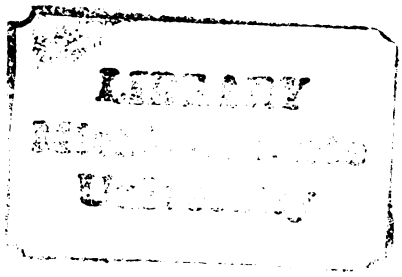

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ESOPHAGEAL MUCOSAL RESECTION AND ANASTAMOSIS IN THE HORSE : COMPARISON OF THREE FEEDING TECHNIQUES

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ESOPHAGEAL MUCOSAL RESECTION AND ANASTOMOSIS IN THE HORSE: COMPARISON OF THREE FEEDING TECHNIQUES

By

Rory James Todhunter

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1983

ABSTRACT

ESOPHAGEAL MUCOSAL RESECTION AND ANASTOMOSIS IN THE HORSE: COMPARISON OF THREE FEEDING TECHNIQUES

By

Rory James Todhunter

Successful surgical management of esophageal stricture in horses is difficult and the surgical techniques have been poorly studied. I investigated the effects of feeding techniques on the healing process following a method of resecting a strictured area of esophageal mucosa. Twenty horses had a three centimeter circumferential segment of cervical esophageal mucosa resected and anastomosed. Five horses were fed a moistened pelleted diet postoperatively; five were fed this diet in slurry form via nasogastric tube and ten were fed the same diet via an esophagostomy tube until the fourteenth postoperative day. The pelleted diet was then fed until euthanasia on the sixtieth postoperative day. Endoscopic, radiologic, histopathologic and morphometric techniques and compliance measurements were used to compare healing between the groups of horses. Data were compared using both parametric and nonparametric tests. Strictures developed in all horses. The best feeding technique was nasogastric tube-feeding.

DEDICATION

To my family -

Pam, Jim, Brett, Lisa, Shauna, Paddy, Steve, Nick.

ACKNOWLEDGEMENTS

Without the encouragement and advice of Drs. John Stick, Chris Brown and Ed Robinson and the particular expertise and excellence of Dr. Ron Slocombe, this work would never have matured. Thank you.

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INTRODUCTION AND LITERATURE REVIEW

"Successful" Equine Esophageal Resections and Anastomoses

In the "Auburn Veterinarian" in the winter of 1963, Vaughn and Hoffer described a surgical procedure for the removal of 3 cm of strictured esophagus in a weanling.[1] Unfortunately, the filly died 16 days postoperatively due to an acute hemorrhagic enteritis of undetermined etiology. There was a small sinus communicating with the esophageal lumen near the anastomotic site. In their closing paragraph in that paper, the authors suggest that the method of esophageal closure should be more thoroughly investigated in its application to large animal esophageal problems. Prior to that time only two reports on the treatment of esophageal disease in horses could be found,[2,3] and there have been but a few since then.[4-17] With particular reference to the postoperative care of an esophageal resection and anastomosis, as a treatment for esophageal stricture in horses, I could find only 4 reports.[1,10,16,17] Vaughn and Hoffer[1] as mentioned, removed the nasogastric tube on the 14th postoperative day and allowed the weanling to drink water and milk. She was not allowed access to solid food before she died. In 1964, Lowe[10] resected 2.5 cm of cervical esophagus in a mare, and maintained her on

pellets. She ate hay once and showed signs of "choke". No radiographic assessment was made of the degree of post-operative stricture. However, nasogastric tubes of 1.5 cm and 2.0 cm outside diameters were passed without difficulty. Suann[16] resected 2 cm of cervical esophagus in a 2-year-old colt, which was maintained on a mixture of oats, oaten chaff bran and fresh green feed. However, there was evidence of coughing and regurgitation when fed lucerne hay. Derksen and Stick[17] resected a 2 cm section of abnormal esophageal mucosa and submucosa in a 3-month-old filly. She was fed through an esophagostomy tube for 30 days postoperatively, and was eating hay by the time she was discharged 45 days post-operatively. Endoscopically, the esophagus was normal 2 years later. Postoperative esophagrams were not performed. Thus it appears that in these 4 case reports there is no uniform method of evaluating the "success" of the surgical procedure, and the best that could be hoped for, is that the horses could be maintained on a pelleted ration post- operatively, except in the latest report by Derksen and Stick, in which the horse ate hay.[17]

Previous Research

There are no published controlled experiments dealing with the surgical technique for, and postoperative healing process, following esophageal resection and anastomosis in the horse. The healing of longitudinal

incisions in the normal esophagus has been studied in ponies.[18,19,20] Using endoscopic, radiographic and morphometric techniques, Stick showed the progression of healing in sutured longitudinal esophageal wounds to be a function of diet rather than surgical technique. All the esophagotomies in the hay-fed ponies dehisced, while first intention healing occurred in all esophagotomies when the ponies were fed a soft diet.[20]

The most common indication for esophageal resection is stricture removal. The causes of stricture formation vary among species. In horses, prolonged esophageal mucosal damage as a result of esophageal obstruction ("choke") most often results in stricture formation. Choke in horses can occur as a result of food impaction,[13] orally administered caustic or corrosive medicinal agents,[3,21] trauma to the neck,[10] and as a sequela to esophageal resection and anastomosis.[11] External trauma can lead to stricture also, due to inflammation and secondary fibrosis in the muscularis externa or periesophageal tissues, but this occurs less commonly than primary mucosal erosion. In people, esophageal tumors[23] and severe esophagitis due to ingestion of caustic agents,[24] are the common causes of stricture formation. Many advances have been made in the treatment of human esophageal disease since World War II. Esophageal surgery in people is based on experimental animals, and since the dog,[24-32] cat,[33] pig,[34-49]

monkey,[50] and rabbit[51] have been used as experimental models for human esophageal reconstruction following resection and anastomosis, a review of the human literature is in order.

Historical Review (Human Esophageal Surgery)

In 1877, Czerny[52] first successfully resected cancer of the cervical esophagus in a person. Through his work and that of Bilroth,[53] new sophistication developed in gastrointestinal surgical techniques. In the early 1900's, staged reconstructive procedures for corrosive stricture and malignant lesions were performed. In 1909, the pharynx, larynx and cervical esophagus was resected in a patient.[54] Four years later, Torek[55] successfully resected the thoracic esophagus, performing cervical esophagostomy and gastrostomy. A successful one-stage, transpleural esophageal resection and esophagogastrostomy for carcinoma remained an unattainable goal until Oshawa's report in 1933.[56] In the United States, the first successful esophagogastrectomy for cancer was performed in the Lahey Clinic in 1937.[57] In 1941, the first successful closure of a fistula and primary esophageal anastomosis in congenital esophageal atresia and tracheo-esophageal fistula was performed.[58]

It was not until after World War II, that esophageal surgeons became aware of the many complexities of esophageal function, which are so often disturbed by disease and by surgical intervention.[59] In 1945, the first esophageal resections with esophagogastrostomy and the first high thoracic gastric replacements were performed in California.[60] Extensive literature is available on the subjects of primary esophageal repair, viable and non-viable esophageal replacements,[61] and complete historical descriptions of esophageal surgery in people.[62]

Esophageal disease in people is often extensive and the major postoperative complication is leakage of luminal contents at the surgical site. Since both leakage and anastomotic tension predispose to stricture formation following esophageal resection, a number of viable tissue grafts and prostheses have been used for esophageal substitution, in order to reduce these complications. Viable substitutes have included:[61]

A. Pedicled gastrointestinal segments of ileocecum,[63] colon[64] and jejunum;[65]

B. Stomach via esophagogastrostomy,[66] reverse gastric tube formation based on the left gastroepiploic artery and vein[67] and isoperistaltic gastric tubes;[68]

C. Gastric antrum,[69] jejunum,[70] and colon[63] using microvascular anastomosis techniques;

D. Free skin grafts using split thickness grafts,[71] and full thickness grafts;[63] and

E. Musculocutaneous flaps.[72]

The advantage of using the stomach as a replacement organ in people is that it has excellent blood supply, mobility and length. The distance it has to be stretched in a human neck and thorax is proportionately much less than in a horse for example. In addition, due to a person's upright posture, together with vagotomy and pyloroplasty, gastric emptying is greatly facilitated. The use of the colon has increased dramatically since the 1950's, with the advent of antibiotics and improved preoperative bowel preparation. Its vascularity is good and it is relatively resistant to peptic ulceration. It can also be protected by vagotomy and gastric drainage procedures. Gastric and colonic esophageal replacements constitute the majority of substitutes today.

Non-viable biological tissue and tissue substitutes have also been used to replace esophageal segments or reinforce esophageal anastomoses in animals. These have included: diaphragm grafts,[73] autogenous pericardial grafts,[74,75] fascia latae and aortic homografts,[75] autogenous fibrous tissue tubes,[76] and deviced rings.[77] Even synthetic adhesives have been used to strengthen esophageal anastomoses.[78] Although some success has been attained with non-viable substitutes, graft necrosis,

infection, scarring or leakage suggest the use of viable tissue substitutes is preferable.[79]

Stricture Classification

Esophageal strictures in horses are commonly localized. "Choke" is most commonly caused by foreign body or food impaction, resulting in localized areas of mucosal and in more severe cases, submucosal loss. External neck trauma and esophageal rupture also predispose to stricture development. Full thickness mucosal or submucosal esophageal defects heal predominently by wound contraction and fibrous protein synthesis.[80] The resulting annular lesion can be classified into three types depending on the anatomic location of induration and fibrosis: 1) mural lesions that involve only the adventitia and muscularis, 2) esophageal rings or webs that involve only the mucosa-submucosa, and 3) annular stenosis that involves all layers of the esophageal wall.[81] The size of the horse does not lend itself particularly to esophageal replacements by colon and stomach, due to the prolonged anesthesia period required, the increased incidence of infection in prolonged surgical procedures, and the more localized nature of the lesion, compared to humans. Strictures also occur more commonly in the cervical area, where a one-stage reconstructive procedure is preferable. Depending on the nature of the lesion, strictures of the equine esophagus,

which are unresponsive to medical management may be corrected by esophagomyotomy, complete resection and anastomosis, partial resection, esophagoplasty, or patch grafting.[10,12,82]

Surgical Considerations

Special consideration must be given to surgery of the esophagus.[79] The esophagus lacks an outer serosal surface which would help limit leakage by exuding fibrin. On the mucosal surface, however, a fibrin seal does form at the margin of the healing mucosal incision following longitudinal esophagotomy.[18] Due to the segmental nature of the blood supply to the esophagus[83] special care should be taken to avoid ischemic necrosis.[80] It has been demonstrated, at least in dogs, however, that considerable portions of both the cervical and thoracic esophagus can be mobilized, without subsequent loss of viability.[24,26,31] Parker and Brockington[24] mobilized the entire canine thoracic esophagus from its mediastinal bed and resected about 33%, with a 33% mortality. No intensive care or antibiotics were used. Shek et al[26] in a two-part experiment using dogs, mobilized the thoracic esophagus from the aortic arch to the diaphragm, and resected 3-5 cm portions, followed by anastomosis. Fourteen of 15 dogs in the first part of the experiment survived for two months prior to euthanasia. No strictures were noted.

In the second part, the dogs' entire thoracic esophagi were freed and all their thoracic blood supply were severed. Five of the six animals had a viable esophagus 14 days post-operatively, judged by arteriography and necropsy. Macmanus et al, after performing five different operations on 46 dogs concluded that necrosis of the dog's esophagus does not occur following complete devascularization (division and anastomosis) of the thoracic portion. However, it did occur at the thoracic inlet after cervical and thoracic mobilization.

Constant motion of the esophagus, swallowing and diaphragmatic and adjacent organ movement in the thorax, contradict one of the basic principles of wound healing - tissue rest. Additionally, the esophageal wall poorly tolerates longitudinal stretching and tension.[27,28,49] Consequently, much attention has been given to the reduction of tension at the anastomotic site, with different types of esophageal myotomy. A particular application of myotomy has been to reduce tension on the esophageal anastomosis in children undergoing primary one-stage repair for esophageal atresia or tracheo-esophageal fistula.[84,86] Approximately 1 cm in length can be gained with each myotomy. Experimental work in both dogs[27,28] and pigs[35-39,49] has shown that circular or spiral esophagomyotomies can significantly reduce the degree of anastomotic tension on the esophagus. One circular myotomy in piglets can decrease

the approximating force of a 5-6 cm resection by 50% and a double myotomy by 75%.[49] Circular myotomy in the presence of gross shortening of the esophagus is valuable in the repair of hiatal hernia.[87] Single and double myectomies in piglets, in which 2-4 cm of esophageal muscularis externa was removed, did not affect esophageal motility according to contrast radiographic procedures.[36] Thus, transecting the muscularis externa does not appear to alter esophageal function clinically or radiographically. No manometric studies to investigate motility have been performed following such surgical intervention in these pigs.

The esophagus must be sutured with care to maximize the suture holding power of the mucosa and submucosa and minimize the danger of suture interference with blood supply and wound healing.[80,88] Omentum is not available to help seal or localize a leak in the esophagus. Single interrupted sutures in the esophageal anastomosis cause less vascular compromise and are generally recommended in the mucosal-submucosal closure rather than a continuous pattern.[30,89] However, continuous patterns in esophageal mucosal closure have been shown to heal well.[17,30] Theoretically a continuous line should have less tendency to leak relative to a single interrupted closure. However, continuous suture patterns can create a purse-string effect and pull-through the mucosa when intraluminal pressure increases.[13] Effective closure can also be obtained with an everting

single layer interrupted horizontal mattress pattern. The sutures are placed through the full thickness of the esophageal wall, and tied with firm, but not strangulating tension.[13,90,91] Variable results have been obtained in experiments to assess the difference in healing characteristics following esophageal resection and anastomosis using different suture materials.[43-45,48,89] Several conclusions may be drawn. Less reactive suture materials, e.g. monofilament polypropylene[a] and polyglycolic acid[b] appear to result in less stricture formation than silk. Additionally, the researchers say chromic catgut produces a far more severe reaction than silk.[92]

Single and double layer closures will alter lumen size with either silk or polyglycolic acid.[b] However, in an experiment comparing one layer, single-interrupted chromic catgut and non-absorbable Teflon-coated polyester fiber in esophageal anastomoses without resection, there were 50% fewer survivors when non-absorbable suture material was used, rather than an absorbable one. With a 5 cm esophageal resection, there were 66% fewer survivors, following anastomosis with non-absorbable material than with absorbable material. Deaths were attributed to anastomotic leaks, which seemed related to loosening and cutting through of the suture, rather than a defect in the anastomotic

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[a]Prolene, Ethicon, Inc., Somerville, NJ.

[b]Dexon, Davis & Geck, American Cyanamid Co., Pearl River, NY.

technique. The explanation proposed was that perhaps catgut swells, increases in diameter and therefore may move and loosen less.[93] There does seem to be a correlation between the technical difficulty of the procedure (i.e. working in the thorax compared with the neck) and the degree of post-operative stricture. More experienced surgeons have less postoperative strictures than less experienced ones. There is a very strong correlation between the degree of postoperative stricture formation and the degree of mucosal dehiscence.[34,35,39,42] Consequently, strictures may develop even without luminal leakage because of excessive tension alone, which then leads to mucosal separation. Most surgeons tie the suture knots in the lumen to reduce scar production, and promote extrusion of the suture into the lumen.[44,91] Most surgeons recommend closure of the esophageal muscle with an interrupted mattress pattern.[65,88,90,91]

Almost every author on esophageal surgery quotes the leaking suture line as the major immediate complication, and both leakage and surgical field contamination can predispose to infection. Experiments have been done comparing post-operative results following esophageal resection and anastomosis, with and without the use of antibiotics. Pearlstein showed that leakage increased without antibiotics and systemic antibiotics (procaine penicillin G and dihydrostreptomycin) significantly decreased operative

mortality.[33] There is general agreement that antibiotics are beneficial. No trials have been done comparing the postoperative mortality with different antibiotics. Nor is there any information on the normal equine esophageal bacterial flora. Under scanning electron microscopy large numbers of bacterial colonies can be seen, predominantly composed of coccobacilli.[94] The population of bacteria and the population of desquamated cells increases in the more caudal esophagus. However, the specific bacterial species were not identified in this study.

Extraoral Alimentation

There is some contradiction in the literature with regard to the use of intraluminal tubes following esophageal surgery. Some authors suggest that they are contraindicated and slow mucosal regeneration.[80] They may also affect certain segments of the esophageal wall, but not the whole circumference.[92] Conversely, in piglets, an intraluminal transanastomotic tube is beneficial in long gap correction to permit mucosal regeneration in a situation where some degree of dehiscence is likely.[37,40] Strictures, though less severe than with no tube at all in the lumen, still form. Others claim an indwelling pharyngeal feeding tube is indicated to minimize movement of the organ and encourage healing.[91]

Since the nature of the diet does affect the healing process in the esophageal wound,[20] researchers have used a variety of postoperative feeding techniques following esophageal resection and anastomosis. Dogs and piglets have been placed on a soft diet within 2-4 days of surgery and soon resumed a normal diet.[24,25,29,30,32,34,36,37,43-45,47,48] Projects using piglets, in which the use of an intraluminal tube was included,[37,40,46] merely stated that when there was a good chance that mucosal separation would occur, an indwelling tube across the anastomosis would allow mucosal regeneration to take place, and decrease the degree of stricture formation. Nasogastric and esophagostomy tube-feeding have been used extensively in people to permit extraoral alimentation during treatment of oral and pharyngeal disease. Human surgical patients are usually fed intravenously after esophageal resection and then placed on a liquid diet or several days. The cost involved in the use of total parenteral nutrition in horses and the difficulty of finding a palatable liquid diet with its own attendant problems, e.g. diarrhea, make these means of feeding impractical in horses. Esophagitis has been induced in the dog by the use of pharyngostomy tubes left in place for 14 days. There was mild gastric reflux and erosive and ulcerative lesions along the esophagus.[95] The potential complications of esophagostomy tube-feeding in horses include: traction diverticuli, reflux of food around the

feeding tube, obstruction of the feeding tubes, mediastinitis, dissecting tracts in the neck, fistulae, jugular thrombophlebitis, and dislodgement of the tubes.[4,13,19] However, its use in association with esophageal resection and anastomosis in horses has not been fully evaluated. Nasogastric tube-feeding has been used extensively in horses, and descriptions of tubes left in place for up to 14 days have been made.[96] Horses have also been fed using a nasogastric tube passed 3 times daily for 18 days.[97] Chronic nasopharyngeal tubes have also been associated with a number of complications in people -- esophageal stricture, traumatic pharyngeal pseudodiverticulum, peritonitis, laryngeal necrosis, abscessation of the nasal septum and inability to adequately clear lower respiratory tact secretions.[98-102]

Diagnostic Techniques

The method most commonly used to assess the degree of stricture postoperatively is contrast radiography, both in vivo or at postmortem. In the large number of projects performed by both Livaditis[34,36] and Kornfalt,[7-41] on esophageal resection and anastomosis in piglets, radiographic postmortem stricture diameter measurements were slightly larger than those measured in vivo.[41] It is disappointing that the postoperative appearance of the cervical esophagus in the 4 successful equine esophageal

resections and anastomoses discussed at the beginning of this review, was not documented by contrast radiography. Methods for employing contrast radiography, and the radiographic appearance of both the normal and diseased equine cervical esophagus have been well described.[13,18,81,92,93]

The advent of the flexible fiberoptic endoscope in equine practice, has greatly facilitated examination of the esophagus in horses. The endoscopic appearance of the normal esophagus, as well as the healing process after sutured and non-sutured esophagotomies in ponies, has also been documented.[18]

It is clear from the foregoing discussion that most of the experimental data gathered on esophageal resection and anastomosis has come from research on small animals and piglets. The remainder has accumulated from clinical results in people. There are many avenues for exploration concerning esophageal resection and anastomosis in horses. We know that feeding method has a significant effect on the way a longitudinal incision in the esophagus heals. The surgical techniques used did not change the final outcome, however.[20] This project therefore was designed to assess the effect of three different, clinically applicable feeding methods on the healing process following an esophageal mucosal resection and anastomosis. A mucosal resection was chosen since lesions resulting in stricture

formation in horses are often confined only to the mucosa and submucosa, and are often of a localized nature.

MATERIALS AND METHODS

Experimental Design

Twenty clinically normal horses (15 geldings and 5 mares) were used. Preoperative endoscopy and contrast radiography of each horse's esophagus showed no anatomic abnormalities.

A ventral cervical midline approach was used to perform an esophageal mucosal resection and anastomosis through a longitudinal incision in the esophageal muscle on all horses. Five horses (Group I) were given access to water only for 2 days postoperatively, and then were fed a mash diet[a] (14 g/kg of body weight/day), until the 14th postoperative day. Five horses (Group II) were fed the same diet in slurry form, via a nasogastric tube (placed at the time of surgery), until the 14th postoperative day. Ten horses (Group III) were fed the same diet through a distal cervical esophagostomy tube, until the 14th postoperative day. The slurry was made by soaking the daily pelleted requirement in water, and dividing this into three daily feedings. The quantity of water required to administer this via a tube, causes marked diuresis and consequently

[a]Complete Horse Feed No. 705, The Andersons, Maumee, OH.

adequately fulfills the daily water requirement of the horse. After the 14th postoperative day, all horses were given the dry pelleted ration.

Surgery

Immediately prior to anesthetic induction, a nasogastric tube was passed as far as the distal esophagus. The horses were premedicated with xylazine[b] (0.05 mg/kg of body weight), and were anesthetized with thiamylal sodium[c] (2%) and guaifenesin[d] given to effect. The horses were placed in dorsal recumbency. Anesthesia was maintained with halothane administered in a semiclosed system by endotracheal tube. The skin on the ventral surface of the neck was prepared for aseptic surgery.

A 15-cm incision was made on the ventral midline, centered over the junction of proximal and middle thirds of the neck. The cutaneous colli and paired muscles of the sternohyoid, sternothyroid, and omohyoid were separated along the midline to expose the trachea. The trachea was retracted to the right, and the esophagus was identified with the nasogastric tube in its lumen. Electrocautery was used to control bleeding. A balfour retractor was used to retract structures within the carotid sheath abaxially and

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[b]Rompun, Chemagro, Division of Baychem Corp., Kansas City, MO.
[c]Surital, Parke, Davis and Co., Detroit, MI.
[d]Glycodex (5%), Burns-Biotec Laboratories, Oakland, CA.

the trachea to the right of midline. The neighboring tissues were protected with 2% providone-iodine[e] soaked sponges to reduce contamination from the luminal contents.

An 8-cm longitudinal incision was made through the muscularis externa and submucosa of the esophagus, using a scalpel. Using blunt dissection, the mucosa was then separated from the submucosa and muscularis externa around its entire circumference, for a length of about 4 cm. The nasogastric tube was removed just proximal to the surgery site, and a 3-cm length of esophageal mucosa resected. Suction was used to evacuate the contents from the esophageal lumen adjacent to the surgery site. Electrocautery was used on the esophageal wall only if hemorrhage obscured the surgical site and could not be controlled with pressure. The mucosa was apposed beginning on the dorsal surface with 4 continuous sutures of 2-0 monofilament polypropylene.[f] Each was tied when 90^{o} of the mucosal circumference was apposed. The second suture was begun on the dorsal surface and brought 90^{o} around the mucosal circumference in the other direction and tied. The two remaining sutures were used to complete the anastomosis on the ventral surface. All knots were tied within the lumen. The suture was pulled only tight enough to prevent leakage. By distending the mucosa with air blown

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[e]Betadine, Purdue Frederick Co., Norwalk, CT.

[f]Prolene, Ethicon, Inc., Somerville, NJ.

gently through the nasogastric tube, the anastomosis could be checked for leakage. If any leaks were detected, a simple interrupted suture was placed over the defect. For horses in Group II, the feeding tube was passed through the anastomosis into the stomach. In Group III horses, the tube was passed into the thorax, to facilitate location of the esophagus for the esophagostomy. The esophageal muscle and submucosa were closed using simple interrupted sutures of 2-0 monofilament polypropylene.[f] A polyethylene drain[g] (6.5 mm OD) was placed beside the esophagus, and brought out distal to the skin incision through a small stab wound. Muscle layers and subcutaneous tissues were apposed with 2-0 monofilament polypropylene in a simple continuous pattern, except distally, where simple interrupted sutures were used to close the distal 4 cm of each incision in case further drainage was required. Lavage with 2% povidone-iodine continued during surgery and closure. A continuous horizontal mattress suture pattern was used in the skin except the distal 4 cm which was closed with simple interrupted sutures. Suction was maintained on the drain using a 60 ml syringe. A 14 gauge needle was placed through the plunger and over the end of the syringe to maintain the plunger at the 50 ml graduation. A 3-way stop-cock was connected between the syringe and the drain and enabled evacuation of fluid and re-establishment of suction every 2

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[g]Hemovac, Snyder Laboratories, New Philadelphia, OH.

hours initially, and then at longer intervals as less fluid accumulated.

Placement of Feeding Tubes

In Group II horses, the distal end of the nasogastric tube was positioned in the stomach and sutured to the false nostril prior to recovery from anesthesia. Group III horses were placed in right lateral recumbency while still under general anesthesia and the left distal jugular furrow was prepared for surgery. A 5-cm incision was made ventral to the left external jugular vein, as close to the thoracic inlet as possible, followed by blunt dissection dorsal to the sternocephalicus muscle toward the trachea. The nasogastric tube was identified within the esophageal lumen. The esophagus was elevated to permit a 4-cm longitudinal incision to be made in the muscularis externa. The mucosa was grasped with Allis tissue forceps and the nasogastric tube was removed. A longitudinal incision was made in the mucosa just large enough to permit passage of another nasogastric tube through this incision into the stomach. The esophagostomy tube was fastened in place using two butterfly tapes sutured proximally along the neck. The butterfly tapes were fashioned using one inch wide adhesive tape placed around the tube, leaving a flange on each side of the tube which was then sutured to the skin. The skin was left open. Upon recovery from general

anesthesia, the neck was bandaged using a nonadhesive sterile cotton dressing[h] held in place with an adhesive tape[i] placed around the neck. Phenylbutazone (4 mg/kg) was given BID until the 5th postoperative day--intravenously in Group I horses and orally to horses in Groups II and III.

Physical Examination

Skin wounds and suction drains were examined daily. Swelling, discharge and/or dehiscence were used as indicators of infection. The presence of saliva (or food material in Group I) in the suction drain was used as evidence of esophageal mucosal and muscle dehiscence. Purulent material draining into the suction device indicated an infection. When either occurred, the distal sutures in the skin and cervical muscles were removed to allow greater drainage, at which time the drains were removed. In those horses in which dehiscence was severe, all sutures were removed, and the wound left open to granulate. Lavage was performed with 10% povidone-iodine. Remaining sutures were removed when the skin was dry and drainage had stopped. Skin incisions and esophagostomy stomas were considered healed when: (1) they were completely covered with epithelium and food or saliva did not leak from the wound; and (2) barium did not leak from the esophagus or

[h]Triple pad, Parke Davis, Detroit, MI.

[i]Elasticon, Johnson and Johnson, New Brunswick, NJ.

esophagostomy stoma when the esophagus was placed under pressure during the positive pressure esophagram. This latter criteria was found a more reliable indicator than the leakage of food or saliva after the approach incision had healed. A fistula was defined as a narrow communication between the esophageal lumen and the skin, and occurred subsequent to leakage or dehiscence of the esophageal mucosa and muscle. If the same communication existed but did not reach the skin, it was called a sinus tract. These were only demonstrable radiographically.

Endoscopic Examination

The mucosal anastomoses were examined endoscopically[j] every other day starting on day 1 postoperatively, until the 14th postoperative day in the 1st and 3rd groups of horses. All horses were examined weekly after that time. Examination was facilitated by distending the esophagus with air through the endoscope. An assessment of the degree of dehiscence and stricture formation, and the degree of mucosal healing was made. A stricture was defined as any compromise in the lumen diameter demonstrated either endoscopically or radiographically. The mucosa was considered healed when (i) a defect was not observed in the mucosa, (ii) the edges of the mucosal incision were in

[j]Gastroscope GIF, type D3, Olympus Corp. of America, Elk Grove Village, IL.

apposition, (iii) saliva did not leak from the external wound[18] and (iv) a fistula or sinus tract could not be demonstrated radiographically.

Radiographic Procedure

The cervical esophagus of all horses was radiographed 15, 30, 45 and 60 days after surgery. Each study included a lateral survey cervical radiograph, barium paste esophagram, and esophagrams with barium liquid administered under pressure through a 14 ounce dose syringe connected to a nasogastric tube (10 mm OD) fitted with an inflatable cuff[k] to prevent barium reflux, followed by a double contrast film using air under pressure. The paste and liquid contrast media were made by mixing 98.6% barium sulfate powder[l] and 30% barium gastric suspension[m] (paste = 3.1 g of powder/ml of suspension, liquid = 2.1 g of powder/ml of suspension). The following measurements were made from the radiographs, as shown in Figure 1: absolute stricture diameter (a), maximum esophageal diameter cranial to the stricture measured under barium positive pressure (b), and upper and lower esophageal wall defect areas measured at the surgical site. The wall defect areas were determined by extending the line created by the dorsal and

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[k] Silastic tube with inflatable cuff (12 mm inner diameter), Bivona Surgical Inc., Gary, IN.

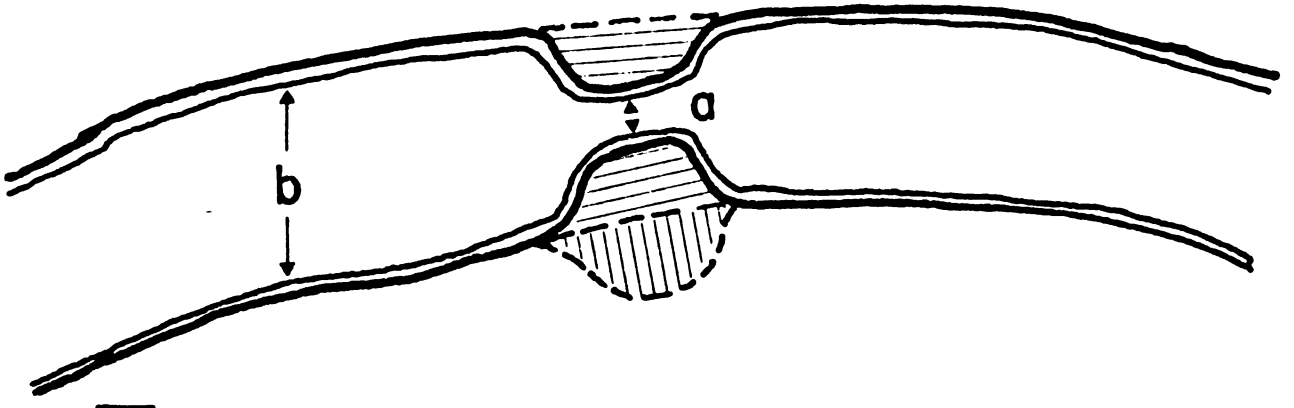
[l] Sol-o-Pake, E-Z-EM Co., Inc., Westbury, NY.

[m] Liquid Sol-o-Pake, E-Z-EM Co., Inc., Westbury, NY.

FIGURE 1

A radiographic representation of esophagus at the surgery site distended under barium positive pressure.

ESOPHAGEAL WALL DEFECTS



DEFECT AT TRACTION DIVERTICULUM

DEFECT AT STRICTURE

a DIAMETER AT STRICTURE

b MAXIMUM DIAMETER

ventral esophageal wall margins on the barium positive pressure esophagrams cranial to the stricture, across to their respective wall margins distal to the stricture. The area encompassed by this line and the outline of the stricture was then measured. In order to differentiate quantitatively between those ventral areas at the stricture site where a traction diverticulum was present (3 horses in Group II) instead of an invagination of the wall, the former areas were designated as negative (Figure 1). The term traction diverticulum was used to describe a cone-shaped outpouching of the esophageal wall at the surgical site, demonstrated radiographically, and sometimes endoscopically. In order to facilitate statistical calculation, the measurements were transformed by adding 10 square cms. The areas were measured using a planimeter.[n] A percentage stricture diameter was calculated by expressing a as a percentage of b.

Necropsy

All animals were euthanatized 60 days postoperatively, using pentobarbital sodium[o] at a dose rate of 7.0 mg/kg injected intravenously. Compliance studies were performed in situ immediately upon euthanasia and then the esophagus was removed for qualitative and quantitative histopathology.

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[n]Compensating Polar Planimeter, No. 62 0002, Kueffel and Esser Co., NY.

[o]Fatal Plus, Vortech Pharmaceuticals Ltd., Dearborn, MI.

Difficulty was encountered in removing the esophagi due to extensive adhesion formation at the surgical site.

1. Pressure-Volume Measurements

The lateral aspect of the esophageal wall was approached at the surgery site. Sufficient dissection was carried out to enable clamps[p] to be placed around the esophagus, to occlude 3 adjacent 7 cm sections, the middle one incorporating the anastomotic site (Figure 2). Any fistulae were closed with a hemostat, close to the muscularis externa. Beginning with the distal segment, a glass Y-piece was introduced through the distal clamp on the segment. One arm was attached to a 3-way stopcock and a 60 cc syringe, and the other arm of the Y-piece to a transducer.[q] We measured the pressure changes of each segment independently by injecting saline into the lumen in 5 cc increments and measuring the resultant changes in pressure with the transducer. Saline was introduced until the segment appeared maximally distended (approximately 50 cc). Following inflation measurements, the measurements were repeated as the esophagus was deflated by removing 5 cc of saline each time, back to base line pressure measurement. The inflation and deflation measurements were repeated. The same procedure was repeated on the other 2 segments. The

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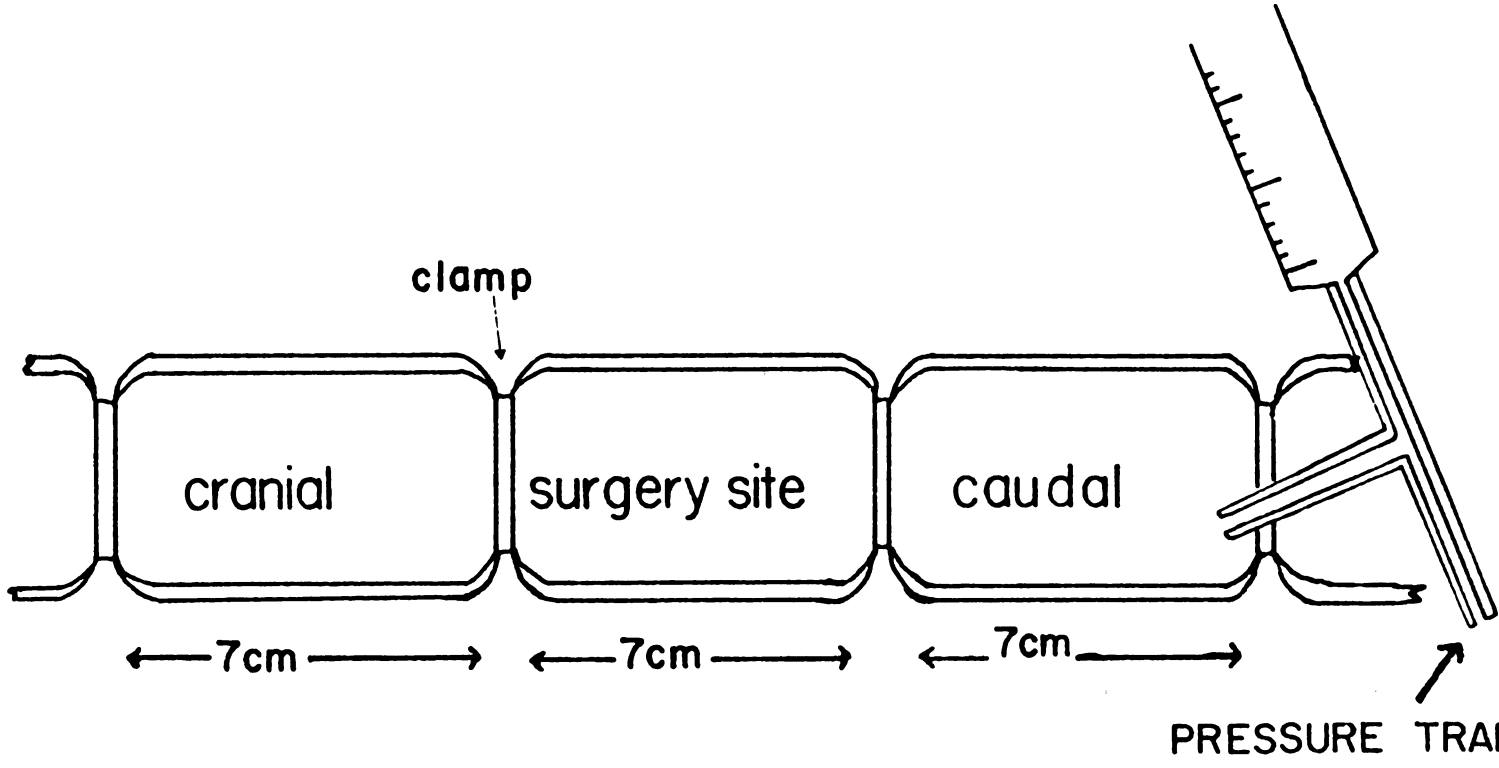
[p]Bar-Lok, Cable Tie Tool, Dennison Manufacturing Co., Framingham, MA.

[q]VR-6, Physiological Recorder, Electronics for Medicine, White Plains, NY.

FIGURE 2

Diagrammatic representation of esophageal wall pressure-volume measurement.

ESOPHAGEAL PRESSURE-VOLUME MEASUREMENT



data were averaged for the inflation and deflation limbs separately. Using a data digitizer,[r] a computer based curve-fitting routine was performed on each section. The computer estimates the parameters (A and B) of the equation $Y = A[1-10^{(BX)}]$, where Y = volume and X = pressure. Both inflation and deflation limbs of the pressure-volume curve were single rising exponentials.

2. Qualitative Pathology

The esophagus was incised longitudinally along its dorsal wall, and the gross appearance of the mucosal incision was examined for the presence of the circumferential scar and any fistulae. The segment which included the surgery site was removed, pinned to a cardboard base under tension, to prevent separation and fragmentation of the layers, and fixed in 10% phosphate-buffered formalin, which is the most suitable fixative for esophageal tissue.[94] The sections for histologic examination were embedded in paraffin in batches,[s] and sectioned[t] with sharpened steel knives at 4 um. Hematoxylin and eosin (H&E) staining[106] was applied to sections automatically[u] in batches, but the remaining stains (Gomori's trichrome,[107] Laidlow's reticulum,[108] and orcein elastin[109]) were done manually.

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[r] GP-6, Sonic Data Digitizer, Science Accessories Corp., Southport, CT.

[s] Histomatic Tissue Processor, Model 166, Fisher Scientific, Pittsburg, PA.

[t] American Optical Microtome, American Optical Scientific Instruments Division, Buffalo, NY.

[u] Model GLS-360, Honeywell Inc., Denver, CO.

3. Quantitative Pathology

Sections stained with H&E and Gomori's trichrome were used for assessing the width of each layer in the esophageal wall.[94] The following layers were identified for the morphometric analysis: keratinized and nonkeratinized epithelium, lamina propria, muscularis mucosa, submucosa and muscularis externa. In those sections where no muscularis mucosa was identified, the lamina propria and submucosa were collectively called the submucosa (Figure 3). The width of each esophageal wall layer was measured directly from a light microscope with planachromatic lenses,[v] using an ocular micrometer. Using the x4 objective, 50 gradations was equal to 1 mm.

Sections stained with orcein-elastin and Laidlow's reticulum stains were suitable for density-dependent image analysis. The relative area of selectively stained fibers (elastin and reticulum), compared to background area, was assessed by an area count of a 60,000 bit video camera,[w] which viewed an area of tissue 0.81 x 0.56 mm for each measurement. The relative proportion of stained to unstained tissue, expessed as a fraction of the total area, was determined for submucosa and muscularis externa on each slide.

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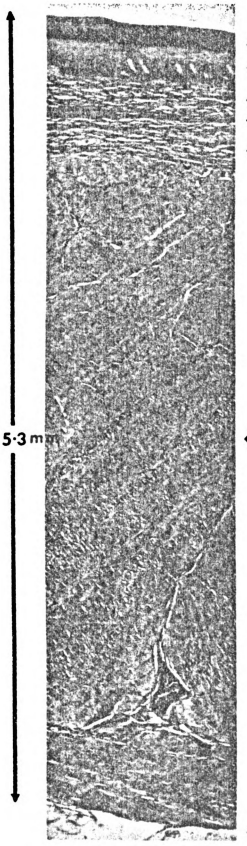
[v]Optomax 2 Inc., Hollis, NH.

[w]Nikon Optiphot, Mager Scientific Inc., Dexter, MI.


KERATINIZED EPITHELIUM
NON-KERATINIZED EPITHELIUM
LAMINA PROPRIA
MUSCULARIS MUCOSA
SUBMUCOSA
5·3 mm
MUSCULARIS EXTERNA
ADVENTITIA

Statistical Analysis

Percent live/dead ratios for each group of horses were compared using a row X column contingency table. Skin healing (SH) and mucosal healing (MH) times were compared for each group using non-parametric test for replicated measurements: the Rank Sum Test (Mann Whitney u).[109] Quantitative data were analyzed using a split plot factorial analysis of variance. Significant differences between means were compared using Tukey's procedure at $p<0.05$.

RESULTS

1. Clinical Data

(a) Group I: Only 2 of the 5 horses survived to the 60th postoperative day. The results are summarized in Tables 1 and 2. Statistical analysis of such a small number was not feasible, so only the data collected from Group II (nasogastric tube-fed) and Group III (esophagostomy tube-fed) horses were analyzed. All mucosal anastomoses dehisced by day 3 postoperatively (Table 1). The retraction of the mucosa at the distal edge of the anastomosis was so severe in 3 of the horses, that it prevented passage of both ingesta and saliva. For this reason, 2 horses were euthanatized 4 days postoperatively (horses 4 and 5), and 1 horse 5 days postoperatively (horse 2). Two horses had their skin, subcutaneous and muscular approach incisions opened completely to facilitate drainage. One of these horses survived (horse 1). The other survivor had the distal portion of the approach incision opened 6 days postoperatively, at which time the drain was removed (horse 3). The approach incisions of the other 2 horses were not opened. The suction drains in the 2 survivors were removed 3 days postoperatively. The remaining 2 horses were

TABLE 1

Number of days between surgery and mucosal dehiscence (MD), muscularis externa dehiscence (MED), opening of approach incision (OA), drain removal (DR) and death (D) in all groups of horses

No. of horses	No. of days between surgery and				
Group I (oral)	MD	MED	OA	DR	D
1	3	3	3	3	NA
2	3	3	3	3	5[b]
3	2	6	6	6	NA
4	3	NA	NA	NA	4[b]
5	3	3	NA	NA	4[b]
Means±SEM	2.8±0.2	3.8±0.8	4.0±1.0	4.0±1.0	4.7±0.3
Group II (nasogastric)[a]					
6	14	5	4	2	NA
7	14	5	2	2	NA
8	14	5	5	5	NA
9	14	3	5	5	NA
10	14	4	11	5	NA
Means±SEM	14.0	4.4±0.4	5.4±1.5	3.8±0.7	
Group III (esophagostomy)					
11	NA	NA	NA	NA	0[b]
12	7	NA	7	7	NA
13	3	NA	5	5	8
14	3	NA	5	5	4
15	3	NA	4	7	NA
16	3	4	4	4	NA
17	5	NA	5	5	28
18	3	NA	NA	5	NA
19	3	NA	5	5	8[b]
20	3	NA	5	5	14[b]
Mean±SEM	3.7±0.5	4.0	5.0±0.3	5.3±0.3	10.3±4.0

NA = not applicable

[a]No. endoscopic examinations performed till day 14 postoperatively

[b]These horses were euthanatized

euthanatized before the drains were removed. Dehiscence of the esophageal muscle incision occurred in 4 of the horses. The mean skin healing time was 45.0 ± 15.0 days and the mean mucosal healing time was 53.5 ± 9.2 days (Table 2). Both these animals developed esophageal strictures.

TABLE 2

Clinical Data Results of Group 1 Horses (n = 5)

Fistula	4/5	horses
Sinus tract	N/A	
Skin healing time (n = 2)	45.0 ± 15.0	days
Mucosal healing time (n = 2)	53.5 ± 9.2	days

(b) Group II: All 5 horses survived to the 60th postoperative day. The clinical data from horses in Groups II and III are summarized in Tables 1 and 3. All mucosal anastomoses had dehisced to varying degrees by the 14th postoperative day (Figure 4). All horses had their approach incisions opened distally to provide drainage, subsequent to drain removal. Two horses developed fistulae and 2 developed sinus tracts (Figures 5 and 6). Mean skin healing time was 50.0 ± 6.0 days and mean mucosal healing time 52.0 ± 7.4 days. Strictures developed in all horses and traction diverticuli developed in 3 of these horses (Figure 5).

TABLE 3

Clinical data results of Group II and Group III horses

	Group II (nasogastric tube-fed)	(Group III) (esophagostomy tube-fed)	
60-day survival	5/5[a]	4/10[a]	horses
Fistula development	2	1	horses
Sinus tract	2	1	horses
Skin healing time	50.0 ± 6.0[b]	35.8 ± 17.7[b]	days
Mucosal healing time	52.0 ± 7.4[c]	25.5 ± 13.9[c]	days
Stricture development	5	5	horses
Traction diverticulum	3	-	horses
Esophagostomy closure		33.0 ± 8.2	days

Data marked by similar superscripts were significantly different at $p = 0.05$.

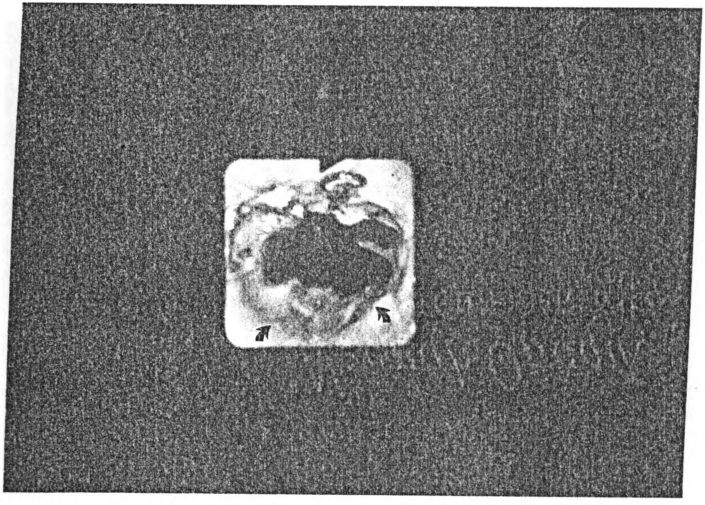


FIGURE 4

Endoscopic appearance of the esophageal mucosa 3 days postoperatively (Horse 10, Group II) demonstrating considerable mucosal separation along the suture line, exposing the submucosa (arrows). The photograph was taken when the horse dislodged its' nasogastric tube.

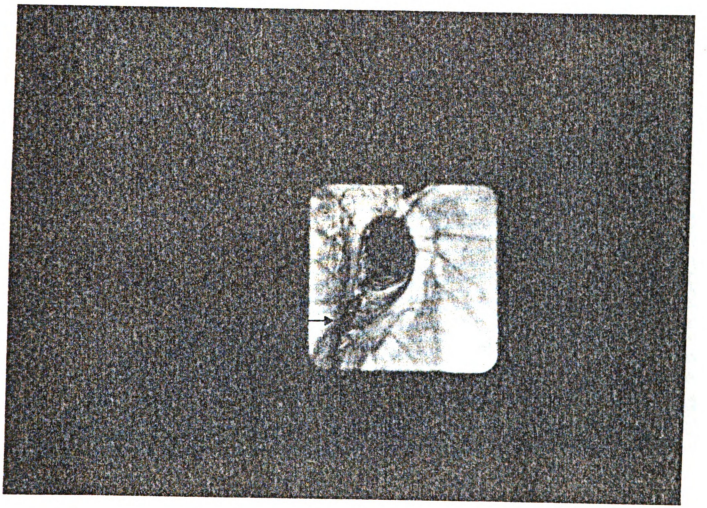


FIGURE 5

Endoscopic appearance at anastomotic site showing strictured area, traction diverticulum and a fistula (arrow) at the base of the diverticulum on the 50th postoperative day (Horse 6, Group II).

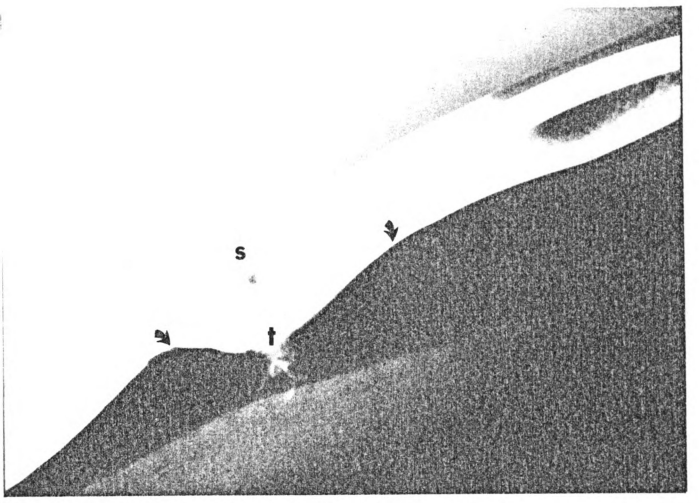


FIGURE 6

Barium positive pressure esophagram of Horse 7 in Group II 30 days postoperatively, illustrating a stricture site (s), traction diverticulum (arrows) and sinus tract (t).

(c) Group III: The results are summarized in Tables 1 and 3. Only 4 of the 10 horses in this group survived to the 60th postoperative day. This number was significantly less than the Group II horses. Mucosal dehiscence occurred to varying degrees in this group also. There was edema and signs of mucosal separation as early as day 1 postoperatively (Figure 7). The time and causes of death in Group III horses are listed in Table 4. Three horses had their incisions opened completely to provide drainage, and the incisions of another 5 horses were opened distally only. The drains were removed when these procedures were carried out. The remaining horse's drain was removed 3 days postoperatively, but no further drainage procedures were necessary.

Horse 11 was euthanatized on the recovery room floor immediately postoperatively due to a forelimb myositis/ neuritis. Horse 6 was also euthanatized because he choked on wood shavings the day following esophagostomy tube removal, and in an effort to remove the shavings with lavage, the nasogastric tube created a perimucosal tract, distal to the surgery site. In an effort to replace the esophagostomy tube, to facilitate further feeding and allow the surgical site to rest, the same problem occurred. Peri-esophageal tracts were made into the thoracic inlet, as the lumen could not be found through the esophagostomy stoma. The horse was humanely destroyed.

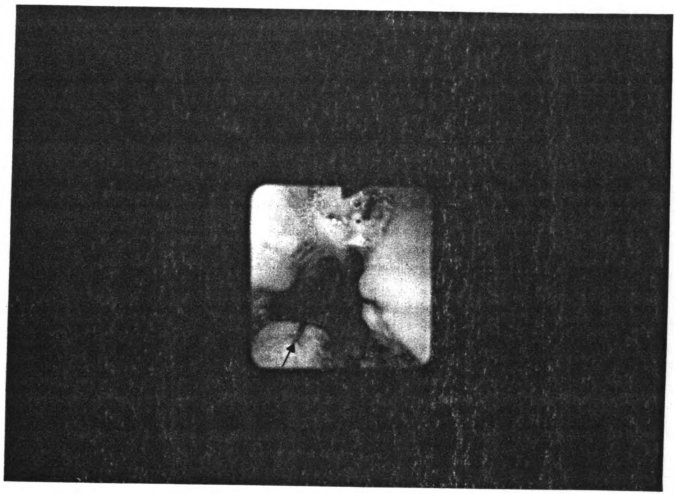


FIGURE 7

Endoscopic appearance of the esophageal mucosa 1 day postoperatively, from Horse 18 in Group III, demonstrating mucosal swelling and early appearance of submucosa at the suture line (arrow), indicating tension on the anastomosis.

TABLE 4

Horse, day of death postoperatively and cause of death in Group III (esophagostomy tube-fed horses)

Horse	Time (days postoperatively)	Cause
11*	0	Forelimb myositis/neuritis
13	8	Asphyxiation
14	4	Asphyxiation
17	28	Unknown
19	8	**Phenoxybenzamine overdose
20*	15	Peri-esophageal tracts

*euthanasia

**Dibenzaline, Smith, Kline and French, Division of Smithkleine, Beckman Corp., Philadelphia, PA 19101.

Horse 17 died of unknown causes 28 days postoperatively. Horse 19 developed acute laminitis, and died when it was treated with the alpha-blocker, phenoxybenzamine, for the second time. Horses 13 and 14 died from asphyxiation due to bilateral laryngeal paralysis.

One horse developed a fistula (Figure 8), and one a sinus tract. Mean skin healing time of 35.8 $\pm$ 17.7 days was significantly faster than the Group II horses. Similarly, mean mucosal healing time (25.5 $\pm$ 13.9 days) was significantly faster than that of Group II. Five horses developed strictures i.e., all those that survived long enough to demonstrate them radiographically. The mean esophagostomy stoma closure time was 33.0 $\pm$ 8.2 days.

Miscellaneous Complications

Apart from the surgical complications already described, there were a number of other problems, some of which were not related directly to the surgery. The nasogastric tube, which was left in place for 14 days in the horses in Group II caused a rhinitis characterized by mucopurulent nasal discharge and nasal mucosal ulceration. Wretching movements were not uncommon in these horses and they occasionally managed to displace their tubes also. Reflux of mash around and through the nasogastric tubes occurred when the stomach was full. Tubal obstruction could usually be relieved by pressure applied by mouth or a 14

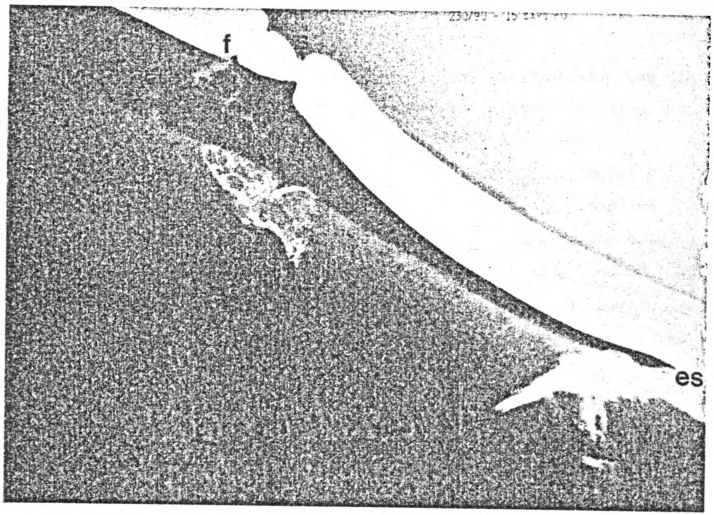


FIGURE 8

Barium positive pressure esophagram illustrating a stricture (s), fistula (f) and esophagostomy stoma (es) (Horse 16, Group III).

ounce dose syringe. Variable quantities of saliva leaked from the esophagostomy stomas in the Group III horses depending on the size of the incision in the esophageal mucosa. Two of the surviving horses in this group developed jugular thrombosis. In addition to the 2 horses in Group III that asphyxiated due to bilateral laryngeal paralysis, 2 other horses in this group developed left laryngeal hemiplegia (Figure 9), one of which did not resolve. One of the horses in Group III that asphyxiated (horse 14) also had radial nerve paralysis in the immediate postoperative period. Two horses in Group II developed colic. Horse 7 had ileus immediately postoperatively and horse 9 had two episodes of spasmodic colic 28 and 55 days postoperatively. Both horses recovered. Two horses in this group, one of whom died 28 days postoperatively (horse 17, Table 4) of unknown etiology, developed retro-pharyngeal swelling in the immediate postoperative period (Figure 10). The other in this duo needed a tracheostomy (horse 16).

Choke was a continuing problem particularly in some of the esophagostomy tube-fed and orally fed horses, due to stricture formation (Figure 5). There was a tendency for the horses to ingest the wood shavings from the stall floor, necessitating the use of a bare stall for these animals. The esophagostomy tube-fed horses also had more depressed appetites when the tubes were removed 14 days post-operatively, and some needed supplementary tube-feeding.

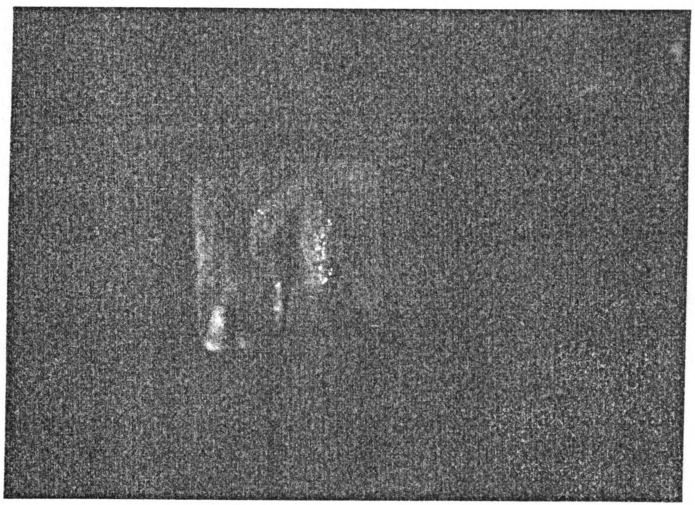


FIGURE 9

Endoscopic appearance of the larynx of one of the horses (Horse 15, Group III) showing left laryngeal hemiplegia in which the left arytenoid cartilage fails to abduct on inspiration.

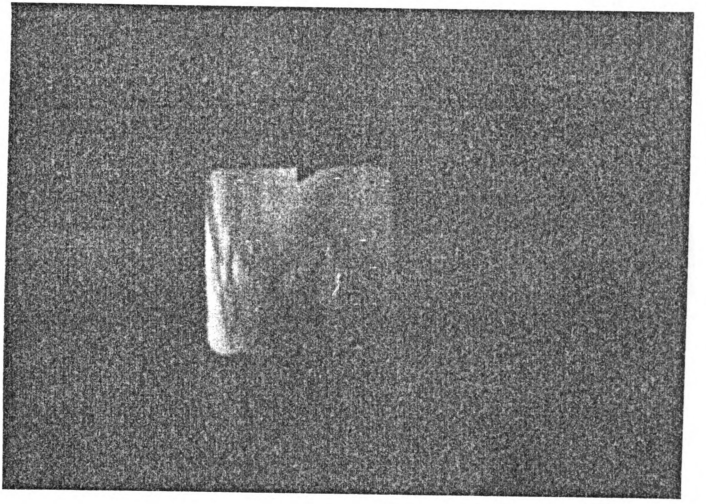


FIGURE 10

Endoscopic appearance of the larynx and caudal dorsal pharyngeal area showing left laryngeal hemiplegia and occlusion of the pharyngeal lumen due to pressure from a retropharyngeal swelling (Horse 16, Group III).

2. Radiology

(a) Group I: The mean absolute stricture diameter (Figure 1) for the two horses that survived in this group, is shown in Table 5. The calculated percentage stricture diameters for the same time periods are shown in Table 6. Although statistical analyses could not be performed as only 2 horses survived, the trends in the changes in the absolute lumen diameter and percentage stricture diameter did not follow the same pattern as those for the other two groups of horses. There was a decrease in absolute lumen diameter and percentage stricture diameter between 15 and 30 days postoperatively, followed by an increase at the 45 and 60 postoperative day time periods. The decrease in diameter was not seen in the other two groups of horses between 15 and 30 days postoperatively.

The upper and lower esophageal wall defect areas are shown in Table 7. The general trend was for the upper wall area to decrease, as the lumen enlarged over time, while the lower wall area remained about the same.

(b) Group II and Group III: There was no significant difference between these two groups in absolute stricture diameter at the surgery site, percentage stricture diameter, and wall defect area measurements above and below the stricture site. Absolute stricture diameter and percentage stricture diameter increased with time in both

TABLE 5

Absolute stricture diameter ($\bar{x}$+SEM in cm) for each group of horses at 15, 30, 45 and 60 days postoperatively measured from barium positive pressure esophagrams

	Days Postoperatively			
	15	30	45	60
Group I (n = 2)	10.0 ± 2.0	8.5 ± 0.5	9.0 ± 2.0	13.0 ± 5.0
Group II (n = 5)	17.6 ± 2.4	19.0 ± 2.8	23.0 ± 3.5	24.8 ± 3.3
Group III (n = 4)	12.5 ± 1.8	13.8 ± 3.4	15.8 ± 3.8	15.5 ± 2.3

Means of Groups II and III underscored by the same line are not significantly different at the 0.05 level. Statistical analysis was not performed on Group I since there were only 2 horses.

TABLE 6

Percentage stricture diameter (absolute stricture diameter expressed as a percentage of the maximum cranial esophageal diameter) ($\bar{x}$±SEM) at 15, 30, 45 and 60 days postoperatively, measured from barium positive pressure esophagrams

	Days Postoperatively			
	15	30	45	60
Group I (n = 2)	24.5 ± 5.5	20.0 ± 1.0	23.5 ± 0.5	30.0 ± 0.4
Group II (n = 5)	57.6 ± 7.8	58.8 ± 2.2	79.0 ± 5.0	78.4 ± 2.2
Group III (n = 4)	37.5 ± 5.4	37.8 ± 8.7	49.3 ± 2.2	52.5 ± 10.0

Means from Groups II and III underscored by the same line are not significantly different at the 0.05 level. Statistical analysis was not performed on Group I.

TABLE 7

Upper and lower esophageal wall defect areas ($\bar{x}$+SEM in cm^2) for each group of horses at 15, 30, 45 and 60 days postoperatively

	Days Postoperatively			
	15	30	45	60
Group I				
Upper	1.5 ± 0.8	0.8 ± 0.1	0.4 ± 0.3	1.3 ± 0.1
Lower	2.2 ± 0.2	2.7 ± 1.0	1.7 ± 0.1	2.4 ± 0.2
Group II				
Upper	1.4 ± 0.3	1.7 ± 0.5	0.7 ± 0.3	0.0 ± 0.8
Lower	1.0 ± 0.5	-1.9 ± 1.5	-1.4 ± 1.2	-0.7 ± 1.3
Group III				
Upper	1.2 ± 0.3	0.7 ± 0.1	0.4 ± 0.1	0.6 ± 0.2
Lower	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.2	0.3 ± 0.1

There was no significant time effect.

groups (Tables 5 and 6). In Group II, the nasogastric tube-fed horses, there was a significant increase in absolute lumen diameter between 30, 45 and 60 days postoperatively (Figure 11). The greatest increase in absolute lumen diameter occurred between 30 and 45 days postoperatively. The same changes occurred in the Group III (esophagostomy tube-fed) horses, the significant increase in absolute lumen diameter occurring between 30 and 45 days postoperatively. This change in lumen diameter in the same horse is demcnstrated by the endoscopic appearance of the esophagus in horse 12, Group III, 30 days postoperatively (Figure 12) and then at 60 days postoperatively (Figure 13). The corresponding radiographic appearance of the esophagus at the stricture site at the same time is shown in Figures 14 and 15. At each of the time periods measured, the percentage stricture diameter also increased significantly except between the 45 and 60 day time period in Group II and between the 15 and 30 day time period in Group III horses. The major changes occurred however, in both Groups between 30 and 45 days postoperatively. At 60 days postoperatively the mean percentage stricture diameter was 78% of the maximum cranial diameter in the Group II horses and 52% in the Group III horses. These comparative differences in lumen diameter are demonstrated raiographically in Figures 16 and 17.

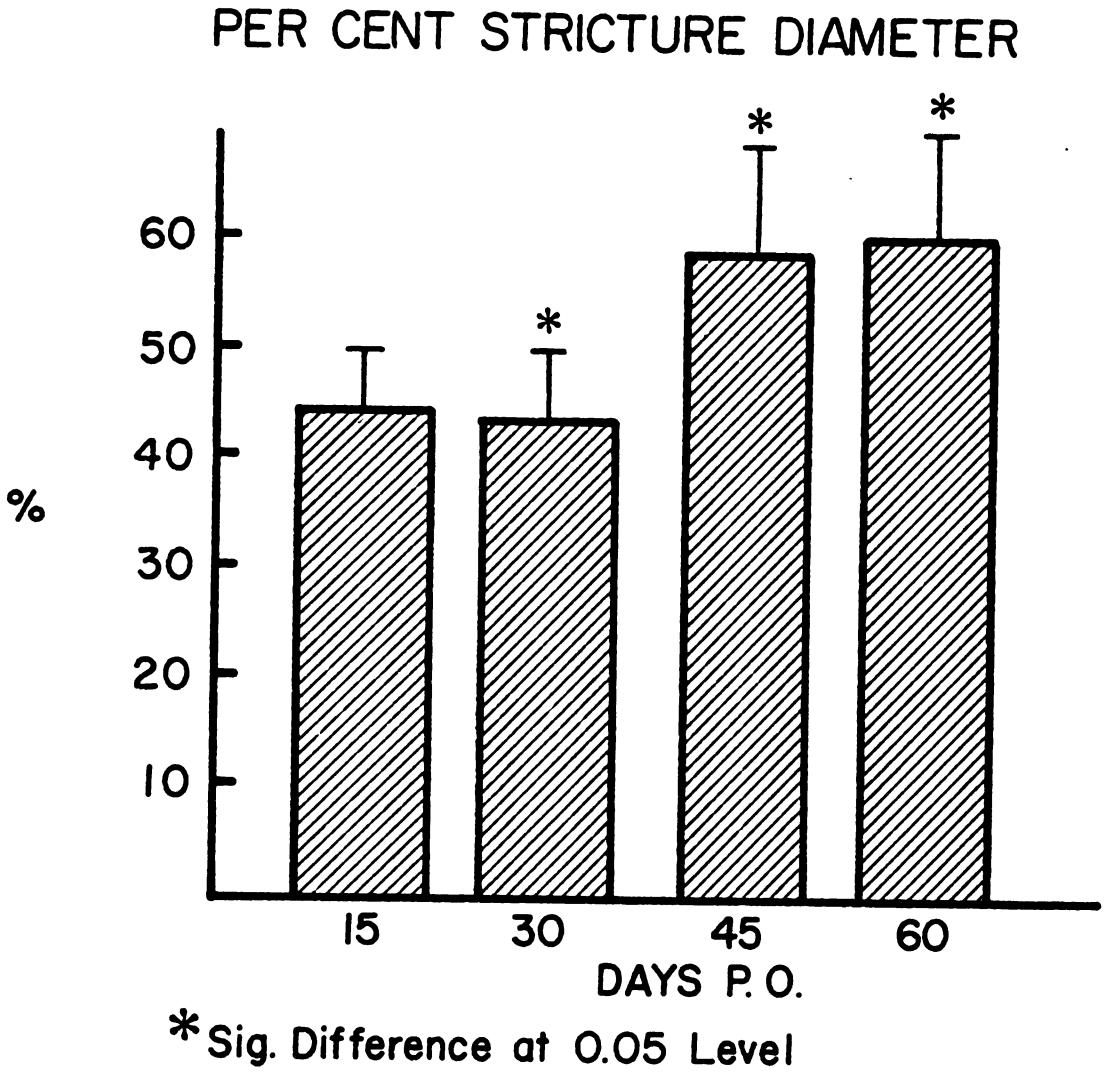


FIGURE 11

Histogram illustrating average percentage stricture diameter (vertical axis) of all Groups II and III horses with days postoperatively on the horizontal axis.

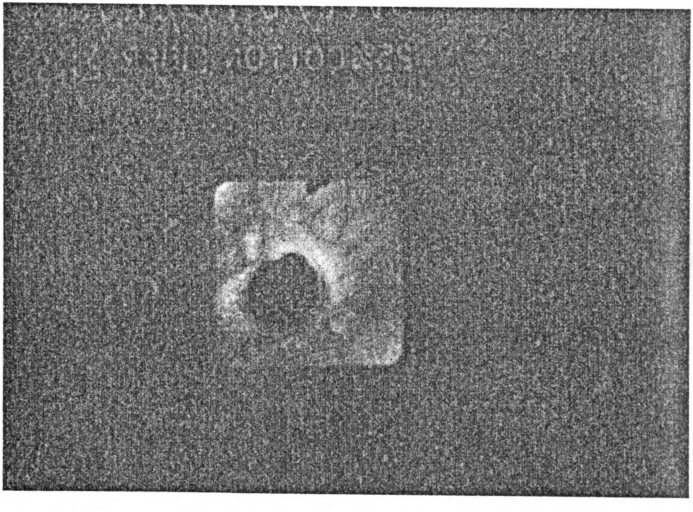


FIGURE 12

Endoscopic appearance of the stricture 30 days postoperatively in Horse 12, Group III.

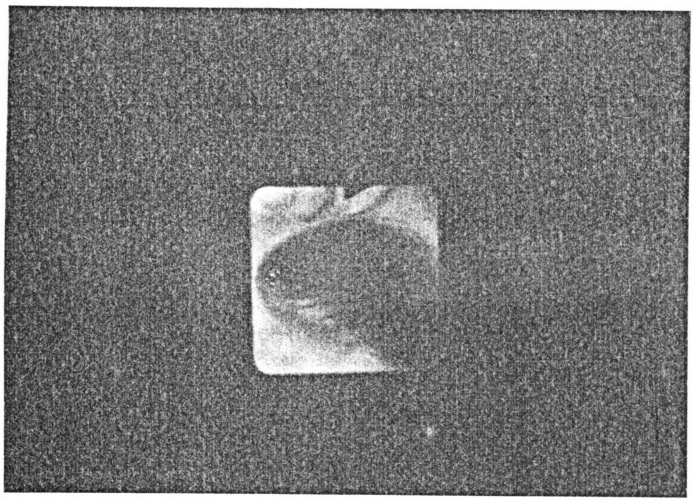


FIGURE 13

Endoscopic appearance of the stricture in the same horse as Figure 12, 60 days postoperatively.

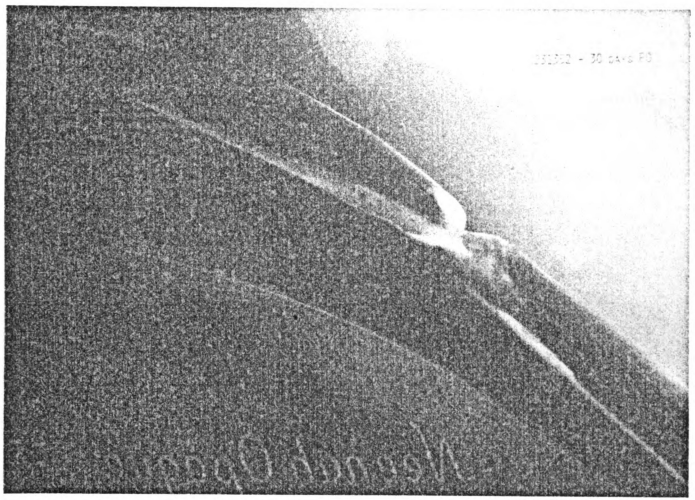


FIGURE 14

Barium double contrast esophagram made 30 days postoperatively from the same horse as in Figures 12 and 13.

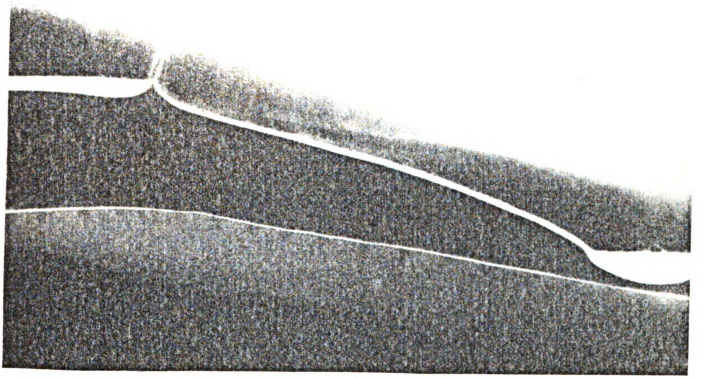


FIGURE 15

Barium double contrast esophagram made 60 days postoperatively from the same horse as in Figures 12, 13, and 14.

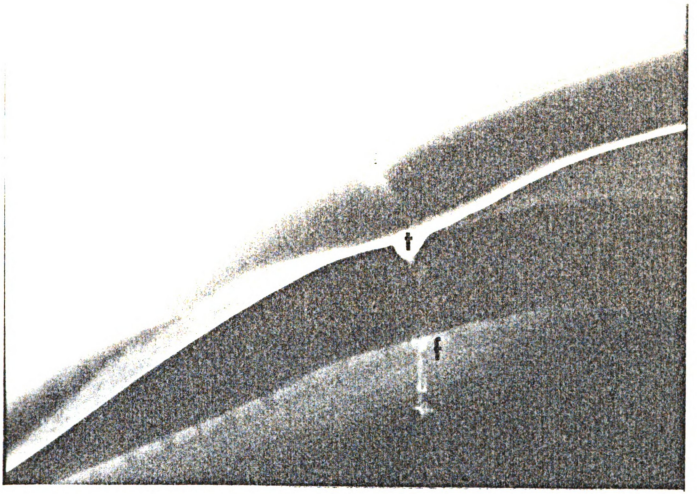


FIGURE 16

Barium double contrast esophagram of Horse 7, Group II, taken 60 days postoperatively. Note the traction diverticulum (t) and fistula (f).

FIGURE 17

Barium positive pressure esophagram of Horse 12, Group III, taken 60 days postoperatively.

No significant difference could be demonstrated between groups in the esophageal wall defect areas (Table 7). Nor was there a significant alteration over time. However, the mean upper wall defect area was significantly larger than the lower wall defect area in both Groups II and III (Table 8) (Figure 18). This is a reflection of the traction diverticuli that predominated in the healing process in the Group II horses.

TABLE 8

Upper and lower esophageal wall defect areas for horses in Groups II and III ($\bar{x}\pm$SEM in cm^2)

	Upper*	Lower
Group II	1.0 ± 0.4	-0.8 ± 0.6
Group III	0.7 ± 0.2	0.5 ± 0.1

*Significant difference at 0.05 level between mean upper and lower areas.

3. Pressure-Volume Measurements

The procedure for measuring the pressure-volume curve of the esophageal wall was only performed on Group I and II. Because there was no difference in compliance between the area in which the surgery had been performed and the relatively normal esophagus cranial and caudal to it in

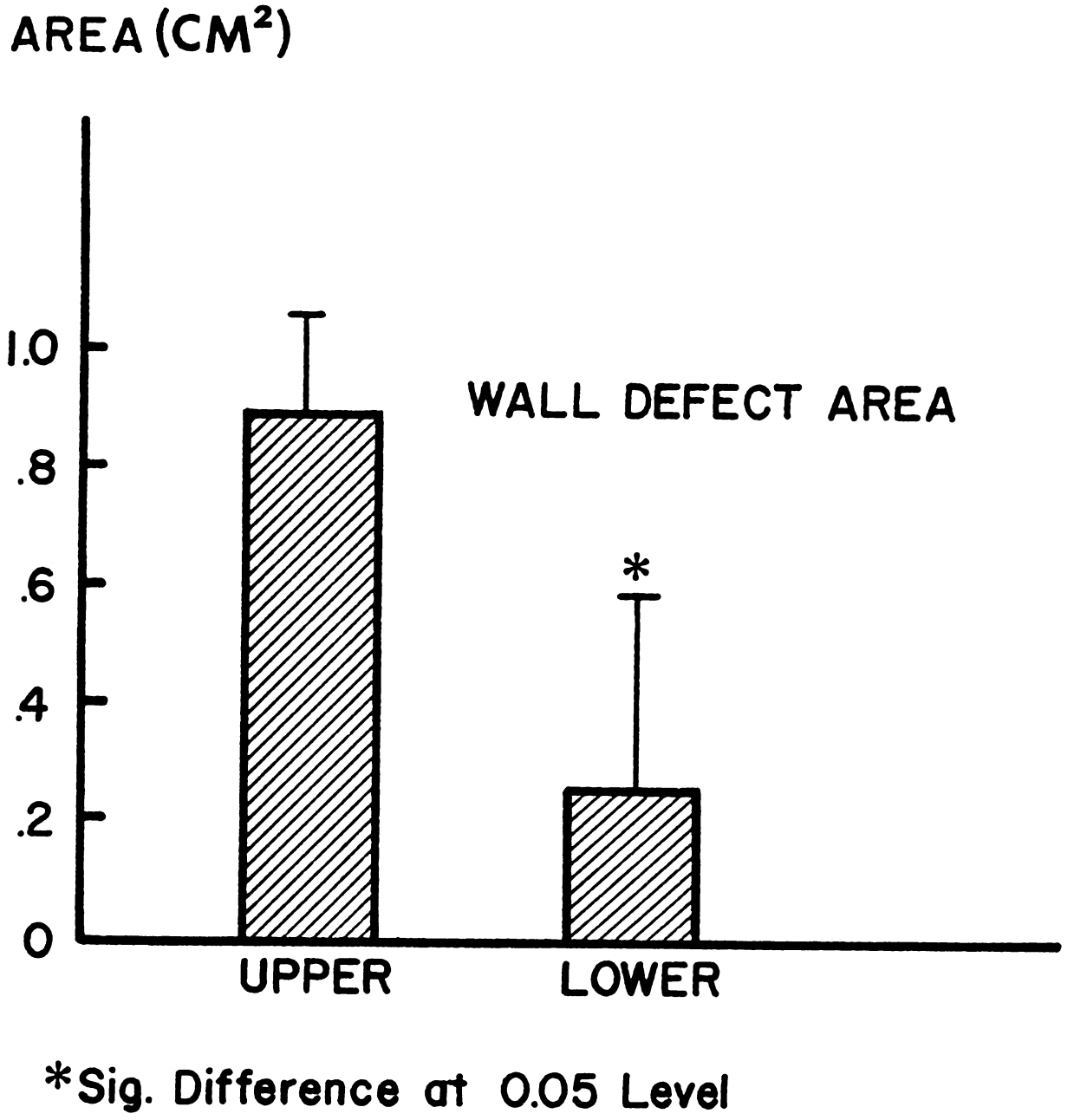


FIGURE 18

Histogram showing upper and lower wall defect areas for all horses in Groups II and III.

these groups, I did not perform the measurements for Group III. The mean pressure changes occurring in all segments in Group I and II horses, for each 5 ml change in volume are shown in Table 9. The average pressure-volume curve derived from all these values in Group II is illustrated in Figure 19. The esophagus was more compliant on deflation than inflation. A computer-based curve-fitting routine was used to derive the values of A and B, as already described and these values were used to compare each curve and each section (Table 10).

4. Qualitative Pathology

The sections stained with hematoxylin and eosin (H&E) and Gomori's trichrome were used for qualitative light microscopic evaluation and esophageal wall cross-sectional measurements.

(a) Group I: Because 3 horses in this group had to be euthanatized less than five days postoperatively, the surgical sites could be examined immediately following dehiscence. Lesions consisted of a suppurative esophagitis which extended on either side of the underrun submucosa in all layers of the esophageal wall (Figure 20). The fibroblasts were hyperplastic and hypertrophic with large nucleoli and irregular cytoplasms. Other changes included abscess formation with bacterial colonization, vasculitis, lymphatic distention and edema (Figure 21). There was also

TABLE 9

Pressure ($\bar{x}$+SEM in torr) and volume (ml) during inflation and deflation of the esophagus. These data were used to estimate the compliance of the esophageal wall for all Groups I and II horses. The pressures are a composite of the cranial, surgical and caudal sites

Volume (ml)	Pressure			
	Inflation		Deflation	
	Group I	Group II	Group I	Group II
0	0	0	0	0
5	6.16 ± 3.20	2.74 ± 0.36	4.49 ± 2.64	1.27 ± 6.23
10	8.97 ± 4.88	5.61 ± 0.65	5.60 ± 2.66	2.76 ± 0.36
15	14.73 ± 7.69	11.08 ± 0.79	7.99 ± 3.32	5.48 ± 0.57
20	23.55 ± 11.45	20.77 ± 1.38	11.73 ± 4.06	9.25 ± 0.71
25	37.05 ± 17.96	32.92 ± 2.06	16.54 ± 5.42	18.52 ± 1.35
30	61.95 ± 29.09	67.27 ± 6.10	25.84 ± 9.95	43.04 ± 4.92
35	99.45 ± 48.9	104.44 ± 9.74	47.35 ± 23.47	60.47 ± 6.67
40	174.65 ± 72.05	142.51 ± 13.02	103.57 ± 63.90	117.50 ± 11.93
45	198.03 ± 89.47	164.15 ± 19.20	184.60 ± 98.91	121.32 ± 18.42
50		213.33 ± 28.83		167.55 ± 38.55

TABLE 10

Computer-calculated values of A & B ($\bar{x}$±SEM) for the equation $Y = A[1-10^{(BX)}]$ which describes the single rising exponential pressure-volume curve for Group I and II horses combined. Three regions (cranial, surgical site and caudal) were measured, under both inflation (Infl.) and deflation (Defl.)

Cranial		Surgical Site		Caudal	
Infl.		Infl.		Infl.	
A	B	A	B	A	B
46.9 ± 4.5	-.0416 ± .0095	44.3 ± 2.2	-.0276 ± .0050	41.3 ± 1.8	-.0286 ± .0058
Defl.		Defl.		Defl.	
A	B	A	B	A	B
45.7 ± 4.7	-.0366 ± .0068	45.0 ± 3.0	-.0349 ± .0056	41.3 ± 1.8	-.0379 ± .0071

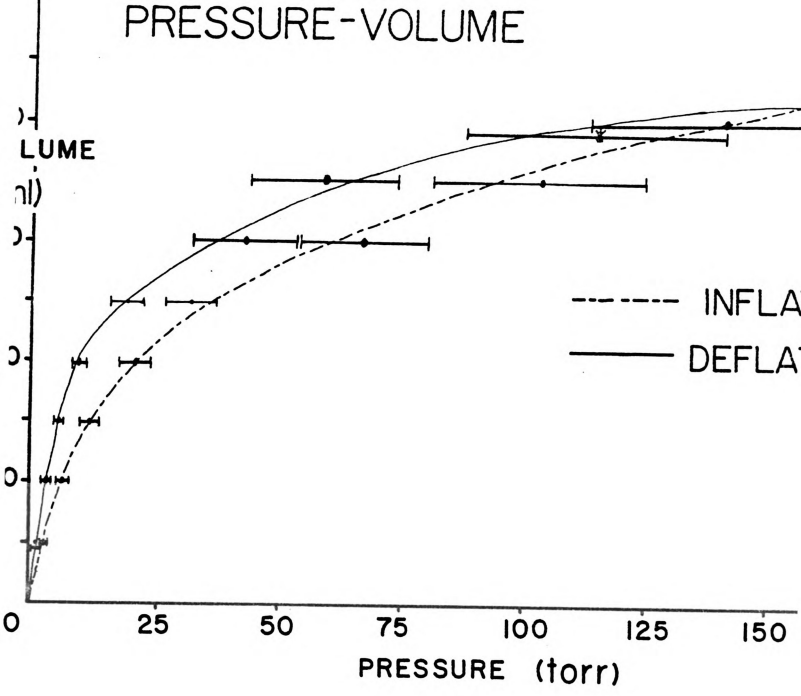


FIGURE 19

Pressure-volume curve of the esophagus representing the average inflation and deflation limbs of all horses in Group II. The intraluminal pressure is shown on the horizontal axis, and the volume of saline administered is shown on the vertical axis. Standard error bars are marked. There was a significant difference between the inflation and deflation limbs at the 0.05 level.

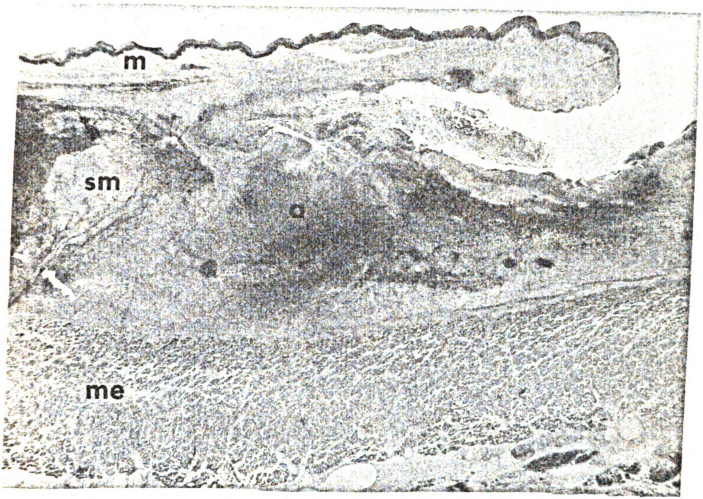


FIGURE 20

Histopathologic appearance of a longitudinal cross-section of the esophageal wall from Horse 2, Group I, 3 days postoperatively. Note the underrunning of the submucosa and the abscess formation in the same area (Gomori's Trichrome stain, original magnification X2). m = mucosa; sm = submucosa; a = abscess; me = muscularis externa.

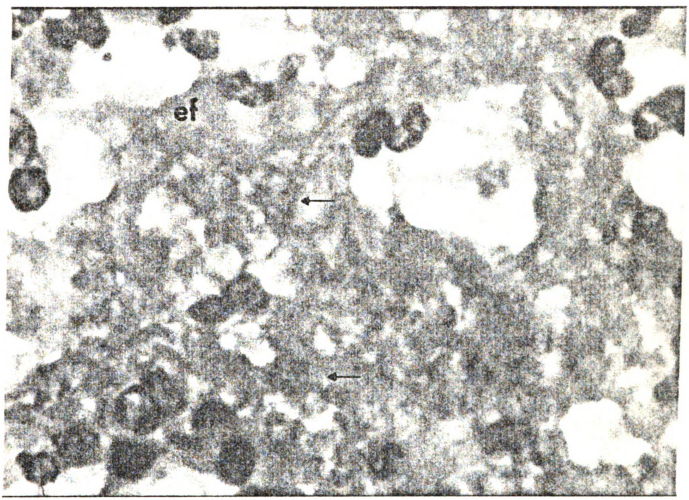


FIGURE 21

Submucosal inflammation 3 days postoperatively in the same horse as in Figure 20. Submucosal tissues contain extensive amounts of proteinaceous edema fluid (ef) in which numerous bacteria are present (arrows). The inflammatory cells present are predominantly neutrophils (H&E stain; original magnification X1000).

a purulent myositis (Figure 22) and considerable periesophageal suppurative cellulitis.

The histopathologic changes in the two horses in this group that followed the protocol to the 60th postoperative day were those of a chronic inflammation. In longitudinal sections taken across the mucosal scar and extending through the muscularis externa incision, there was dense fibrous tissue obliterating all layers underneath the mucosa (Figure 23). Horse 16, Group III is used as an example. These changes were also characteristic of the other horses in Groups II and III that survived to the 60th postoperative day. In sections away from the muscularis externa incision, there was thickening of the submucosa below the mucosal scar (Figure 24). Horse 6 in Group II is used as an example. Regeneration and keratinization of the hypertrophic hyperplastic mucosa was not always complete (Figure 25). The predominant inflammatory cell types present in the submucosa were macrophages, lymphocytes and neutrophils. There was some atrophy of the muscularis externa, and suture tracts associated with marked granulomata formation and very dense collagen deposition (Figure 26). Horse 10, Group II is used as an example.

(b) Group II: The chronic inflammatory reactions in the esophageal wall in these horses were similar to Group I horses in the 60 day postoperative period. There was variability in the degree of mucosal healing in these

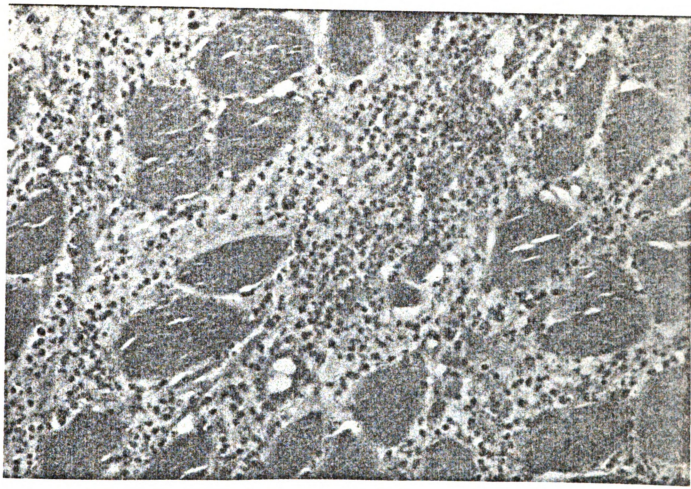


FIGURE 22

Purulent myositis in the muscularis externa of the same horse as in Figures 20 and 21, 3 days postoperatively. The muscle fibers are degenerating, and fibers are widely separated by edema fluid and neutrophils (Gomori's Trichrome stain; original magnification X100).

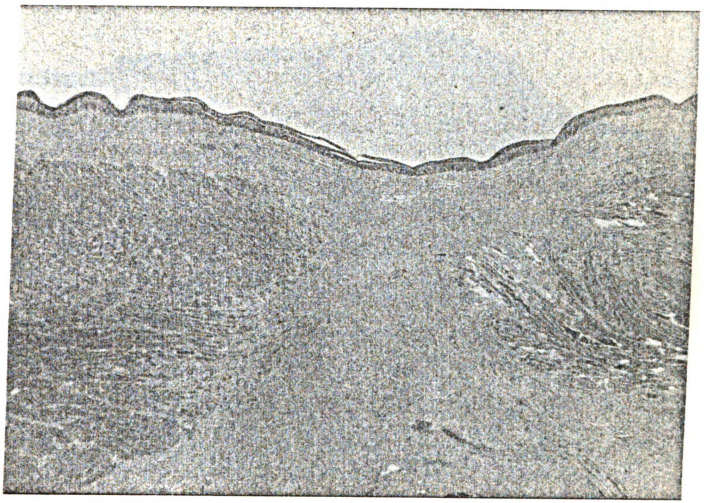


FIGURE 23

Histopathologic appearance of the esophageal wall in Horse 16, Group III, in transverse section, illustrating the dense fibrous tissue in the area through the muscularis externa incision. Note that the mucosa is completely healed (Gomori's Trichrome stain; original magnification X2).

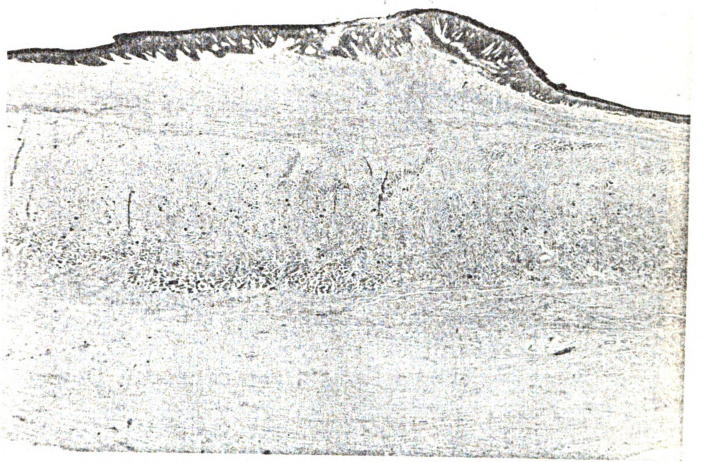


FIGURE 24

Histopathologic appearance of the esophageal wall in longitudinal section, from Horse 6, Group II, showing thickening in the submucosa and hypertrophy and hyperplasia of the mucosa at the surgical site in the center. Normal esophageal wall layers are present on each side (Gomori's Trichrome stain; original magnification X1.5).

FIGURE 25

Histopathologic appearance of the esophageal wall demonstrating on the extreme left an area of ulceration and inflammatory cell lining from Horse 1, Group I. Adjacent to this area, the mucosa has regenerated (arrow) but is abnormal. There is vacuolation of the mucosa and incomplete keratinization. On the right of the photomicrograph, the mucosa is keratinized (magenta color), but the mucosa remains hyperplastic. The submucosa is hypercellular (Gomori's Trichrome stain; original magnification X20).

FIGURE 26

A longitudinal cross-section across the mucosal surgical site in Horse 10, Group II, showing suture granulomata (arrows) and a sinus tract (t). Epithelial regeneration around the sinus tract is incomplete and adjacent epithelium is hypertrophied (Gomori's Trichrome stain; original magnification X2).

horses. An ulcer remained in one horse (Figure 25) while in another, the mucosa was nearly normal. A sinus tract was present in one section (Figure 26). Particles of a rhomboidal shape observed in one granuloma were birefringent under polarized light and were suggestive of talc particles.

(c) Group III: With 2 exceptions, these horses were similar to the above groups: Firstly, in all horses mucosal repair was complete. In most horses the site of surgical incision would still be identified because the mucosa was hypertrophied but in 2 horses no zone of hypertrophy was identified; secondly, this group demonstrated more periesophageal cellulitis than horses in other groups. One horse from Group III had an extensive granulomatous reaction with giant cell formation in both the submucosa and muscularis externa. In some of these giant cells there were refractile fragments whose shape was suggestive of suture material (Figure 27). Other changes in the esophageal adventitia of this horse included nerve fiber degeneration, severe fibroelastosis and thrombosis of arteries and patchy muscular degeneration.

Esophageal Wall Cross-Sectional Dimensions

No significant differences in width could be demonstrated between the horses in Groups II and III in any layer of the esophageal wall that was measured (Table 11). In both groups, however, the submucosa was significantly

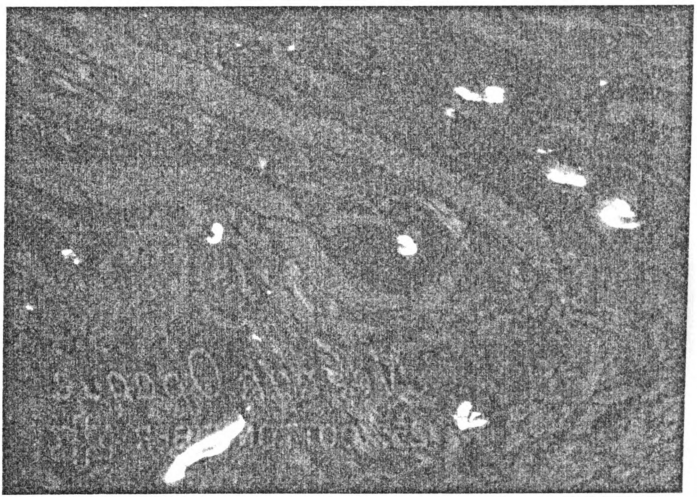


FIGURE 27

Histopathologic appearance of the adventitia in Horse 16, Group III, 60 days postoperatively (viewed under polarized light), illustrating granulomatous inflammation. Numerous giant cells containing fragments of refractile material are present. The fibrillar material that is partially refractile is characteristic of collagen (H&E stain; original magnification X100).

TABLE 11

Cross-sectional width of esophageal tissue layers ($\bar{x}\pm$SEM in mm) for horses in Groups I, II, and III

Tissue layer	Group I	Group II	Group III
Keratinized epithelium	0.079 ± 0.010	0.058 ± 0.008	0.056 ± 0.008
Non-keratinized epithelium	0.260 ± 0.050	0,436 ± 0.128	0.194 ± 0.016
Total epithelium	0.339 ± 0.058	0.492 ± 0.132	0.250 ± 0.032
Lamina propria	0.045 ± 0.028	0.056 ± 0.040	Absent
Muscularis mucosa	0.010 ± 0.006	0.005 ± 0.004	Absent
Submucosa	1.140 ± 0.104	1.162 ± 0.246	1.204 ± 0.080
Total connective tissue	1.196 ± 0.104	1.672 ± 0.232	1.204 ± 0.082
Muscularis externa	3.934 ± 0.208	3.700 ± 0.330	3.066 ± 0.254
Total esophageal wall	5.568 ± 0.260	5.866 ± 0.468	4.518 ± 0.270

thicker at the mucosal surgical site than away from it. These measurements were taken in an area well away from the muscularis externa incision (Figure 24). The mean submucosal width for both Group II and III horses at the surgical site was 1.3 $\pm$ 0.1 mm compared o 1.0 $\pm$ 0.1 mm away from the surgical site.

Image Analysis

The density-dependent image analysis using the reticulum and elastin stains was performed on the submucosa and muscularis externa for horses in Groups II and III (Table 12). There was a significantly greater amount of both elastin and reticulum fiber staining in the Group III horses. There was significantly more elastin and reticulum fiber staining in the submucosa than the muscularis externa in both groups. However, the reticulum staining was greater in the muscularis externa in the Group II horses, but in the submucosa in the Group III horses.

TABLE 12

The relative area ($\bar{x}$+SEM) of selectively stained elastin and reticulum fibers as a ratio of background area, for submucosa and muscularis externa in Groups II and III horses

	Group II		Group III	
	Elastin	Reticulin	Elastin	Reticulin
Submucosa	.0121 ± .0015	.0424 ± .0057	.0167 ± .0047	.3198 ± .1183
Muscularis externa	.0034 ± .0005	.0771 ± .0026	.0094 ± .0031	.2473 ± .0418

Significant difference between groups and sites at 0.05 level.

DISCUSSION AND CONCLUSIONS

The main objective of this study was to evaluate three different feeding regimens in horses by studying esophageal wound healing, following an esophageal mucosal resection and anastomosis. The feeding regimens chosen were ones which could be applied in a clinical situation. It was not the purpose of the study to directly evaluate surgical techniques for esophageal mucosal resections because only one surgical technique was used. However, some comments will be made regarding a resection and anastomosis of the esophagus. It was also my intention to develop some quantitative techniques to better evaluate the healing process occurring in biological issues like the esophagus, following surgical intervention and in doing so, to better relate structural and functional changes that occur in the esophagus following this type of surgery. Unfortunately, not all of these objectives were met. By discussing various aspects of the project in chronological order, I shall attempt to highlight where these objectives were achieved, and where they fell short.

Clinical Observations

Within 3 days postoperatively, the mucosal anastomoses had completely dehisced in all those horses fed per os 2 days after surgery (Group I). The mucosa retracted from the underlying submucosa, completely obliterating the lumen in 3 of these horses and they showed ptyalism and esophagismus. Because they were unable to eat, they were humanely destroyed. Using this surgical technique and probably for any surgical technique involving resection of esophageal tissue, this feeding method is unacceptable. However, variable degrees of dehiscence occurred in the mucosal anastomoses in the other 2 groups also. Unfortunately, due to the difficulty of maneuvering the endoscope in the esophagus with a large nasogastric tube in place, the horses in the nasogastric tube-fed group were not examined before the 14th postoperative day. Due to the formation of strictures in all the groups and the predominance of fistulae and sinus tracts in the second group, it is reasonable to assume that mucosal dehiscence also occurred in this group. Extraoral alimentation facilitated healing in the second and third groups of horses.

Surgical Technique and Related Complications

According to the endoscopic appearance of the mucosal anastomosis, dehiscence began as early as 1 day

postoperatively. This was too early for infection or compromised blood supply to be contributing to tissue weakness and necrosis. Tension on the mucosa, as a result of the 3 cm resection, and tissue edema caused early tearing out of the suture. The type of suture material, polypropylene, and the pattern may have contributed to the degree of breakdown in the anastomosis. Continuous suture lines have a greater effect on decreasing vascular supply to the ends of the tissues, but tension on the anastomosis appears to contribute predominantly to the breakdown, at least in the initial stages. In an experiment comparing one-layer simple interrupted chromic catgut and non-absorbable Teflon-coated polyester fiber, after a 5 cm resection was performed, deaths were attributed to anastomotic leaks.. There was a higher occurrence in the group in which non-absorbable material was used. However, the dehiscence was related to loosening and cutting through to the suture, rather than to the anastomotic technique.[92] Strictures may develop without luminal leakage due to excessive tension, leading to mucosal separation.[33,34,38,41] In this project, tension on the anastomosis appeared to contribute greatly to early mucosal dehiscence.

Significantly more horses survived in the nasogastric tube-fed group than in the esophagostomy tube-fed one. This data alone suggested that nasogastric

tube feeding was superior to esophagostomy tube-feeding following this technique of esophageal mucosal resection. The second surgical incision in the necks of the third group of horses and the presence of the esophagostomy tube predisposed these horses to a variety of other complications, several of which were fatal. Sepsis appeared to play a major role in the pathogenesis of these problems. There was accumulation of saliva and purulent discharge which together resulted in phlegmon development.

All but one of the horses in the esophagostomy tube-fed group needed extra drainage at the surgical site. The suction drains were not able to cope with the exudate that developed as a result of incisional inflammation. The drains themselves may have contributed to the infection rate. The decision not to use prophylactic antibiotics in a surgery that invaded the lumen of the gastrointestinal tract may have contributed to the complications. Cellulitis however, was not only related to breakdown of the muscularis externa incision and leakage, with the subsequent formation of fistulae; since only one horse in the third group developed a fistula, yet sepsis was a major problem in this group. All but one of the surgical incisions in this group required additional drainage. The increased complication rate in this group appeared to be a result of the presence of two incisions in the same area.

I planned to remove the drains by the third postoperative day, or at such time as the quantity of exudate was approaching 40 mls per day, which is compatible with the presence of the drain acting as a foreign body in the wound. However, the quantities either never decreased to this volume, or the character of the drainage became purulent necessitating the opening of the distal portion, or all, of the incision. The presence of the drains themselves may have contributed to the sepsis rate. Additionally, this surgical procedure required some tissue trauma with the placement of large retractors in the wound for a prolonged period and the tissues were generally exposed to the operating room environment in excess of 2 hours. Contamination from the lumen and the environment therefore also contributed to the complication rate.

Skin and mucosa healed in a shorter time in the esophagostomy tube-fed group due to the larger number of fistulae and sinus tracts present in the nasogastric tube-fed group. Indeed, once the mucosal ulcer had healed, these strictures were often only demonstrable radiographically, in the esophagostomy tube-fed group.

The incidence of fistulae and sinus tracts which indicate the extent of mucosal and muscular leakage were highest in Group II (nasogastric tube-fed). The presence of traction diverticuli was greatest in the nasogastric

tube-fed horses. It appears then that leakage predisposes to traction diverticulum formation.

Intraluminal Tubes

The presence of a nasogastric tube in the esophageal lumen appeared to predispose to leakage at the surgical site, due to the high incidence of wall defects in the second group. The statements by some authors that intraluminal tubes place greater pressure on some parts of the wall compared to other parts cannot be proven by this study.[79,91] It does seem however, that the tube either increases the intraluminal pressure sufficiently to cause a breakdown in the suture line, or simply by mechnical trauma it delays healing at the mucosal anastomosis and subsequently causes a breakdown in the muscularis externa incision. It does not seem to minimize movement of the organ and encourage healing.[90] According to the absolute stricture and percentage stricture diameter measurements, there was no difference in the esophageal lumen diameters between Groups II and III. However, the mean diameter of the lumen 60 days postoperatively in the nasogastric tube-fed group of horses was 78.4 $\pm$ 2.2 percent of maximal cranial diameter, but was 52.5 $\pm$ 10.0 percent in the esophagostomy tube-fed horses (Group III). Some of this increase in lumen diameter in the second group is due to the traction diverticulum formation at the mucosal anastomosis.

However, the presence of a large bore tube across the surgical site appeared to keep the esophageal walls further apart as the mucosa begins to regenerate. This lends credence to the experiment that showed that in piglets undergoing long gap correction, strictures formed but were less severe if a transanastomotic tube was present.[36,39,45]

Esophagi of the second and third groups of horses showed an increase in lumen diameter particularly between 30 and 45 days postoperatively. The natural bougienage of eating must have caused the increase in lumen diameter that occurred. At this stage, the collagenous tissue is presumably still amenable to stretching but by 60 days, the collagen is dense and mature histologically, and the fibroblastic activity, with proliferation of reticulin fibrils is greatly decreased. Also there is no change in the traction diverticulum shape and size by 60 days postoperatively, in experimental work done on ponies.[19]

Esophagostomy Complications

In the esophagostomy tube-fed group of horses, there were 6 of 10 fatalities (Table 1). The first horse had to be euthanatized immediately on recovery from anesthesia due to bilateral forelimb paralysis which was attributed to a rhabdomyositis/radial neuritis. This loss was not directly related to the surgical procedure and was probably the

result of poor positioning or padding. The same can be said of the third horse that died as a result of a phenoxybenzamine overdose which was used as a treatment for this horse's acute laminitis. However, laminitis is not an uncommon sequela to surgery and anesthesia in horses.

The second horse died of unknown causes 28 days postoperatively. However, at necropsy, there was a septic left jugular thrombophlebitis and pulmonary microabscessation. Two of the horses asphyxiated as a result of bilateral laryngeal paralysis. Evidence of a respiratory problem did not develop in these horses until about the fourth postoperative day. This coincided with the development of the septic incisional complications and purulent drainage. The suppurative cellulitis, associated with the trauma of the surgery, probably affected the function of both the left and right recurrent laryngeal nerves. The same factors probably resulted in the retropharyngeal swelling and left laryngeal hemiplegia seen in the other two horses in the study. These complications can be related to the combination of two surgical procedures on the same animal in close proximity, resulting in increased inflammation and infection. The occurrence of postoperative ileus in one of the horses in Group II could be a result of vagal inflammation and edema. This can again be related to sepsis.

Difficulty encountered on re-passage of esophagostomy tubes has been previously reported.[18] However, on the occasions that horses in the second group dislodged their nasogastric tubes, no difficulty was encountered on their re-passage through the anastomotic site.

The use of three different radiographic measurements did not highlight any greater differences between groups than absolute stricture diameter alone. There was no real advantage using the percentage stricture diameter measurement. However, it did permit a better appreciation of the relative degree of compromise of the esophageal lumen. It was anticipated that some of the variation between horses might be eliminated using this technique because even under the influence of xylazine, it is not always possible to uniformly and consistently distend the esophagus under barium or barium/air positive pressure, and simultaneously radiograph each horse.

Pressure-Volume Measurements

The pressure-volume measurements were an attempt to correlate a measure of esophageal function with the degree of structural change we knew existed at the surgical site. We were unable to demonstrate any difference between the compliance of the surgical site and the sites cranial and caudal to it, in any of the horses. This was surprising, as

there was a large amount of fibrosis, both in the esophageal wall at the surgical site and in the more ventral periesophageal tissues. Presumably due to the two-compartmental nature of the model we were testing, there was enough normal esophageal and periesophageal tissue to mask the less compliant nature of the fibrous tissue. The only significant difference we identified was between the inflation and deflation limbs of the pressure-volume curve. The deflation limb was the more compliant. The esophagus undergoing deflation distended more than when undergoing inflation under the same pressure. This phenomenon, called hysteresis, is also observed in tissues like the lung. The fact that we were unable to demonstrate a change in the pressure-volume curve at the surgical site, is consistent with the way the esophagus behaved under barium positive pressure.

Qualitative Histopathology

Histopathologic changes occurred in all layers of the esophageal wall, even in those sections taken away from the longitudinal muscularis externa incision. Since all mucosal anastomoses dehisced to varying degrees, all the surgical incisions were heavily colonized by bacteria particularly in the submucosa, and underwent the chronic suppurative reaction seen in the 3 horses in the first group less than 5 days postoperatively. This explains the dense

fibrous tissue and chronic inflammation seen in the 60 day postoperative esophageal sections. The presence of an ulcer in one horse and the presence of a fistulous tract on longitudinal section in another horse in Group II show that healing was still incomplete as the chronic suppurative reaction had still not resolved. Even by 60 days, most of the horses had hypertrophic, hyperplastic mucosae, illustrating that healing was not complete. Both the severity of the initial acute reaction and presence of non-absorbable suture material in the presence of an infection could contribute to the long healing time in the esophagus. However, the suture material in the mucosa usually sloughed as soon as the mucosal anastomosis dehisced. In Group II, the irritation of the transanastomotic nasogastric tube for the first 14 days postoperatively would also contribute to the slower healing of the mucosa, as well as the presence of fistulae and sinus tracts. In support of this, the mucosa in the Group III horses, although still hypertrophic and hyperplastic, was completely keratinized, indicating the stage of healing was more advanced.

A chronic periesophagitis was present in all horses but was accentuated in the adventitia of the esophagostomy tube-fed group. These horses suffered a more severe septic reaction in their surgical incisions, as discussed previously. The severe degenerative changes, particularly

evident in one of the group characterized by adventitial nerve fiber degeneration, indicate that there is a functional abnormality in the esophagus as well as the structural changes already described.

The foreign bodies - talc and non-absorbable suture material - induced a severe granulomatous reaction, characterized by giant cell formation. The presence of fragments of suture material would invite one to question whether the non-absorbable suture material used retains its strength for 60 days after insertion. However, in the presence of such a severe reaction in the esophagi of most of these horses, the cellular and enzymatic response was probably more pronounced than in most other surgical procedures, that might be used to assess suture material characteristics.

Morphometrics

Morphometric analysis, where the thickness of individual layers in the esophageal wall were measured in cross section, did not demonstrate changes in cross-sectional esophageal width between horses on different feeding regimens. However, the technique is reproducible and accurate,[94] and in a surgical procedure where healing by primary intention is achieved, it may be more helpful. Quantitation of pathologic change is necessary so

that structure and function can be better related, and the degree of structural alteration assessed.

The density-dependent image analysis was used to try and assess the relative contributions of reticulum and elastic fibers to the healing esophageal wall. Laidlow's reticulum is a silver-based stain. Argyrophilic fibers, consisting of very fine fibrils seen close to the cell surface of the fibroblast have been termed eticulin. Collagenous reticulins are found in association with actively synthesizing fibroblasts. The staining reaction appears to be due to associated with carbohydrate or lipid components.[79] The very dense collagen seen histologically in these tissues, 60 days postoperatively is apparently mature and not undergoing any significant remodeling. This would suggest that the structural form of the esophageal wall at 60 days postoperatively will not undergo much change or at most, very slow change. The larger quantities of reticulum and elastin fiber staining in the Group III horses, is probably more a reflection of tissue preparation and staining procedure, than a real difference between groups.

As can be seen from the radiographic measurements, most of the increase in stricture diameter occurred between 30 and 45 days postoperatively. Not much increase occurred after that time. This is consistent with the presence of the mature dense collagen 60 days after surgery. This

change in lumen size that occurs between 30 and 45 days postoperatively has important clinical applications. In horses presenting with circumferential mucosal and/or submucosal esophageal erosion, there is an advantage in encouraging horse owners to persist in feeding their horses a sloppy mashed ration until 30 to 45 days after the original injury. At this time the esophageal lumen should enlarge, often enough to permit maintenance on a pelleted diet, if not hay.

Conclusion

The survival rate alone in the first group makes the oral method of feeding unacceptable. Although no significant increase could be demonstrated in lumen diameter between the nasogastric and tube-fed horses, the trend was for the nasogastric tube-fed group to have larger mean lumen diameters over all time periods and specifically at 60 days postoperatively. Additionally, all the nasogastric tube-fed horses (Group II) survived to the end of the project, which outweighs the complications of fistula and sinus tract development which predominated in this group over the esophagostomy tube-fed one. Using this surgical technique of esophageal mucosal resection and anastomosis, the nasogastric tube-feeding technique is the preferred one to use. Of the three feeding techniques tested, this one best permits return toward normal, and most importantly, provides the best survival rate.

SUMMARY

1. All mucosal anastomoses dehisced to varying degrees.
2. All horses developed strictures, subsequent to anastomotic dehiscence.
3. Esophageal lumen diameter enlarged predominantly between 30 and 45 days postoperatively.
4. Barium and barium-air positive pressure esophagrams are very useful for delineating strictures, fistulae and sinus tracts.
5. The presence of a nasogastric tube across an esophageal mucosal resection and anastomosis predisposes to fistula, sinus tract and traction diverticulum formation.
6. The presence of both an esophagostomy and an esophageal mucosal resection and anastomosis in the same horse greatly increases the complication rate.
7. Of the three feeding regimens used, nasogastric tube feeding resulted in the best postoperative healing, following the esophageal mucosal resection and anastomosis.
8. Compliance measurements failed to reflect the degree of esophageal structural damage.

9. Morphometric procedures - cross-sectional wall compartment dimensions and density dependent image analysis, did not assist in differentiating between effects of the different feeding regimens.
10. Histologic changes at the surgery site consisted of extensive fibrosis, abscess and granuloma formation in all esophageal layers beneath the mucosa.

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LIST OF REFERENCES

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