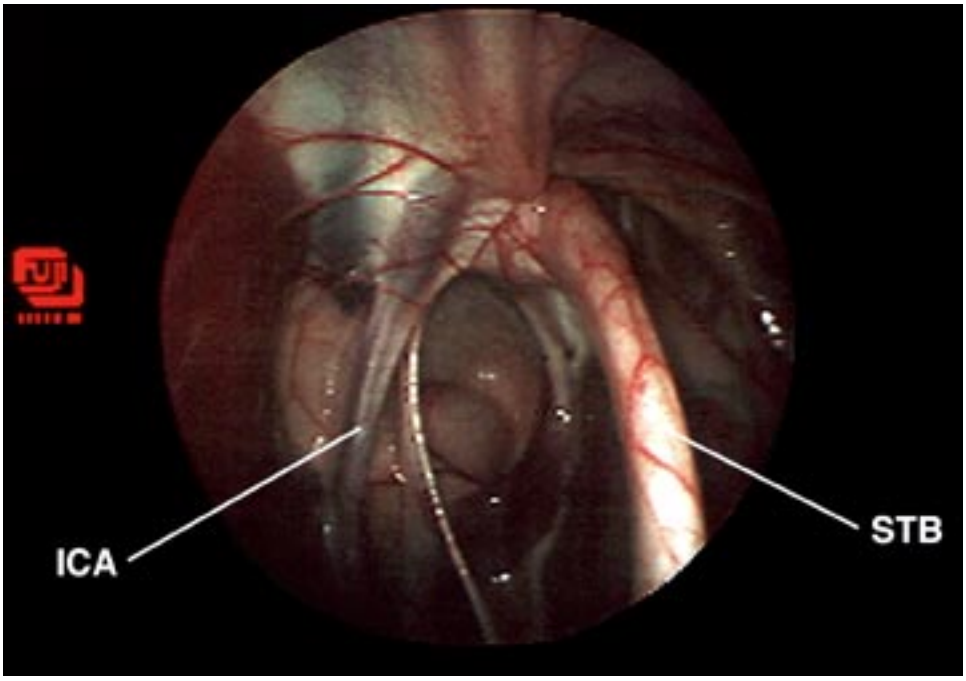

Figure 9. Normal guttural pouch. Endoscopic view of the caudodorsal aspect of the medial compartment of the left guttural pouch in a normal horse. The lining is transparent and the underlying structures are easily observed. ICA = internal carotid artery, STB = stylohyoid bone.

Back

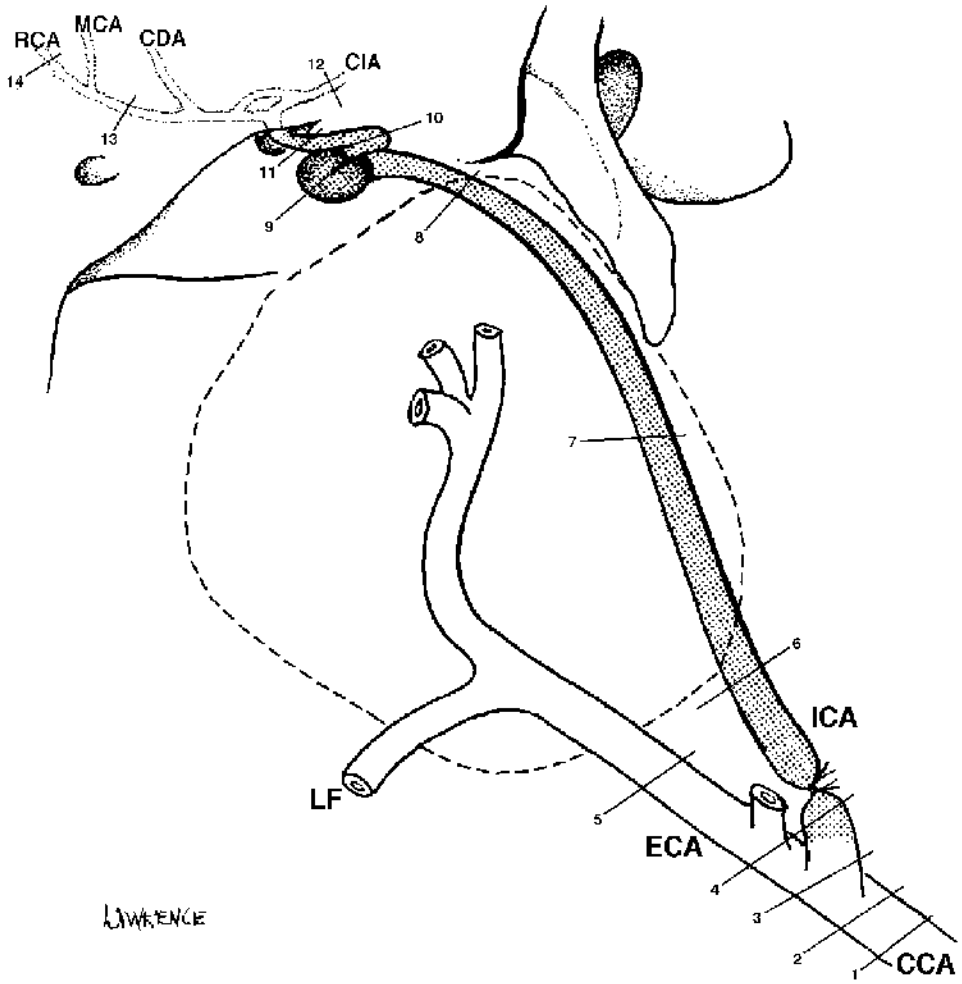

Figure 10. Sites of histologic examination. Illustration demonstrating the 14 sites of histologic examination of both the left and right arterial trees in each horse. CCA = common carotid artery, ECA = external carotid artery, ICA = internal carotid artery, LF = linguofacial artery, CIA = caudal intercarotid artery, CDA = caudal communicating artery, MCA = middle cerebral artery, RCA = rostral cerebral artery.

Back

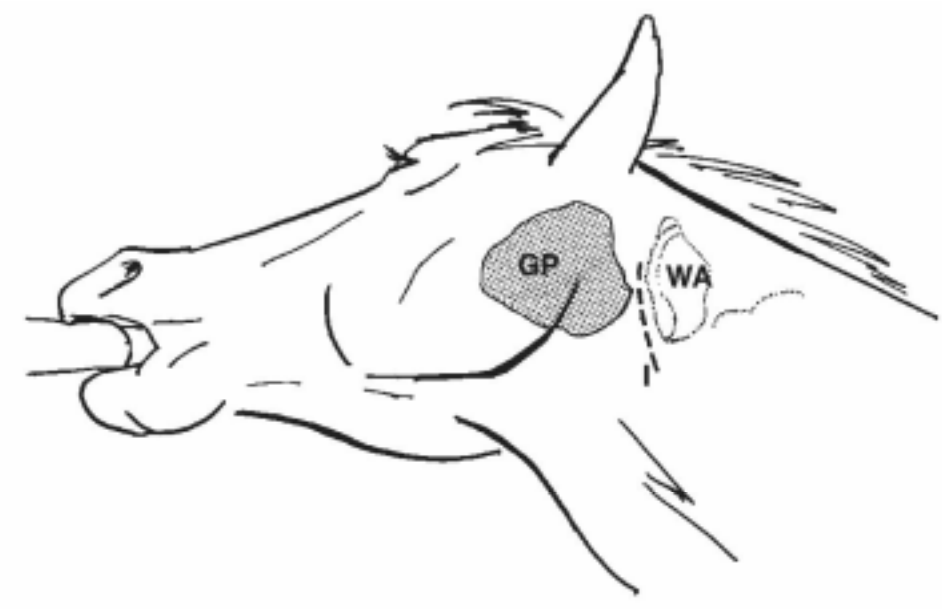

Figure 11. Surgical approach. Illustration representing the positioning of each horse in right lateral recumbency and the site of the incision for a modified hyovertebrotomy approach to the origin of the internal carotid artery. GP = Guttural Pouch, I = incision, WA = wing of the atlas.

Back

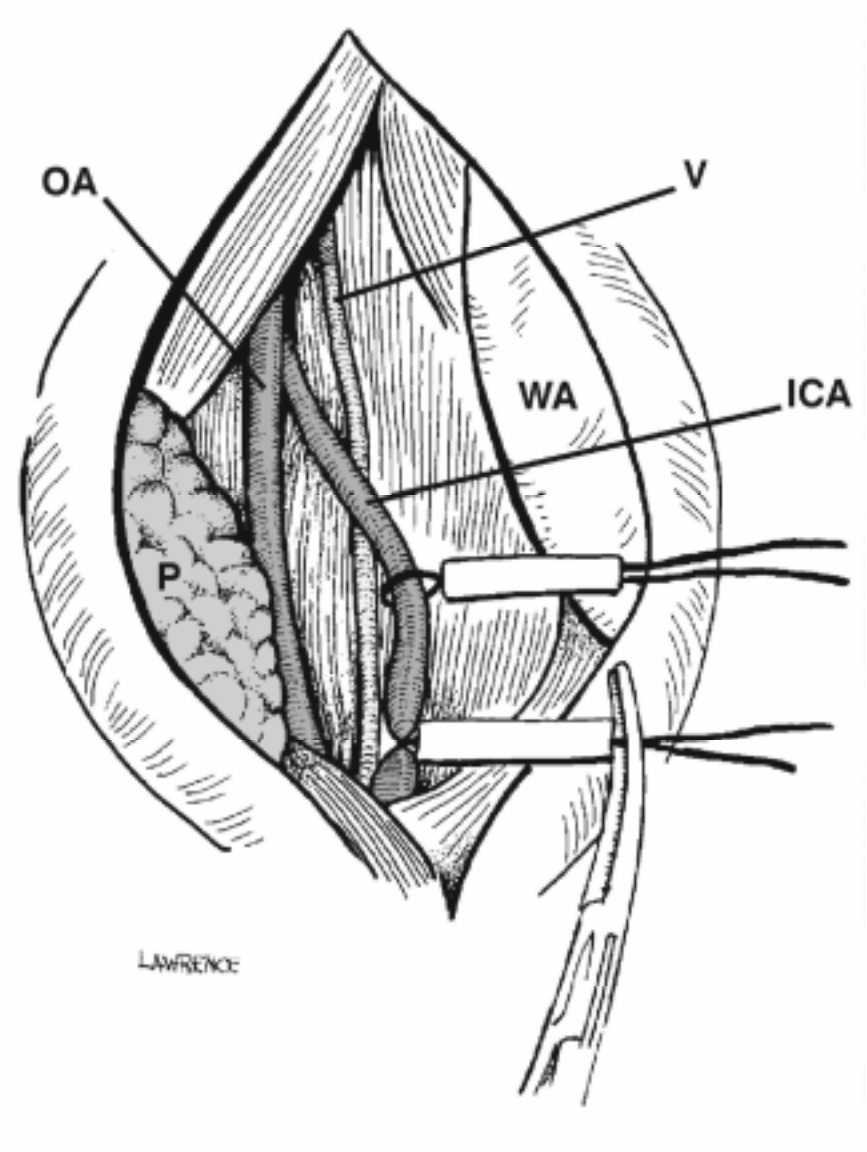

Figure 12. Exposure of the internal carotid artery. Illustration of the surgical dissection exposing the internal carotid artery. Two Rumel tourniquets are in place. ICA = internal carotid artery, OA = occipital artery, V = vagus, P = parotid gland, WA = wing of the atlas.

Back

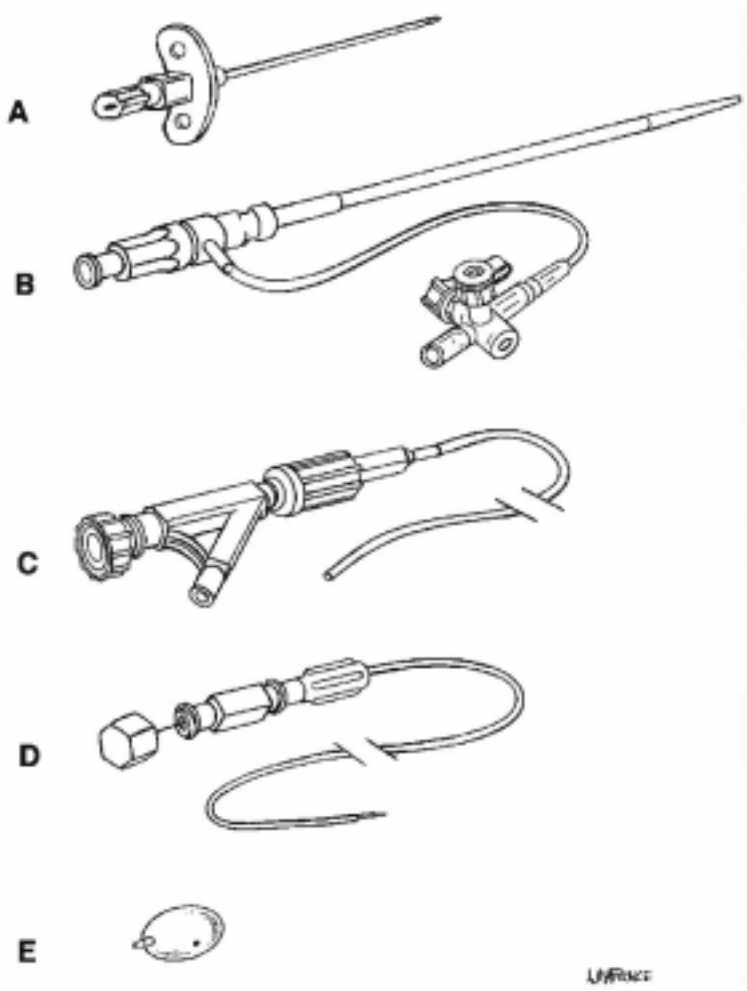

Figure 13. Vascular access and balloon delivery system. Illustration demonstrating the components used for vascular access and balloon delivery. A = 19 ga arterial access cannula, B = 8 Fr introducer sheath with dilator, C = 8 Fr guide catheter with Tuohy-Borst adapter, D = 2 Fr carrier catheter with stylet, E = inflated 8.5 mm detachable latex balloon.

Back

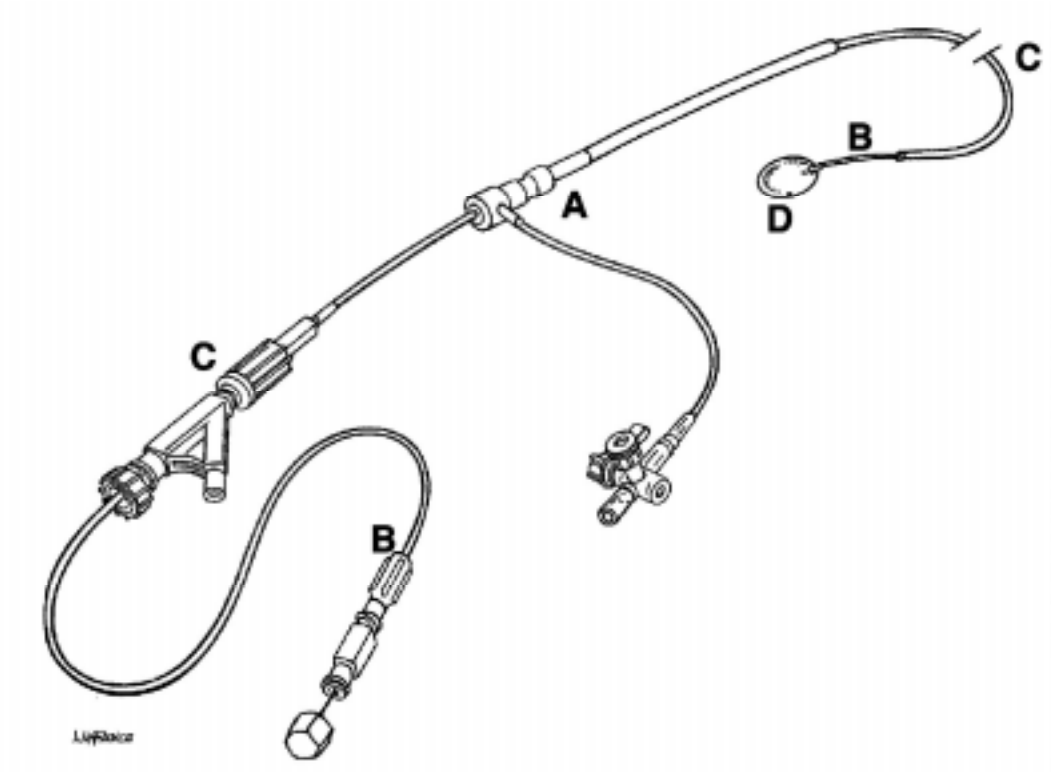

Figure 14. Assembled vascular access and balloon delivery system. Illustration of components of the vascular access and balloon delivery system as it would appear at the time of balloon deployment. A = 8 Fr introducer sheath, B = 8 Fr guide catheter with Tuohy-Borst adapter, C = 2 Fr carrier catheter, D = inflated 8.5 mm detachable latex balloon.

Back

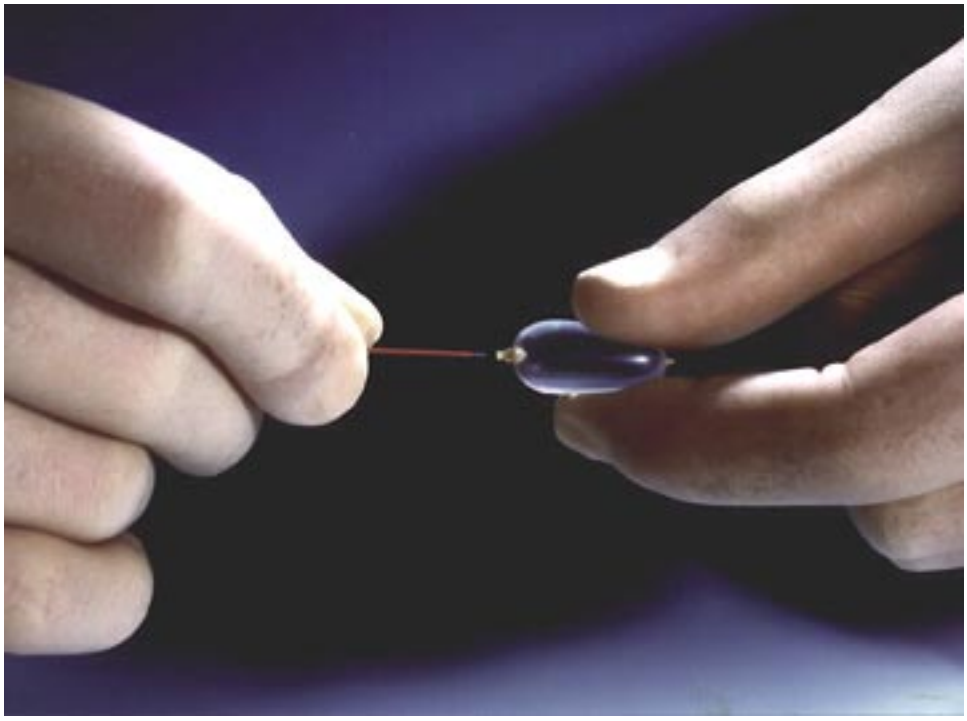

Figure 15. Detachable latex balloon. Photograph of an 8.5 mm detachable, latex balloon being mounted onto a 2 Fr carrier catheter.

Back

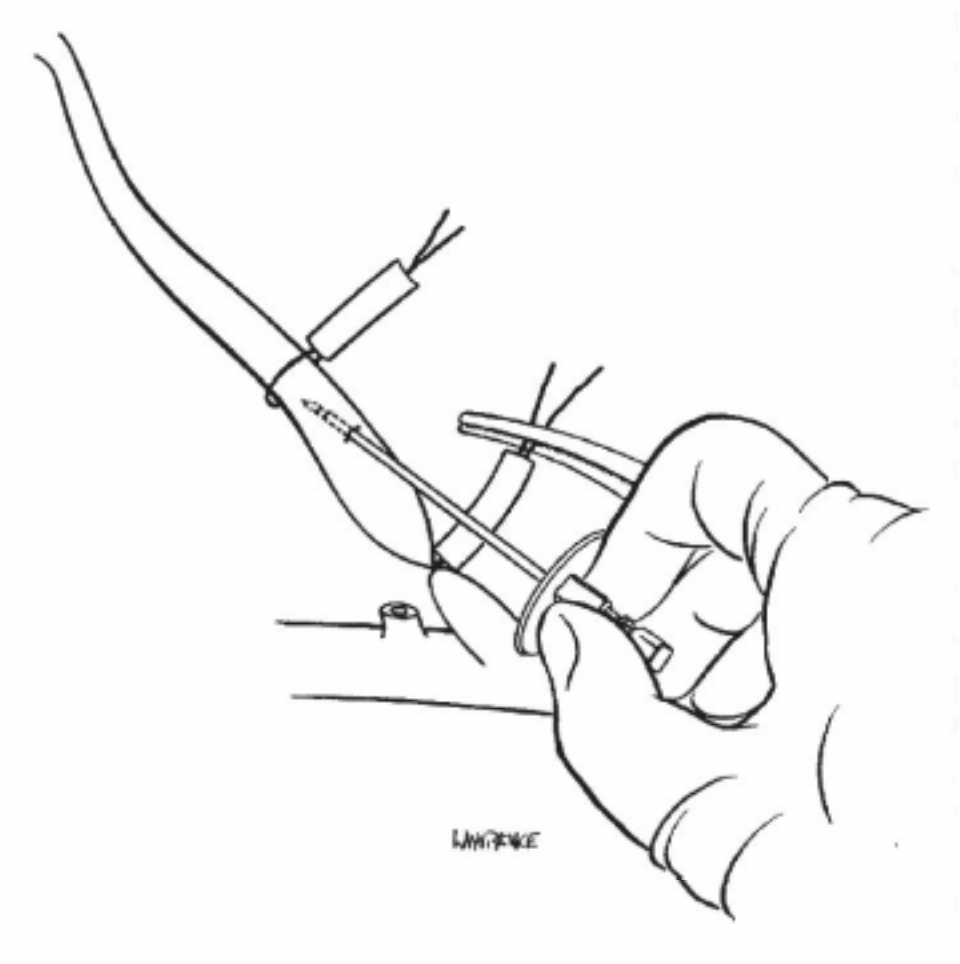

Figure 16. Placement of access cannula. Illustration demonstrating placement of the arterial access cannula between the 2 Rumel tourniquets.

Back

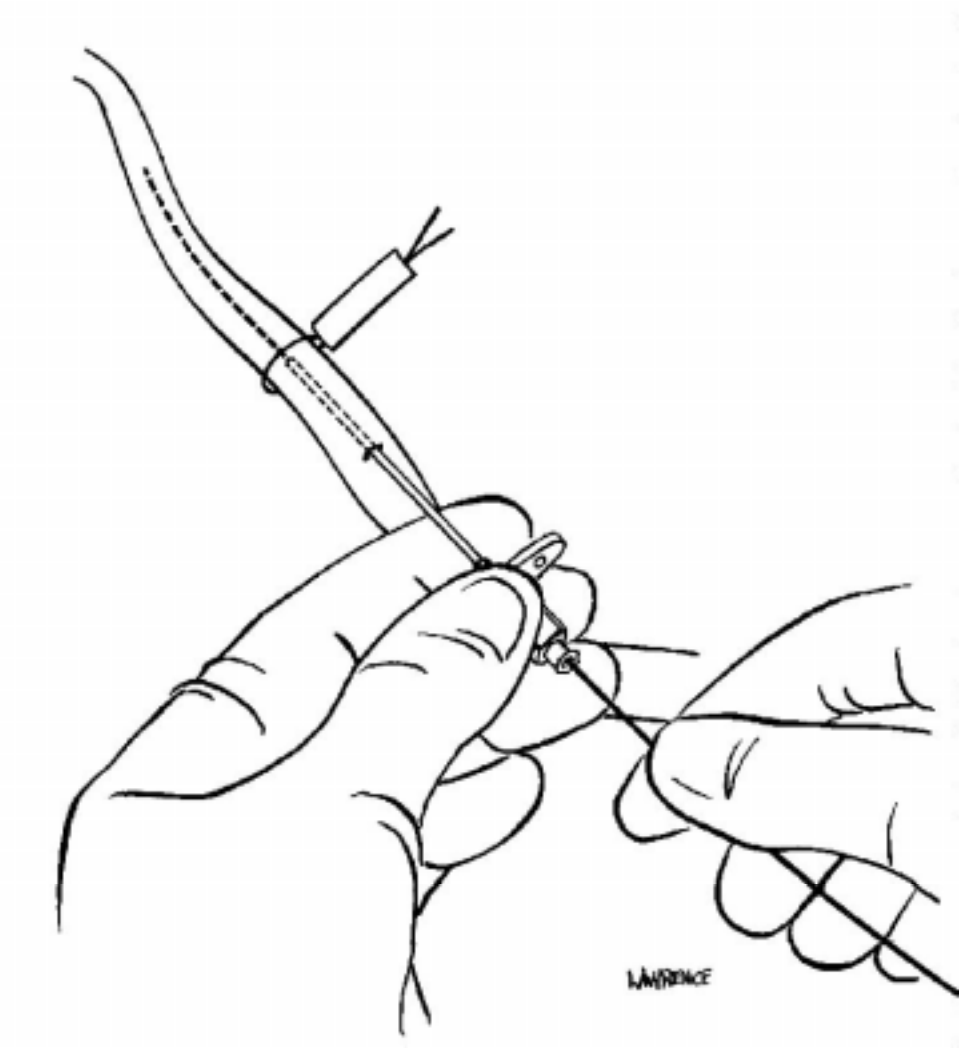

Figure 17. Placement of guide wire. Illustration demonstrating placement of the 0.035 inch guide wire through the arterial access cannula.

Back

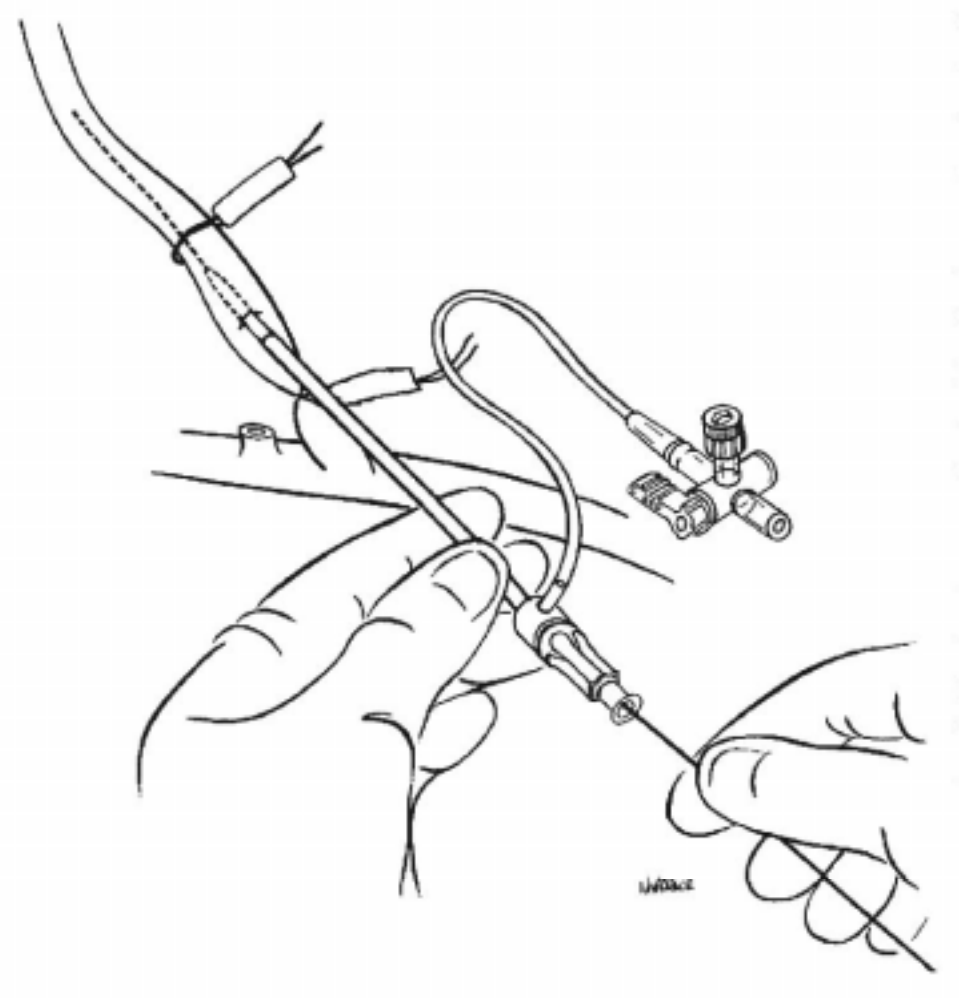

Figure 18. Placement of introducer sheath. Illustration demonstrating placement of the 8 Fr introducer sheath with dilator over the guide wire into the artery.

Back

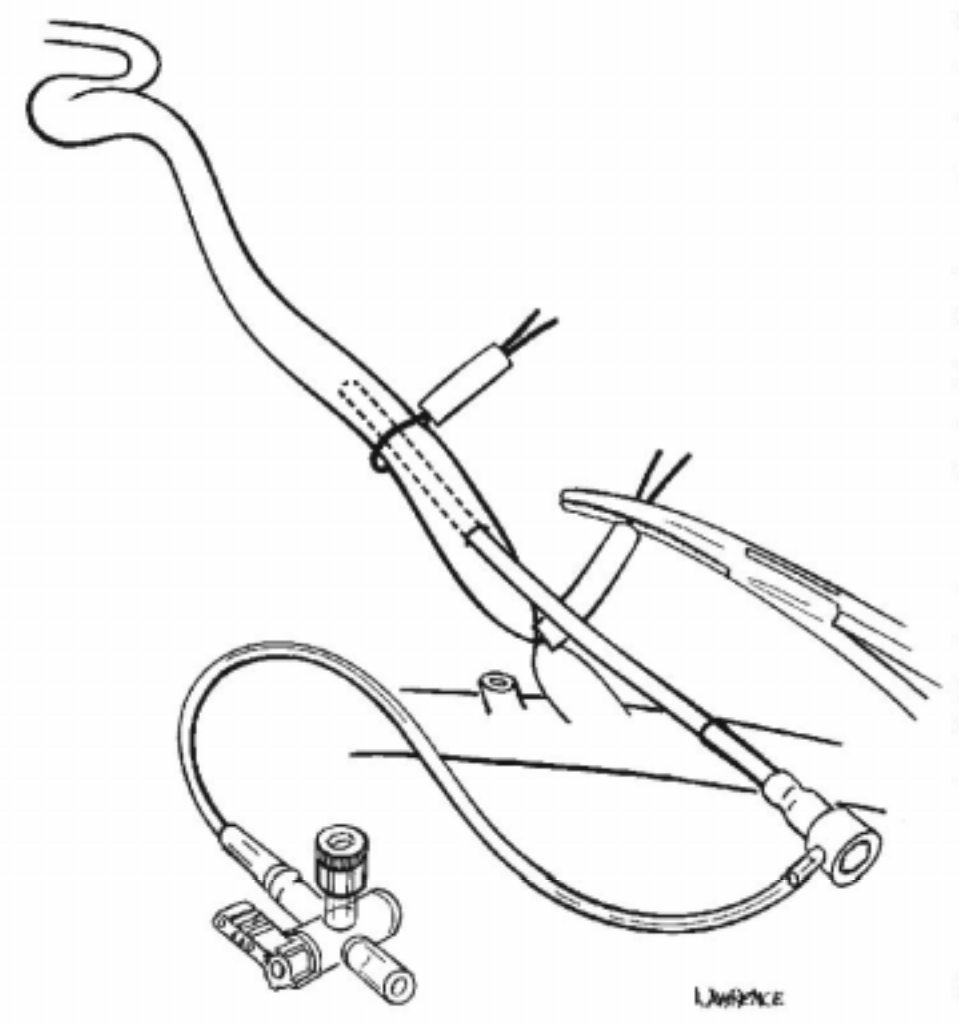

Figure 19. Introducer sheath in place. Illustration demonstrating the 8 Fr introducer sheath in position within the artery.

Back

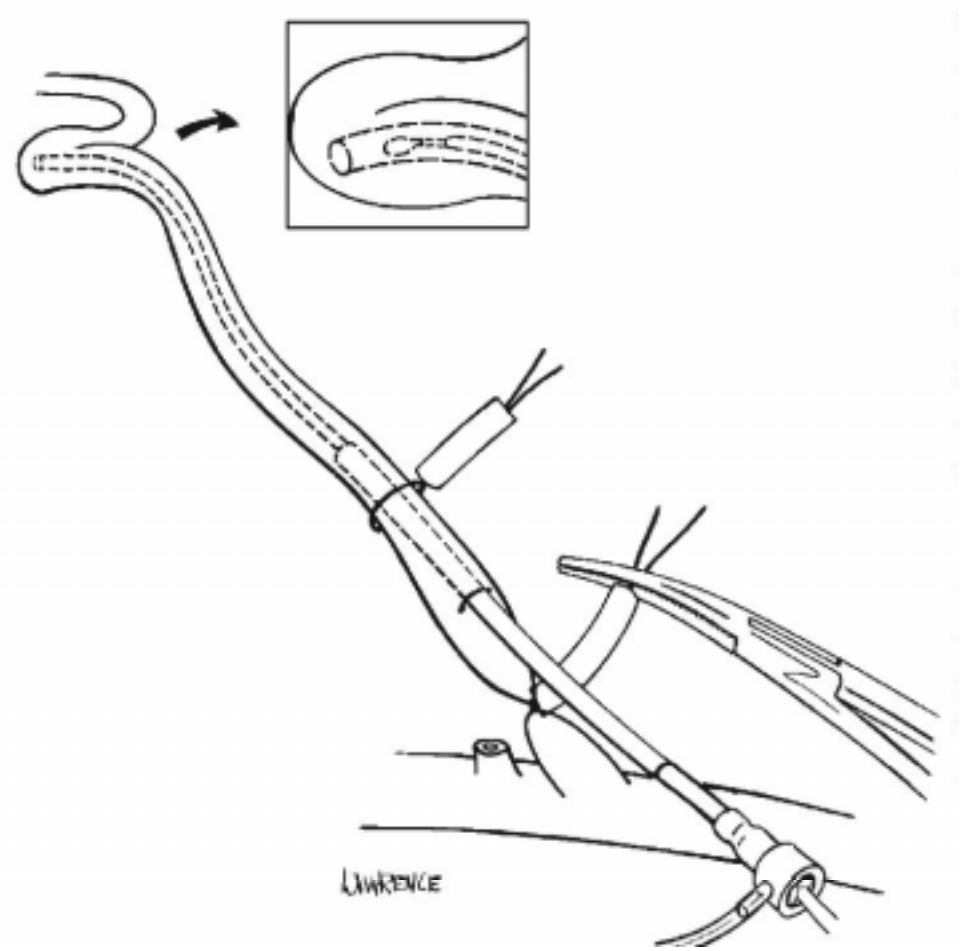

Figure 20. Advancement of guide catheter. Illustration demonstrating advancement of the guide catheter to the proximal bend of the sigmoid flexure of the internal carotid artery. The balloon mounted onto the carrier catheter is within the guide catheter (inset). Back

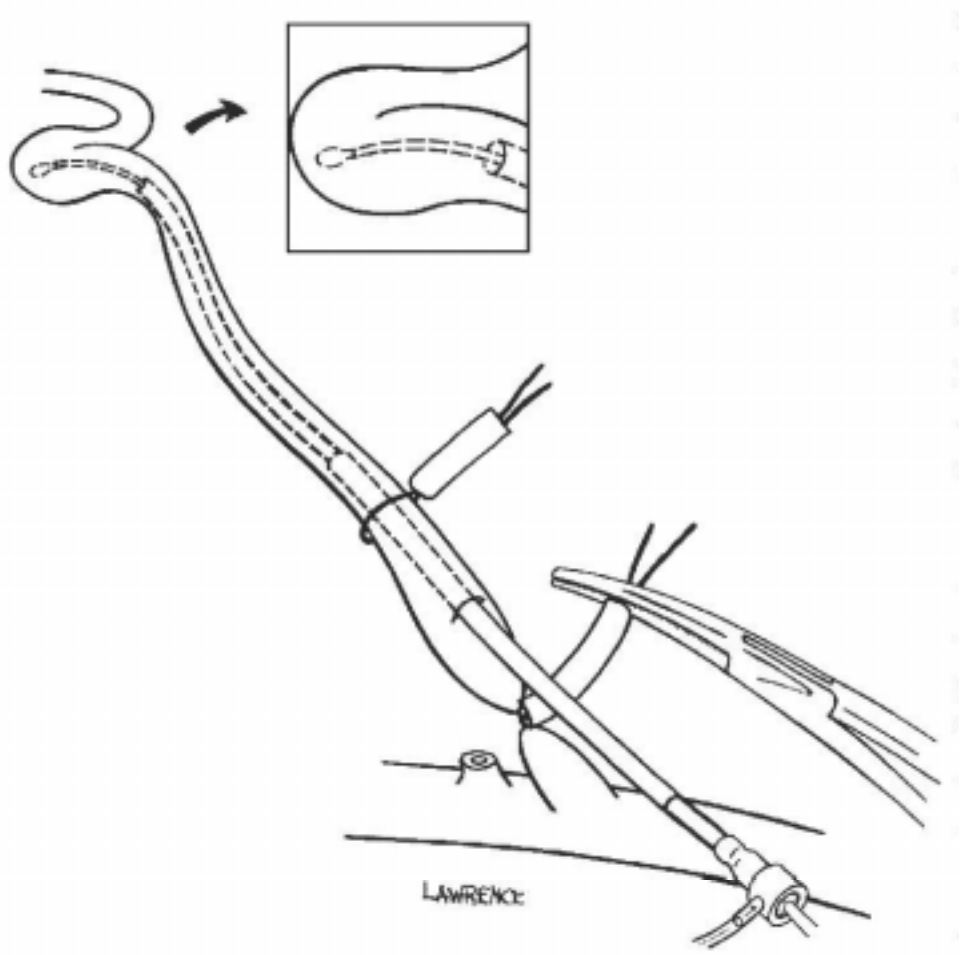

Figure 21. Balloon deployment. Illustration demonstrating deployment of the balloon into the sigmoid flexure of the internal carotid artery.

Back

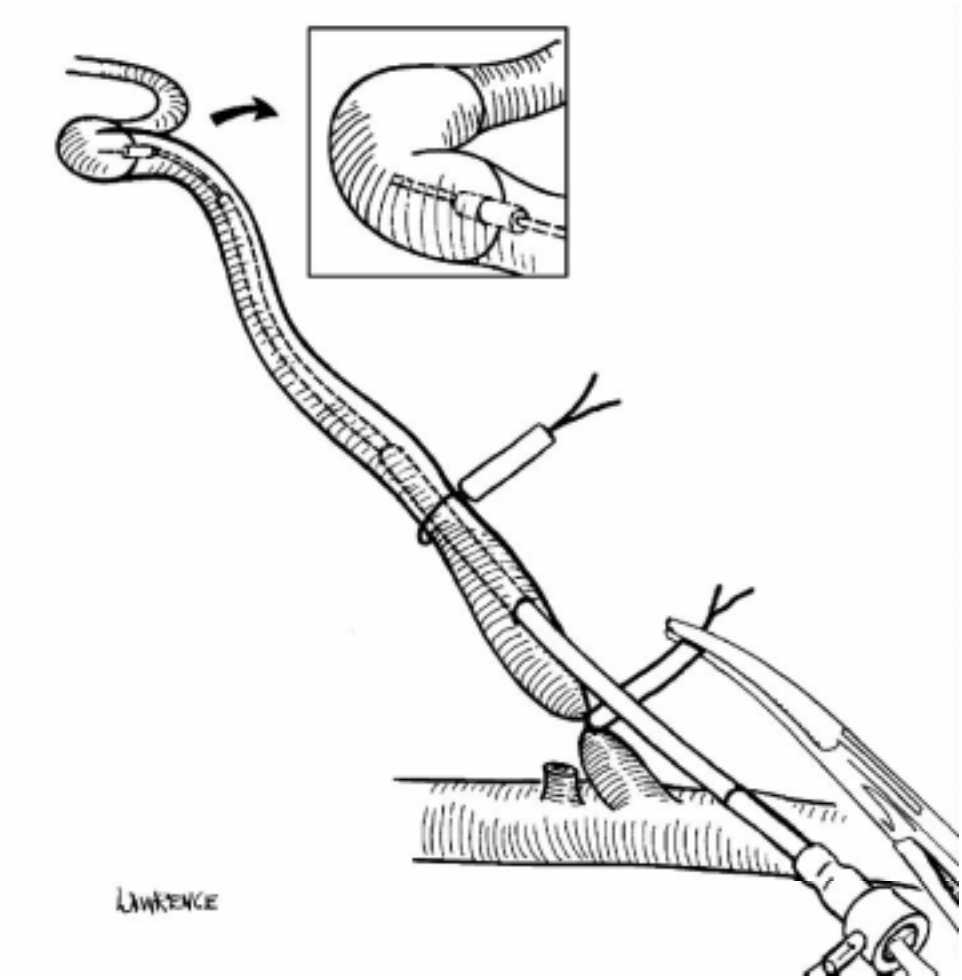

Figure 22. Balloon inflation. Illustration demonstrating inflation of the balloon within the proximal bend of the sigmoid flexure.

Back

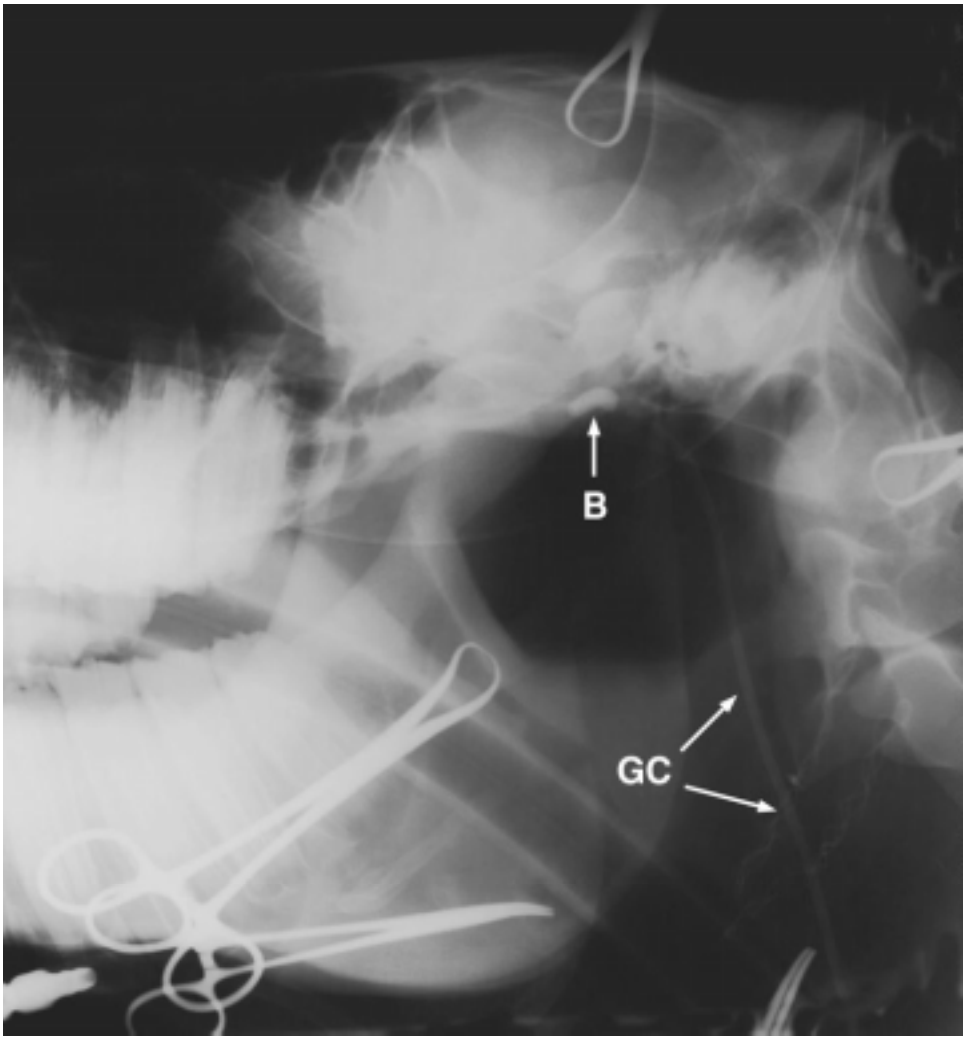

Figure 23. Intraoperative radiograph. Intraoperative lateral radiograph demonstrating the inflated balloon within the sigmoid flexure of the internal carotid artery (horse 6). B = balloon, GC = guide catheter.

Back

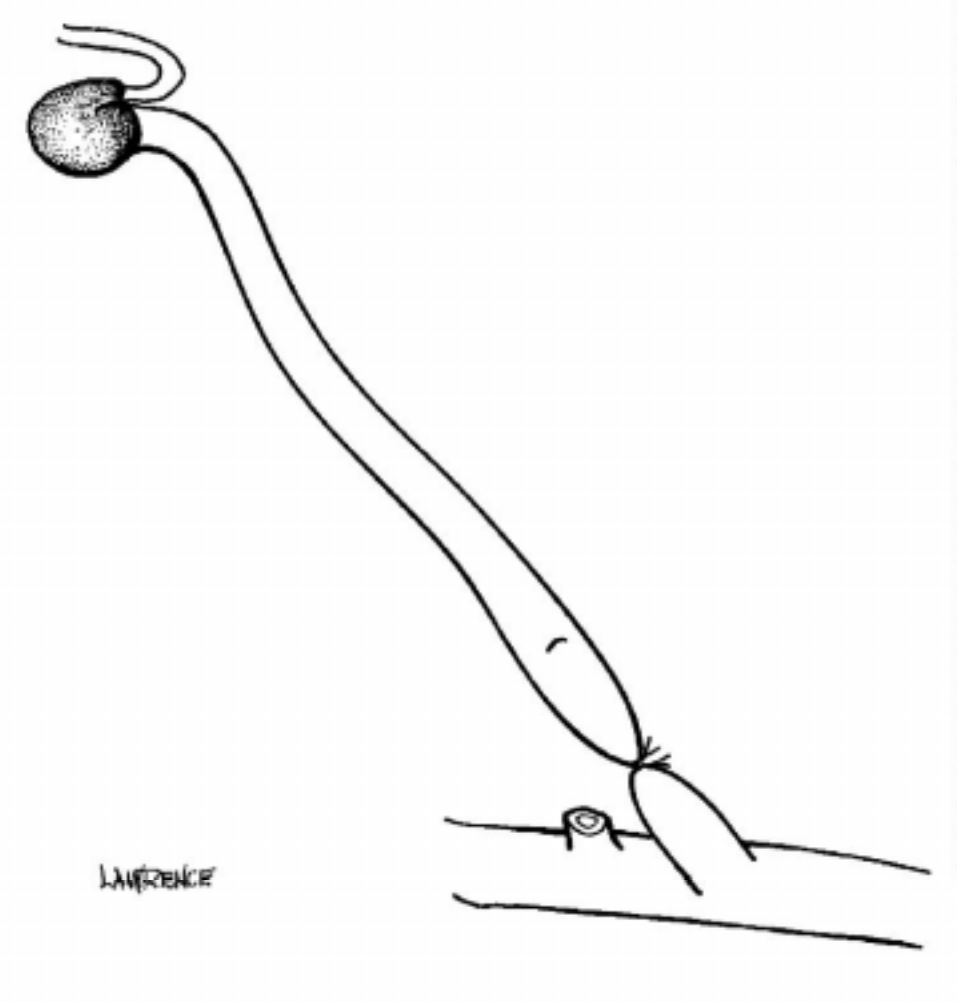

Figure 24. Occluded internal carotid artery. Illustration demonstrating deployed balloon within the sigmoid flexure of the internal carotid artery and double ligation of the origin of the internal carotid artery.

Back

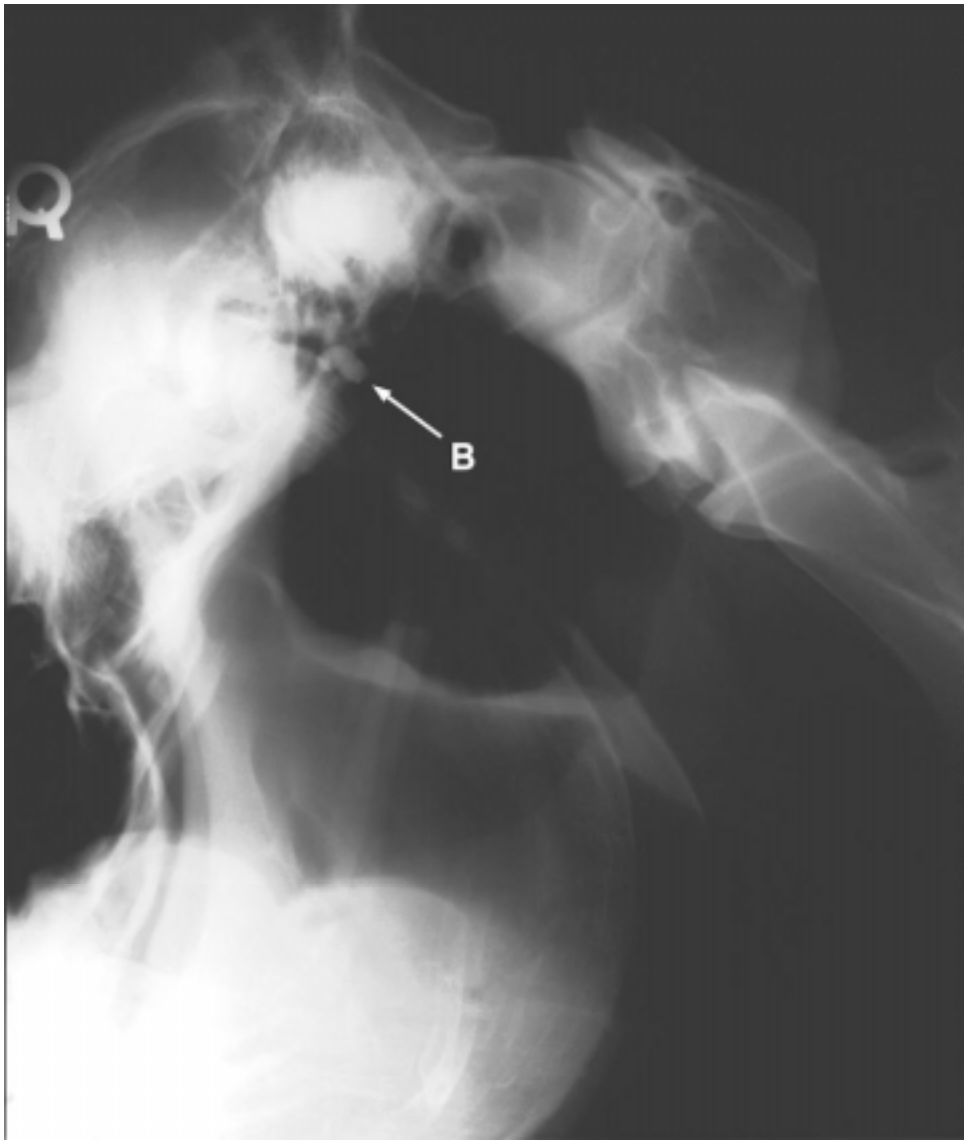

Figure 25. Postoperative radiograph. Lateral radiograph of the guttural pouches on day 30. The balloon (B) is still inflated and has not migrated from its original placement (horse 4).

Back

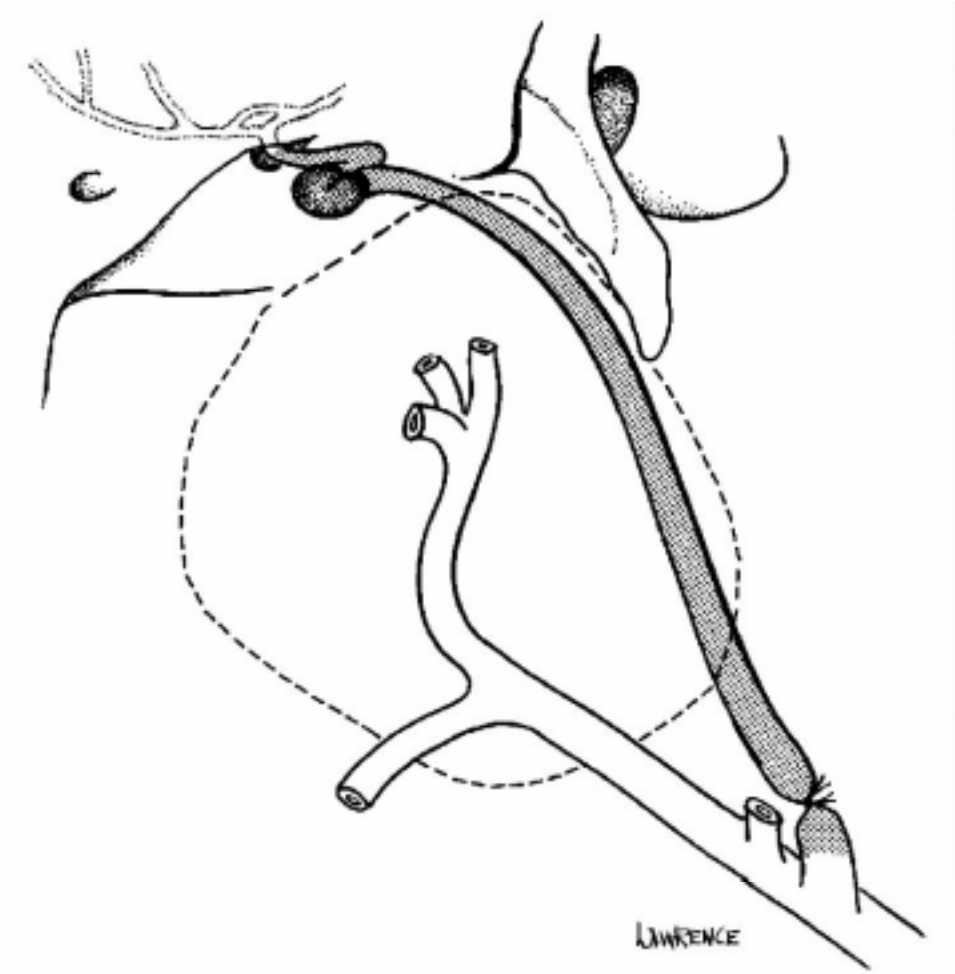

Figure 26. Extent of thrombus. Illustration representing the gross findings at necropsy. The stippled area represents the thrombus within the internal carotid artery.

Back

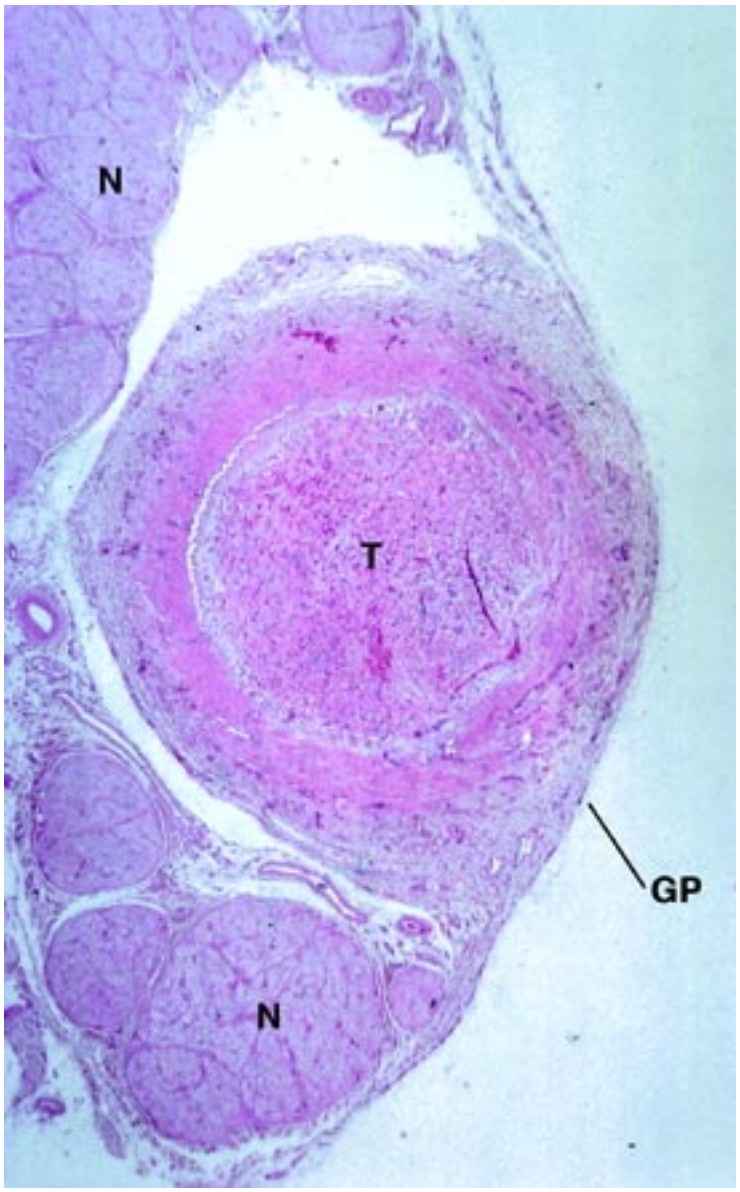

Figure 27. Thrombus. Photomicrograph of a section of thrombosed internal carotid artery as it courses along the lining of the guttural pouch (horse 5, original magnification = 10x). T = thrombus, GP = guttural pouch lining, N = neural tissue.

Back

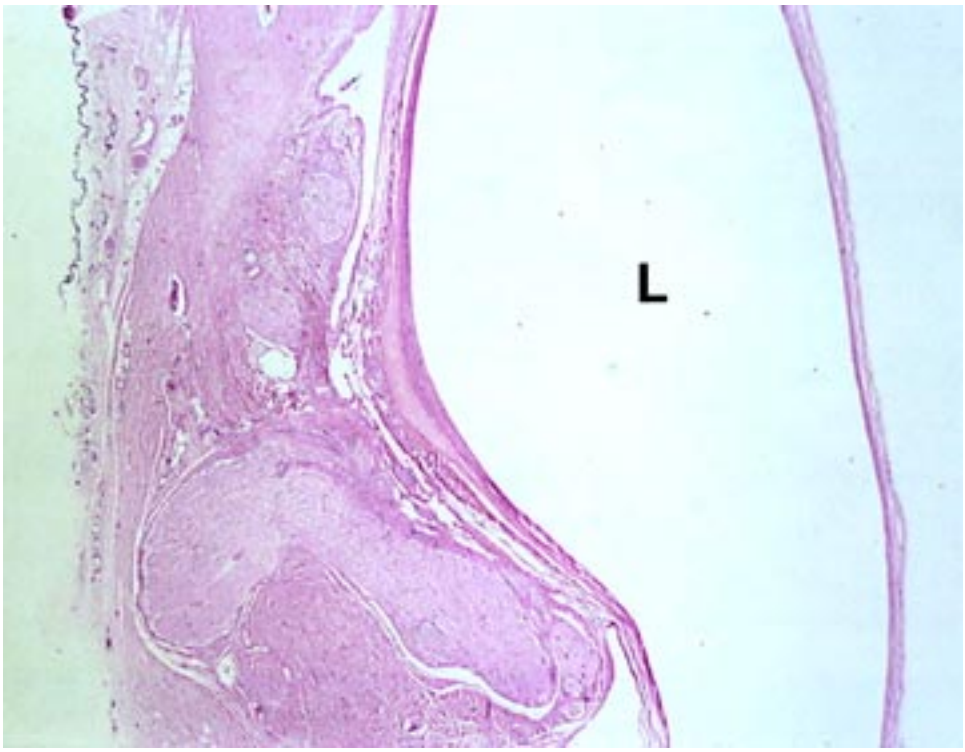

Figure 28. Balloon site. Photomicrograph of a section of internal carotid artery at the site of balloon placement. The arterial wall is thin but was completely intact (horse 6, original magnification = 25x). L = arterial lumen.

Back

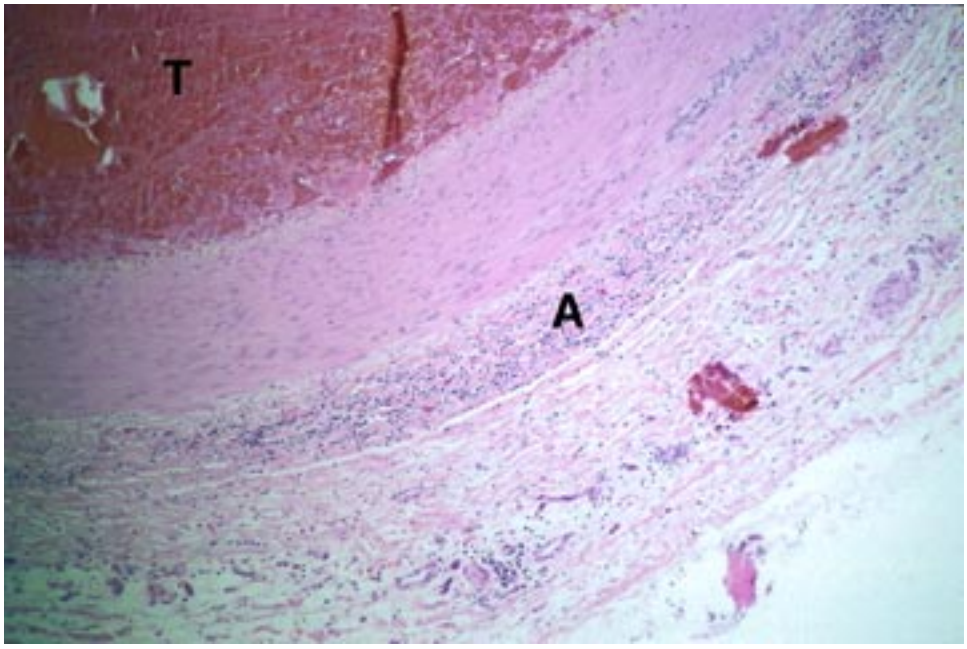

Figure 29. Inflammation. Photomicrograph of a section of internal carotid artery demonstrating moderate diffuse inflammation with the adventitial layer of the arterial wall (horse 3, original magnification = 25x). T = thrombus, A = adventitial layer.

Back

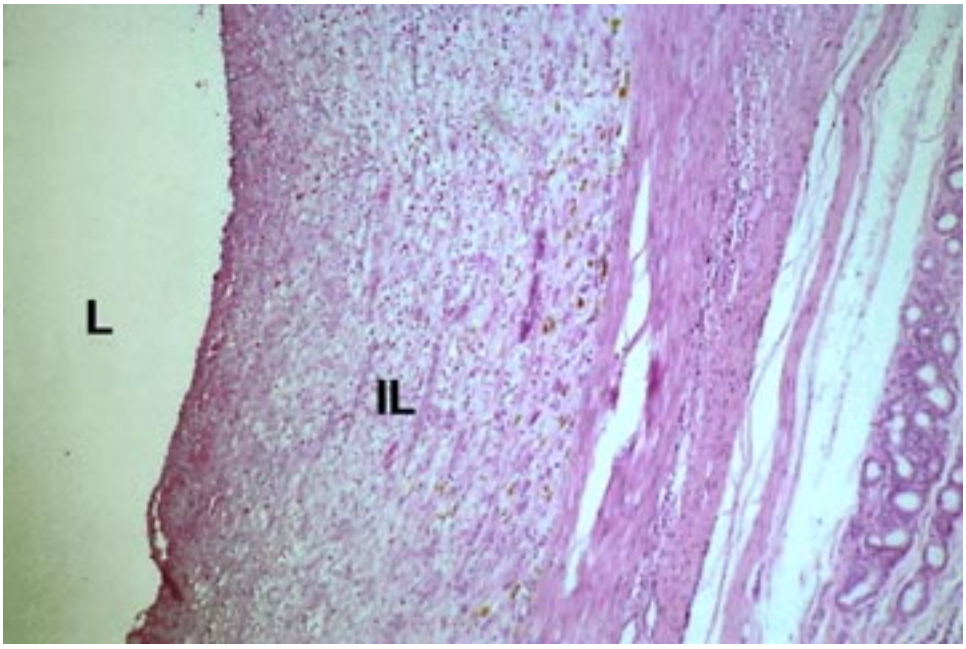

Figure 30. Fibrosis. Photomicrograph of a section of internal carotid artery at the site of balloon placement demonstrating multifocal fibrosis of the intimal layer of the arterial wall (horse 1, original magnification = 25x). L = arterial lumen, IL = intimal layer.

Back

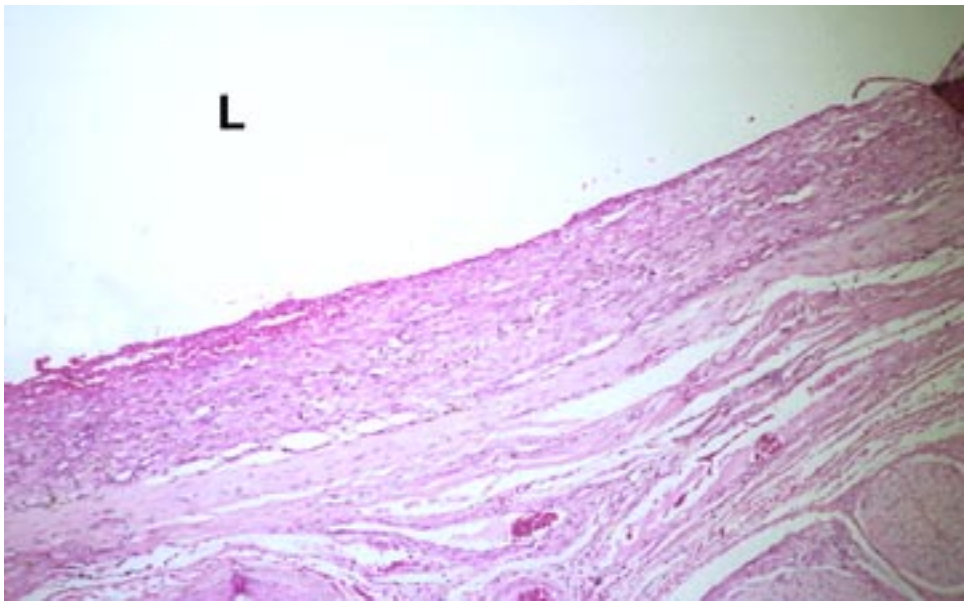

Figure 31. Endothelial proliferation. Photomicrograph of a section of internal carotid artery at the site of balloon placement demonstrating endothelial proliferation (horse 4, original magnification = 25x). L = arterial lumen.

Back

APPENDICES

APPENDIX 1

Identification and Signalment

Horse Name	Study Number	Clinic Number	Age	Breed	Sex	Weight (kg)	Reason Donated
Shot of Bourbon	1	043856	6	TWH	G	453	Lameness
Sunshine	2	042566	20	THB	G	513	Lameness
Gallahad	3	044222	10	THB	G	577	Lameness
Monte	4	041901	18	AQH	G	487	Lameness
Red Bar Moon	5	044568	20	AQH	G	500	Lameness
Ranis Karyess	6	044241	3	Arab	M	367	Lameness

TWH = Tennessee Walking Horse
THB = Thoroughbred
AQH = American Quarter Horse

G = Gelding
M = Mare

APPENDIX 2

Surgical Times

Horse	Randomly Assigned Study Number	Surgical Order	Surgical Time (minutes)
Monte	4	1	132
Sunshine	2	2	120
Gallahad	3	3	97
Shot of Bourbon	1	4	90
Ranis Karyess	6	5	92
Red Bar Moon	5	6	92

APPENDIX 3

Distances from thrombus to origin of internal carotid artery and to the caudal intercarotid artery

Horse	Distance between ICA origin and beginning of thrombus (cm)	Distance between thrombus and caudal intercarotid artery (cm)
Shot of Bourbon	1.3	0.8
Sunshine	0.9	0.9
Gallahad	1.2	0.8
Monte	1.3	0.6
Red Bar Moon	1.1	0.9
Ranis Karyess	1.4	0.7

ICA = Internal Carotid Artery

APPENDIX 4

Presence of thrombus and degree of inflammation scores[a] for sections of the left and right arterial trees

Site	n	Thrombus[b]	Inflammation				
			Grade 1	Grade 2	Grade 3	Grade 4	Total
Left Common Carotid	18	N	2	0	0	0	2
Left External Carotid	12	N	4	0	1	0	5
Left Internal Carotid[c]	18	Y	4	1	0	0	5
Balloon Site	6	N	3	0	1	0	4
Left Internal Carotid[d]	12	y	4	0	0	0	4
Left Internal Carotid[e]	6	N	0	0	0	0	0
Caudal Intercarotid	6	N	0	0	0	0	0
Left Rostral Cerebral	6	N	0	0	0	0	0
Right Arterial Tree	84	N	1[f]	0	0	0	1
	168		18	1	2	0	21

n = 168

[a] 1 = mild, 2 = moderate, 3 = marked, 4 = severe

[b] N = no thrombus, Y = thrombus present

[c] Proximal to balloon site

[d] Between balloon site and caudal intercarotid artery

[e] Distal to caudal intercarotid artery

[f] Common carotid artery

APPENDIX 5

Histologic Grading of Left and Right Arterial Trees of Horse 1

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	1 - D	0	0	0
A-4	1 - D	0	0	0
A-5	0	0	0	0
A-6	0	0	0	0
A-7	0	0	0	0
A-8	0	0	0	0
A-9	3 - MF	3 - MF	0	0
A-10	1 - MF	0	0	0
A-11	1 - MF	0	0	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	1 -F	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

APPENDIX 6

Histologic Grading of Left and Right Arterial Trees of Horse 2

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	1 - F	0	0	0
A-4	1 - MF	0	0	0
A-5	0	0	0	0
A-6	0	0	0	0
A-7	0	0	0	0
A-8	0	0	0	0
A-9	0	0	0	0
A-10	1 - D	0	0	0
A-11	0	0	0	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	0	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

APPENDIX 7

Histologic Grading of Left and Right Arterial Trees of Horse 3

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	0	0	0	0
A-4	1 - F	0	0	0
A-5	0	0	0	0
A-6	1 - F	0	0	0
A-7	2- D	0	0	0
A-8	1 - D	0	0	0
A-9	1 - D	0	0	0
A-10	0	0	0	0
A-11	0	0	0	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	0	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

APPENDIX 8

Histologic Grading of Left and Right Arterial Trees of Horse 4

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	0	0	0	0
A-4	0	0	0	0
A-5	3 - MF	0	0	0
A-6	0	0	0	0
A-7	0	0	0	0
A-8	0	0	0	0
A-9	1 - MF	1 - F	1 - F	0
A-10	0	0	0	0
A-11	0	0	1 - F	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	0	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

APPENDIX 9

Histologic Grading of Left and Right Arterial Trees of Horse 5

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	0	0	0	0
A-4	0	0	0	0
A-5	0	0	0	0
A-6	0	0	0	0
A-7	0	0	0	0
A-8	0	0	0	0
A-9	1 - F	0	0	0
A-10	0	0	0	0
A-11	0	0	0	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	0	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

APPENDIX 10

Histologic Grading of Left and Right Arterial Trees of Horse 6

Site	Inflammation	Fibrosis	Endothelial Proliferation	Vascular Necrosis
A-1	0	0	0	0
A-2	0	0	0	0
A-3	0	0	0	0
A-4	1 - F	0	0	0
A-5	0	0	0	0
A-6	0	0	0	0
A-7	1 - D	0	0	0
A-8	1 - D	0	0	0
A-9	0	0	0	0
A-10	0	0	0	0
A-11	0	0	0	0
A-12	0	0	0	0
A-13	0	0	0	0
A-14	0	0	0	0
B-1	0	0	0	0
B-2	0	0	0	0
B-3	0	0	0	0
B-4	0	0	0	0
B-5	0	0	0	0
B-6	0	0	0	0
B-7	0	0	0	0
B-8	0	0	0	0
B-9	0	0	0	0
B-10	0	0	0	0
B-11	0	0	0	0
B-12	0	0	0	0
B-13	0	0	0	0
B-14	0	0	0	0

A = Left Side
B = Right Side
F = Focal
MF = Multifocal
D = Diffuse
1 = mild, 2 = moderate, 3 = marked, 4 = severe

VITA

Hoyt Stephen Cheramie was born September 18, 1967 in Centreville, Mississippi, and is the son of Christine R. Brandon of Cut Off, Louisiana, and Steve J. Cheramie, Sr. of Woodville, Mississippi. He attended South Lafourche High School in Galliano, Louisiana and graduated with honors in 1985. Hoyt accepted an academic scholarship to attend Louisiana State University, where he graduated in May 1990 with a Bachelor of Science Degree in Dairy Production Science. He entered the Doctor of Veterinary Medicine program at Louisiana State University in August 1989 and graduated in May 1993. During his veterinary education, he was an active member of the student chapters of the AVMA, AAEP and AAHA and served as SCAAEP Secretary and President. During his veterinary education, Hoyt received the Lorio Children Memorial and Salsbury Scholarships, and the Louisiana Veterinary Medical Association Equine Clinical Proficiency Award. After graduation, he spent a year in a mixed animal practice in Lebanon, Kentucky. In July 1994, he began a large animal medicine and surgery internship at the University of Tennessee, College of Veterinary Medicine in Knoxville, Tennessee, which he successfully completed in June 1995.

Since then he has been enrolled in the combined masters/clinical residency program in large animal surgery in the Virginia-Maryland Regional College of Veterinary Medicine, Virginia Tech, Blacksburg, Virginia. Hoyt presented the

results of his graduate work at the 1997 American College of Veterinary Surgeons Symposium in October. This work has also been accepted for publication in *Veterinary Surgery*. Upon completion of the combined program, Hoyt and his wife, Lesley, will stay in Blacksburg, where he has accepted a sponsored research associate/clinical instructor position in large animal surgery in the Virginia-Maryland Regional College of Veterinary Medicine.