COMPARITIVE EVALUATION OF SIMPLE CONTINUOUS AND SIMPLE INTERRUPTED SUTURE PATTERN IN THE EQUINE LINEA ALBA

by

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INTRODUCTION

Exploratory celiotomy of the horse is indicated for management of a variety of disease conditions known to result in an acute abdominal crisis.[1,2,3] The ventral midline incision is the surgical approach most commonly utilized since it provides the greatest single incisional exposure for most procedures in the abdominal cavity.[1,2,4,5,6] A variety of suture patterns have been utilized for closure of the equine ventral midline incision.[6,7] Interrupted patterns of suture placement, although time consuming to employ, are frequently advocated because of their alleged security and ease of placement.[8] Conversely, the simple continuous pattern has been used for closure of abdominal incisions and has many advantages, the most obvious being the speed with which it is placed.[9,10,11] Equine anesthetic morbidity is directly correlated with duration of anesthesia.[12] To the extent that operative procedures which reduce total anesthetic time can be safely employed, those procedures are desirable. Controlled studies and clinical experience have repeatedly demonstrated that simple continuous patterns for closure of the linea alba are both safe and effective in humans and small animal patients.[10,11,13,14] Although the clinical experience of many surgeons would support similiar conclusions in equine patients[11], no controlled studies comparing the various suture patterns have been reported.

Incisional wound healing has been divided into three phases: the lag or latent phase, the proliferative phase, and the phase of maturation. The length of each phase varies with the species and to some degree, between individuals within that species.[15] It is believed however, that the most rapid gain in strength occurs during the proliferative phase of wound healing; that period which occurs classically between the fourth and sixteenth postoperative day.[16] During this period, the wound approaches 70% to 80% of its preoperative strength. The strength of the wound will continue to increase at a slower rate throughout the maturation phase, a period which may last for several months or years.[16] This gradual increase in strength is associated with the continued revision of intermolecular and intramolecular cross-linking of collagen fibers as collagen is resorbed and reformed along the lines of incisional tension. Ultimately, this process permits the development of a stronger scar within the wound.[16,17]

Various devices for measuring tensile strength have been described in the literature.[18-25] The basic designs which have been utilized include the weight loading type, the mechanical type, and pneumatry, each possessing specific advantages and disadvantages.[19] Regardless of the methodology utilized, wound healing is readily comparable within any of these systems when wounds of similiar size are tested repeatedly in similiar fashion.[12]

The objectives of this study were as follows:

1) To evaluate and compare the gross clinical appearance of midline incisions coapted with #2 polygalactin 910 in either simple interrupted or simple continuous fashion at both acute and subsequent sequential postoperative periods.

2) To evaluate and compare the gross pathologic and histologic appearance of midline incisions coapted with #2 polygalactin 910 in either simple interrupted or simple continuous fashion at both acute and subsequent sequential postoperative periods.

3) To compare the gross mechanical strength of midline incisions coapted with #2 Polygalactin 910 in either simple interrupted or simple continuous fashion at both acute and subsequent sequential postoperative periods.

4) To compare the effect of position on the breaking strength of simple interrupted and simple continuous suture patterns in midline incisions coapted with #2 polygalactin 910 at both acute and subsequent sequential postoperative periods.

LITERATURE REVIEW

A knowledge of the process of biologic healing and the repair of injured tissue is of primary importance to the discipline of surgery. At the basic level, tissue repair consists of the replacment of dead or damaged cells by a new population of healthy cells, derived from either parenchymal or connective tissue elememts in and around the damaged tissue. For this reason the process of wound healing has been divided into two primary divisions: 1) healing by regeneration, and 2) healing by connective tissue replacement.(17) The former is functionally and cosmetically desirable, but can occur only in tissues with the cellular capability for regeneration and an intact connective tissue framework. A clean surgical incision with properly apposed edges provides the optimal environment for such healing to take place.

Incisional wound healing has been divided into three phases: the lag or latent phase, the proliferative phase, and the phase of maturation.(15)

The lag or latent phase begins at the time of wounding and is composed of the inflammatory and debridement stages. Following wounding the inflammatory phase is marked by an initial infiltration of the wound by neutrophils. The major function of these neutrophils in the inflammatory response involves their participation in phagocytosis, enzymatic tissue degradation, and the formation and release of chemotactic factors.(17) Macrophages, responsive to chemotactic influences, migrate into the wound simutaneously with neutrophils but at a slower rate with the net effect being that neutrophils are the predominate cell of the acute inflammatory phase and the macrophages dominate in the later phases of the inflammatory reaction. Because the macrophage has a longer life span than do the neutrophils, they persist as active cells into the later inflammatory phase. The primary function of the macrophage is to phagocytose and degrade ingested materials. The macrophage is active against bacteria, fungi, protozoa, viruses, cellular debris, and even whole or altered cells.(17) During the lag phase of healing the wound is mechanically supported by the accumulation of fibrin within the wound and the adhesion of migrating cells together within the fibrin matrix. This phase lasts for a period of four to seven days and is to some degree affected by the magnitude and type of inflammatory reaction. The tensile strength of the healing wound does not increase to an appreciable degree during the lag phase.

During the proliferative phase, neovascularization occurs with new capillary beds growing into and bridging the wound. Although these capillary beds begin to develop in the inflammatory phase, they do not appear as predominate structures until later in wound healing. With capillary ingress there is a mobilization and migration of fibroblasts into the wound which have been derived from the mesenchymal cells located around the wound margin. There is a concomitant increase in the metabolic activity of these activated macrophages which when activated, produce glycoproteins and noncollagenous proteins. Proliferating fibroblasts manufacture new extracellular material, collagen, and mucopolysaccharide ground substances which will eventually fill the tissue deficit within the wound. The collagen is secreted from fibroblasts in a monomeric form and undergoes extracellular aggregation into collagen fibrils. With the increase in collagen content, the tensile strength of the wound increases as well. These activities are generally evident to the greatest degree between the fourth and sixteenth postoperative day, at which time the wound approaches 70% to 80% of its preoperative strength.

There is no sharp demarcation between the end of the proliferative phase and the beginning of the maturation phase. The phases represent a continuum of the biologic processes of wound healing and are useful only to describe the principle activity in a healthy wound at any given point in time. The progressive accumulation of collagen within the wound over time leads to a gradual reduction in vascularization at the incision site. The ultimate end product is an acellular, avascular collagenous scar which fills the tissue defect within the wound.(16,17)

Even though the collagen content of the wound slowly decreases over time, the tensile strength of the wound continues to increase. This gradual process of wound maturation proceedes at a dramatically reduced pace from that observed during the period of proliferation or fibroplasia. The ultimate gain in strength is due to intermolecular and intramolecular remodeling of collagen fiber cross-linkages.(16) Fibers remodel by dissoulution and reform along lines of tension across the wound to produce a stronger, more efficient molecular configuration. This remodeling may require over a year to complete.

Environmental and systemic factors can adversely affect the tensile strength of healing wounds.(15,16) Protein depletion or hypoproteinemia has been implicated as one cause of wound disruption by prolonging the lag phase and by preventing fibroplasia. If the essential metabolites are unavailable for healing, a wound cannot be repaired. The establishment of the proper environment within the wound is also critical. Dehydration may delay healing; conversely, moderate edema may have little or no effect on the gain of tensile strength within the wound. Improper nutrition will have an obvious detrimental effect on the rate and quality of wound healing. A deficiency in copper or ascorbic acid may result in the failure of fibroblasts to produce adequate collagen necessary for wound healing. The oxygen supply to a healing wound is critical and may be a limiting factor in the rate of healing. Hypovolemia, vasoconstriction, or intravascular coagulation associated with tissue trauma will impair oxygen transport and delivery to the healing wound and thus, alter the rate of healing. The effects of these aforementioned conditions may be exacerbated by stress. Systemically administered cortisone has been shown to alter wound healing by preventing capillary proliferation and fibroplasia thereby inhibiting the formation of granulation tissue.(15) Local application of adrenocortical steroids to wounds also inhibits the formation of granulation tissue. The syntesis of both collagen and mucopolysaccharide compounds are inhibited by cortisone, and presumably, by chronic stress. The effects of cytotoxic drugs, various hormones, and irradiation are not thoroughly understood, but may produce alterations in the ultimate tensile strength of a wound.(15)

Fascia is classified histologically as dense irregularly arranged connective tissue.(26) As a tissue, it possesses low degree of cellulary with collagen fibers predominating. The fibers are generally arranged in bundles which cross each other at varying angles. Within thick fascial aponeuroses and perimuscular fascia, the bundles are superimposed in several planes and interlace with one another in three planes: vertical, horizontal, and longitudinal. This arrangement allows for adaptation to withstand stretching forces in any direction. The presence of elastic networks facilitates a fast return to resting conditions. Although fascia heals readily by fibrous protein synthesis and remodeling of the collagen fibers, its regenerative powers are limited.(15) The healing of aponeurotic structures such as the linea alba is slower than other more vascular tissues.(15,27) These facts must be considered when examining the rate at which an incised wound gains tensile strength.

Tensile strength has long been used as a measure of wound healing rate.(15,18-21) Specifically, tensile strength is a measurement of a load applied per unit of cross sectional area.(16,19) It is generally expressed in pounds per square inch or kilograms per square centimeter or square milimeter. Tensile strength is often confused with breaking strength, the latter being the measure of force required to disrupt a wound or tissue without regard to its dimensions.(16,19) Although tensile strength is an important measure from a mechanical point of view, the clinically oriented surgeon is generally most interested in breaking strength of the surgical closure.

A variety of devices for measuring tensile strength have been described in the literature.(18-25) As early as 1929, pioneering studies on the rate of gain of tensile strength of skin, muscle, fascia, and gastric wounds were reported in the dog.(18) Since that time, many tensiometers have been developed and utilized.(19) Several testing devices have been designed using the counterweight principle for measuring the tensile strengths of various tissues. With this design, the tissue to be tested is secured into the testing device and some form of weight added to place tension on the healing wound. The addition of weight is continued until the point of tissue disruption is determined. At that point, the breaking strength of the wound is equal to the amount of weight needed to disrupt the wound. Counterweights which have been utilized have included mercury, air pressure, oil damping, motor driven mechanisms, gram weights, and water flow.(22) Mechanical apparatices in which the tissues are subject to a progressive constant physical stress have been applied with the Instron testing machine most commonly utilized. Pneumatry is the basis for the third major design of tensiometer. In this case wounds of hollow organs are disrupted from within, either by means of introduction of air (or another gas) into the lumen of the viscera or by introduction of the pneumatry gas into a balloon which has previously been placed within the lumen.(25) The pressure is then increased at a constant rate until the wound disrupts. Each of the various testing devices has advantages as well as disadvantages, some of which depend upon the type of tissue being tested and the species of interest. Most testing devices utilize in vitro techniques for ethical reasons which are self evident. In limited cases, testing has also been accomplished in live, anesthetized animals.(19) This multiplicity in design and method of measurement may suggest a lack of uniformly acceptable technique for measuring the tensile strength of biological tissues. Whatever design is utilized, it is essential to obtain reliable, repeatable results such that comparative data may be generated. When wounds of a similiar size and type are tested in an identical fashion, any error associated with the technique is presumed to be constant and the results of the test valid, to the extent that they are used for comparitive analysis.(16,20)

Exploratory celiotomy in the horse is indicated for surgical management of a variety of disease states known to result in an acute abdominal crisis. These conditions include, but are not limited to, the development of intestinal displacements, obstructions, neoplasia, inflammatory lesions, angiopathies, luminal deformities, congenital anomalies, and ruptures and perforations of hollow organs.(1-3) The optimal surgical approach to the abdomen of the horse has been the concern of many workers and a variety of incisions have been utilized.(1,2,28,29) That not withstanding, the ventral midline incision has been repeatedly demonstrated to provide the optimal operative access to the abdominal contents and has therefore become the choice of the large animal surgeon.(1,2,4,5,6)

The anatomy of the ventral abdominal wall of the horse is similiar to that of other domestic animals.(30,31) The external abdominal oblique (EAO) forms the most extensive muscular componentof the abdominal wall. This broad sheet of fibers is directed caudal and ventral running to coalesce with paired fibers at the ventral midline. Running perpendicular and deep to the EAO are the fibers of the internal abdominal oblique muscle (IAO). The interweaving of the aponeuroses of these two muscles comprise the comprise the external lamina of the rectus sheath. The sheath is reinforced by the well developed deep abdominal fascia. The rectus abdominus muscle and the transverse abdominal muscle complete the muscular portion of the abdominal wall. This aggregate structure provides support to the weighty abdominal viscera and acts as a unit for compression. The rectus abdominus muscle and the transverse abdominal muscle complete the muscular portion of the abdominal wall. Their actions aid the aforementioned muscles. The aponeurosis of the transverse abdominal muscle forms the internal lamina of the rectus sheath. The linea alba is a median fibrous raphe which extends from the xyphoid cartilage to the prepubic tendon and is formed primarily by the conjoined aggregation of the fascial aponeuroses of the EAO, IAO and transverse abdominal muscles.(30) The linea alba is thought to have no nerves or vessels crossing it.

The absence of nerve trunks or blood vessels on the linea alba facilitates a nearly bloodless surgical approach to the peritoneal cavity. This incision may be extended cranially or caudally as needed for exposure. The principle disadvantage to the ventral midline approach is the considerable postoperative stress which is placed directly upon the suture line by the weight of the abominal viscera.(2) These stresses have in some cases led to the development of a postoperative hernia. Occasionally, an equine patient may experience a particularly active or violent recovery from general anesthesia, placing extreme stress on the abdominal surgical closure.(7,32) Occasionally patients so affected acutely deconpensate their incisional closure. This situation generally results in acute abdominal eventration.(33) For these reasons, the selection of suture materials and patterns for closure of the linea alba constitutes an important decision.

A variety of suture materials have been used for surgical closure of the linea alba of humans and veterinary surgical patients.(10,33-36) Incisional infection may be supported by the presence of nonabsorbable suture material, notably by those sutures which are multifilament and nonabsorbable. For this reason, many surgeons select monofilament or braided and coated absorbable suture materials for closure of the equine abdomen.(8) Large gauge suture is advocated not only for its relatively higher tensile strength, but also because large suture material is much less likely to cut through fascia and tissues within the healing wound.(11) While individual preference may vary, #2 polygalactin 910 is considered to be quite satisfactory and is commonly utilized for this purpose.(37) Its high tensile strength, good handling properties, and minimal tissue trauma or reaction make polygalactin 910 an acceptable suture.(38) Approximately 60% of its strength is retained at seven days, 30% at fourteen days, and 10% at twenty-one days. Absorbtion of the suture material takes place more than forty days after implantation.(39)

A variety of suture patterns have been utilized for surgical closure of the ventral midline incision.(6,7,9,10) Interrupted patterns of suture placement are frequently advocated because of their alleged security and ease of placement, despite the absence of controlled studies to substantiate the validity of that assumption in the equine patient. The simple continuous pattern of suture placement has also been utilized for closure of equine abdominal incisions.(11) While each pattern is known to have particular and specific advantages, the most obvious advantage to the simple continuous closure is the speed with which it is accomplished. Equine anesthetic morbidity appears to be directly correlated to the duration of equine surgical anesthesia.(12) For this reason, operative procedures which reduce the total surgical and anesthetic time are desirable. The fact that fewer knots are required for placement of the simple continuous suture pattern is advantageous for several reasons. A smaller amount of suture material is left in the wound resulting in a reduced degree of tissue reaction. The need to tie fewer knots reduces the operative time required to close a surgical incision. Knots on a suture represent a point of stress concentration, which is typically where sutures break when tension is applied to the point of material failure.(10) The simple continuous pattern possesses fewer points of stress concentration per unit length of wound than the simple interrupted closure. The effectiveness of the continuous suture might be futher explained by an analysis of the stresses applied to the suture material. When a suture is knotted and a tensile force applied, some of the force is converted to shear force.(10) This is one reason why knotted sutures have a lower breaking strength than unknotted sutures. More shear forces are presumed to be activated in a simple interrupted closure than along a simple continuous closure when tension is applied to the wound.(10) When using a simple continuous pattern it is easier to ensure knot security of the entire abdominal incision because fewer knots are involved than when using interrupted patterns.(9) Tension along the suture line is presumed to become equally distributed along the closure when a simple continuous suture pattern is used. This reduces the likelihood of failure due to the sudden application of forces at one specific point along the incision.(10,11,13) Controlled studies and clinical experience has repeatedly demonstrated that simple continuous patterns for closure of the ventral midline are both safe and effective in humans and small animals.(10,11,13,15)

Wound dehiscence is a serious potential complication of abdominal surgery. Partial dehiscence in the immediate to chronic postoperative periods may lead to the formation of incisional hernias. Total dehiscence as a result of violent postanesthetic recovery may lead to catastrophic eventration in equine patients, a situation accompanied by extremely high rated of postoperative mortality.(2,33) Other complications following surgery that could lead to eventration include incisional infection, suture failure, technical surgical errors, postoperative hemorrhage, and peritonitis. Infection is probably the greatest deterrent to normal wound healing and a principal cause of incisional hernia formation.(40,41) A study of human surgical patients suggests a tenfold increase in abdominal wound dehiscence and incisional herniation has been associated with the infection of surgical wounds.(42,43) It is absolutely essential that there be minimal tissue trauma at the time of celiotomy, that meticulous hemostasis be performed, and, most importantly, that strict adherence to aseptic technique be observed in an effort to prevent incisional infection.

Reports throughout the surgical literature have suggested that obesity, chronic obstructive disease, malnutrition (hypoproteinemia), cardiac or renal disease may predispose to the development of incisional hernias or their recurrance.(15,39,43) It is probable that these factors may influence incisional healing in horses, however an appreciation of their impact is unknown. They should nevertheless be considered in the presurgical evaluation of any equine surgical patient.

MATERIALS AND METHODS

Forty mature horses (18 mares, 18 geldings, and 4 stallions) were utilized as surgical subjects to evaluate the postoperative strength of two different surgical closures of the abdomen. These horses ranged in age from one to twenty-eight years ($\bar{X}$=8 years) and in weight from 360 kg to 545 kg ($\bar{X}$=450 kg).

Each horse received a thorough physical examination prior to surgery and was determined to be free of clinical evidence of infectious disease and obvious intra-abdominal pathology. All horses had been previously dewormed with an avermectin anthelmintic [a] and were vaccinated for tetanus [b] prior to surgery. The animals were fed 2-3% of their body weight in prairie grass and alfalfa hays and received a limited amount of a concentrate ration. Water was provided ad libitum. Feed was withheld from the horses for twelve hour prior to surgical instrumentation. Clinical evaluation consisted of daily physical examinations including rectal body temperature, pulse and respiratory rates, general attitude and appetite, and a visual inspection of the midline surgical incision. Horses in Group 1 (n=24) were euthanized immediately; Group 2 horses (n=6) at five days postoperatively; Group 3 (n=6) at ten days following surgery; and Group 4 (n=4) at twenty-one days postoperation.

Prior to the induction of general anesthesia, horses received an intravenous administration of xylazine [c] (0.30

mg/kg). Anesthesia was induced with an intravenous administration of glyceryl guiacolate [d] to produce gross evidence of skeletal muscle relaxation (50-100 mg/kg), followed by an intravenous injection of thiamylal sodium [e] (5 mg/kg). An orotracheal tube was placed and anesthesia maintained with halothane [f] vaporized into oxygen and delivered through a semiclosed circle system. Arterial blood gas analysis was obtained periodically throughout surgery, with anesthesia and fluid therapy being altered accordingly. Lactated Ringer´s solution was routinely administered IV at a maintenance rate of 10 ml/lb/hr. An arterial catheter was placed in the facial atrery and provided for direct monitoring of arterial blood pressure and blood gases. Continuous monitoring of the electrocardiogram was performed.

With the patient in dorsal recumbency, the ventral midline was clipped, aseptically prepared, and draped for routine ventral midline celiotomy. A 34 centimeter longitudinal skin incision was made on the ventral midline beginning near the umbilicus and extending craniad to a point four cm caudal to the xyphoid. The incision was extended by sharp dissection through the subcutaneous tissues to expose the linea alba. A 32 cm incision was made in the linea alba by sharp dissection. Hemostasis was maintained as needed by electrocautery or ligation. The parietal peritoneum was bluntly opened. Retroperitoneal fat and subcutaneous tissue were dissected away (two cm) from either side of the incision to facilitate incisional closure. Four seven cm segments were delineated with tissue forceps. A one cm transition zone was created between each of the four treatment segments. A 25 gauge stainless steel simple interrupted suture was placed at either end of the incision to facilate subsequent identification of the incisional ends. A sterile moistened laparotomy pad was placed deep to the body wall to act as a temporary visceral retainer during initial stages of closure. The pad was removed prior to completion of the surgical closure. The four segments of body wall were sutured using #2 coated polygalactan 910 [g]. Two segments were closed with a simple continuous pattern and two with a simple interrupted pattern. (Figure 1) The position of each pattern was randomly determined prior to surgery. Placement of each suture was measured to be one cm back from the edge of the incision and one cm away from each adjacent suture; therefore, eight suture passes were made in each 7 cm segment.(Figure 2) Care was taken to insure incorporation of the internal rectus fascial layer as well as the external fascia in the incisional closure. Stainless steel skin staples were placed as markers between adjacent test segments. All surgical instrumentation was performed by the same team of veterinary surgeons. Following irrigation with sterile saline, the subcutaneous tissues were closed with #2-0 polygalactin 910 in a simple continuous pattern. The skin was apposed with stainless steel staples.

Postoperatively all horses received phenylbutazone [h] (4 mg/kg) orally every twelve hours for a 72 hour period. Antibiotics were not routinely administered. Upon anesthetic recovery a sterile abdominal bandage was placed to minimize edema and to reduce environmental contamination prior to the development of a fibrin seal. The horses were monitored for evidence of colic, incisional infection, swelling, drainage, disruption or herniation, and clinically evaluated on each subsequent postoperative day as previously described. Exercise included fifteen minutes of hand walking daily. Skin staples were removed at ten days postoperatively from the horses in Group 4 and at the time of postmortem evaluation in all other horses.

At the appropriate time interval each animal was euthanitized by the intravenous administration of a euthanasia solution [i]. A complete postmortem examination was immediately performed. Surigical incisions were evaluated for evidence of adhesions, disruption, or gross evidence of infection. The ventral abdominal wall was dissected free and cleared of all fat and subcutaneous tissue, exposing the stainless steel marking sutures and staples. Tissue sections from one segment of each suture pattern were harvested for histological evaluation. Specific segments of the incision destined to be evaluated for either histological or strength evaluation were randomly determined prior to the first surgery. The remaining body wall which contained a segment of each pattern, was wrapped in an airtight plastic wrap and placed on a flat surface in an ultra low freezer (-60° C) within two hours of euthanasia and collection. These samples were allowed to freeze and remained frozen until breaking strength determinations were made. Multiple segments from several animals were collected and frozen to facilitate batch testing to enhance testing consistancy and improve efficiency of evaluation.

On the day of strength testing, the frozen segments were trimmed or separated using a band saw. The samples were then placed in a bath of 70° F Lactated Ringer´s solution and allowed to thaw. After thawing, the nonfascial tissues were carefully removed by dissection leaving only external and internal rectus fascia and sutured linea alba. This was necessary to facilitate uniform gripping of the samples within the strength testing apparatus. The samples were trimmed to a length of fifteen cm on either side of the incision. The testing was performed in the Kansas State University Department of Civil Engineering utilizing a pull apart testing apparatus [j]. Samples were positioned in custom tissue grips (Figure 3) with the incision line centered three cm from the edge of each grip. A force was applied causing the grips to move apart in opposite directions at a constant rate of speed (2.54 cm/min). The force in pounds necessary for initial disruption as well as the maximum load applied to the incision were recorded. The linear deformation of the sample at given time periods was also recorded. The data was collected and analyzed using analysis of variance with a two factor treatment structure (location within the suture line and the suture pattern used).

Samples collected for histological evaluation were fixed in 10% neutral buffered formalin, processed by routine methods, and imbedded in paraffin. Samples were sectioned at eight microns and stained in routine fashion with hemotoxylin and eosin (H & E)[k]. Additionally, sections were collected from each specimen and stained with trichrome stain [k] for approximate determination of collagen content. Several sections of each pattern from each horse were examined for histologic evidence of healing. Specific examination was made for evidence of collagen deposition, infection, inflammation, and foreign body reaction to suture material.

RESULTS

CLINICAL OBSERVATIONS

Postoperatively, all horses from Groups 2, 3, and 4 developed subcutaneous edema of the incisional area for three to seven days. Placement of a circumferential abdominal wrap appeared to minimize the accumulation of incisional edema. A small amount of serofibrinous drainage was noted from one to five days postoperatively in five horses. The drainage resolved without treatment or futher complications. No clinical complications of wound healing were observed at the operative site.

Four of the horses exhibited a transient elevation in rectal body temperature (103° F) three to four days postoperatively. All returned to normal without treatment. No other clinical abnormalities or evidence of surgical wound infection were noted.

GROSS EVALUATION OF INCISIONS

Upon postmortem examination, one horse (Group 3) was found to have omentum adhered along the entire ventral abdominal incision, regardless of suture pattern. There were no signs of incisional disruption in any of the horses under study and no gross evidence of infection.

HISTOLOGIC EVALUATION

Histologic evaluation revealed no significant differences in the histologic appearance of incisions within treatment groups with respect to either the specific suture pattern used for closure or the pattern location within the suture line. There was no histologic evidence of aberration in the cellular reaction, the anticipated sequence of healing, or incisional sepsis. Individual variation within groups was evident regarding vascularization, muscle degeneration, type and extent of cellular infiltrates, and maturity of connective tissue. No complications were evident on histologic evaluation.

Generally, sections examined from Group 2 samples (5 days) were well vascularized. Vessels could be seen proliferating from the edges and bridging the wound. Neutrophils were evident in all sections ranging from few to many in number and arranged either diffusely throughout the tissue section, in small pockets, or both. The amount of fibrin present in the wound varied from a wide fibrin clot to smaller clots. Fibroblasts were present in all sections of this group with fibrous tissue proliferating from the edges of the wound. Muscle degeneration existed to some extent in all sections. Muscle fibers were frequently observed to be encircled by and replaced by a fine network of fibrous tissue. Neutrophils were seen surrounding the suture material.

Sections from Group 3 samples (10 days) sections varied primarily in the degree of maturity of the fibrous connective tissue. Sections from three of the six segments closed with the simple continuous suture pattern appeared to have more mature fibrous connective tissue than the corresponding sections taken from the segments closed with the simple interrupted pattern. Neutrophils were again present either as a diffuse infiltrate or in small focal aggrregates of cells. Macrophages containing hemosiderin were observed in several sections. Muscle degeneration and connective tissue replacement were evident to some degree in all sections.

All sections examined from Group 4 samples (21 days) showed a very mature fibrous connective tissue scar. In one section, suture material was seen encircled by a fine rim of neutrophils which was surrounded by a larger ring of mature fibrous tissue. Macrophages laden with hemosiderin were present in many sections. There were few neutrophils present compared with samples from Groups 2 and 3. There was very little variation within this group and all appeared to have a solid union.

Representative histologic photographs of each suture pattern from Group 2, 3, and 4 samples are found in figures 4-9.

BREAKING STRENGTH EVALUATION

All comparisons were evaluated by analysis of variance with a two factor treatment structure. Significance was set at $P \leq 0.05$. The results of the breaking strength evaluation from groups 1,2,3, and 4 are found in Tables 1-3 and Figures 10-12.

The breaking strength of the simple continuous closure was significantly greater (P=0.03) than that of the simple interrupted pattern in Group 1 samples (time 0). There was no significant difference found between the breaking strength values of incisions closed with simple continuous or simple interrupted suture patterns in the segments tested from Group 2 (5 days), Group 3 (10 days), or Group 4 samples (21 days). There was however, a nonsignificant trend toward an increase in the breaking strength in the simple interrupted pattern of the five and ten day samples and the simple continuous pattern of the twenty-one days samples.

No significant difference in breaking strength could be demonstrated between samples taken from Group 2 (5 days) and Group 3 (10 days), however a nonsignificant trend for the breaking strength of the five days samples to be slightly greater than the ten day samples was present in closure with either suture pattern. The breaking strength of Group 4 specimens (21 days) was significantly greater ($p<.05$) than the breaking strength of specimens from either Group 2 (5 days) or Group 3 (10 days)

Analysis of the effect of pattern position along the surgical incision (cranial vs. caudal) revealed no significant differences in the breaking strengths in samples taken from Group 2 (5 days), Group 3 (10 days), or Group 4 (21 days). There was a trend however for the breaking strength of the caudal position to be greater in all three groups. The breaking strength of the caudal position was found to be significantly greater ($p<.05$) than the breaking strength of the cranial position in the Group 1 (time 0) specimens.

TEST OBSERVATIONS

Ultimate failure of the incisional closure was either the result of suture failure (breaking, usually at the knot) or tissue failure (suture pulling through tissue) in every case. There were no apparent differences between suture patterns regarding the method of ultimate failure in Groups 1, 2, or 3. In Group 4, failure did not occur at the incision in six of the samples but rather at the edges of the grips securing the specimen in the testing machine.

It was noted that when interrupted sutures failed, they routinely failed in progressive fashion. That is, when one suture failed it took very little, if any, additional force for the remaining sutures to fail in a similiar segmental fashion. When continuous sutures failed, the incision usually continued to absorb and redistribute energy until another area of the incision failed and went on to complete failure.

DISCUSSION

Exploratory celiotomy in the horse is indicated for surgical management of a variety of disease states.[1-3] The ventral midline incision is the most popular surgical approach since it provides the greatest single incision exposure and access for most abdominal procedures.[1,2,4,5,6] The principal concern regarding this approach has been the considerable postoperative stress placed directly on the suture line by the weight of the abdominal viscera.[2] Traditionally, the ventral midline incision has been repaired with a simple interrupted suture pattern. The strength and secutity of the interrupted pattern were thought to be an advantage. Concern about the consequences of a knot untieing or breaking at one end of a simple continuous suture pattern were that the entire wound would dehisce. For this reason the selection of suture pattern is an important decision. Number 2 polygalactin 910 was chosen for this study since it is quite satisfactory and is commonly utilized clinically in closure of equine ventral midline incisions.[37]

Interrupted patterns of suture placement have traditionally been advocated due to their alleged security and ease of placement.[8] In this study, the simple interrupted pattern was observed to be clinically adequate in strength of closure of the equine ventral midline incision. The simple continuous pattern however, was found to be of equal or greater breaking strength.

As previously indicated, the forty horses utilized in the study were devided into four groups (n1=24, n2=6, n3=6, n4=4). The individuals were distributed in this fashion for a variety of reasons. Group 1 was considered to represent the most critical time period in the course of incisional healing, namely that point just prior to the initiation of the healing process. For all practical purposes, there is no substantial amount of postoperative healing when the patient is recovered from anesthesia. As the patient recovers from general anesthesia, a tremendous force can be placed on the sutured incision. It was thought that if complications regarding the integrity of the suture pattern were to occur it would likely be at this time period. In an effort to more directly identify differences between suture patterns, a large sample size was therefore desirable. In this study all horses assigned to this group had been presented to Kansas State University for elective euthanasia. Although the mitigating circumstances varied between cases, the abdominal wall was determined to be virtually normal and the horses were anesthetized and instrumented for the study prior to euthanasia. Five days (Group 2) and ten days postoperatively (Group 3) were thought to be less critical than time 0 but more critical than twenty-one days postoperatively (Group 4), therefore groups 2 and 3 contained a larger sample size than Group 4.

It was clear from the results of the clinical and gross pathological observations that the specific suture pattern had minimal effect on the healing of the incisions under study. No evidence of herniation or eventration was observed. Only one horse (Group 3) developed any adhesions and those adhesions developed along the entire incision without regard for the specific suture pattern.

Histologic evaluation of the healing incision revealed individual variation within groups but no significant differences with regard to suture pattern utilized or location within the suture line. Muscle degeneration existed in all samples, presumably resulting from tissue handling and suture placement. There were variations between samples regarding the extent of the damage, but these were not specifically attributable to the effect of either pattern. This observation suggests that tissue strangulation is no more severe in one pattern than the other. Sections viewed from a specific time period appeared to vary somewhat in their stage of healing. Samples evaluated from Group 2 (5 days) varied from those in which the wound was filled only with fibrin to those that had fibrous tissue nearly uniting the edges. Group 3 (10 days) samples varied in maturity of the fibrous tissue. By 21 days however, all wounds appeared quite similiar, posessing a mature fibrous connective tissue scar in various stages of reorganization. This observation suggests that there may be some variation in healing between individual animals, particularly early in the healing process. It also suggests that regardless of pattern or position, the clinical result was the same.

The cellular infiltrates within each wound varied as anticipated with postoperative time. In Group 2 samples the infiltrate consisted mainly of neutrophils. Neutrophils were often arranged in small pockets or scattered diffusely. The incisions did not appear to be infected in either pattern based on the magnitude of the cellular response and the ability to locate and identify bacteria within the wound. Neutrophils were still present in the samples from Group 3, however their numbers were reduced. Monocellular phagocytes and in particular, macrophages, were greatly increased in number. Many of these phagocytic cells were filled with the hemoglobin breakdown product, hemosiderin. By 21 postoperative days, the cellular infiltrate had diminished, although neutrophils and macrophages could still be found in numbers exceeding that of the surrounding tissues. All changes in cellular infiltration were consistant with that normally observed in the respective stages of first intention healing.(17)

In many instances it is difficult or inefficient to perform mechanical testing of biological tissue specimens immediately after collection. Post mortem freezing of samples for storage prior to batch testing is often necessary and may be benificial in providing uniformity in sample handling and evaluation. Previous investigation involving rabbit ligments demonstrated no significant differences between tensiometric analysis of fresh and frozen specimens in maximum load or tensile failure.[44] Additional work comparing viscoelastic properties of fresh and frozen cat tendon showed no difference in stress strain limit cycles.[45] There was however, a significant difference found in elastic moduli, suggesting that data of fresh and frozen specimens should not be pooled.[45]

Many different devices have been utilized for evaluation of tensile or breaking strength.[18-25] The testing apparatus utilized in this study was chosen for its simplicity and availability. Custom grips were designed to hold the tissue specimen in place while a mechanical force was applied causing the grips to move apart in opposite directions exerting a constant force on the incision line. Observations of the initial force of disruption and the maximum force applied were noted. The breaking strength values obtained in the study do not represent the absolute breaking strength of the incision in vivo. The data of disruption and force applied is considered to be less than the force vectors and application which result during a violent anesthetic recovery. Nevertheless, the aquisition of these values permits a comparative statement to be made because all tissue specimens were handled and tested in the same manner. For these reasons the data observed should be viewed as comparative.

Observations made during the breaking strength testing did not support the hypothesis that closure with simple interrupted sutures will maintain strength and tissue apposition, should any part of the suture line fail. In those samples where failure was due to suture breakage, all incisions had multiple sutures break simultaneously or with subsequent minimal increase in force. The remaining incisions failed as a result of tissue failure in which the suture pulled through the tissue. Failure of the incisions closed with the simple continuous pattern were also due to multiple breakage of suture or suture pulling through the tissue. In these incisions however, additional energy was absorbed and a higher breaking strength achieved prior to incisional disruption. This was believed to be the result of a redistribution of the disrupting force along the suture line, following initial disruption and prior to ultimate failure. In Group 4 samples (21 days) the incisional preparations failed at the grips in six out of the eight samples. Of the two remaining samples, both had been sutured with simple interrupted pattern. One failed along the original suture line and the other one cm. lateral to the incision line. This observation suggests that the quality of incisional healing has attained a considerable degree of strength by 21 postoperative days. The implication in this observation is that a patient which experiences uncomplicated healing of a midline incision may be turned out to pasture exercise at some point after three weeks without undue concern for incisional integrity.

Statistical analysis demonstrated no significant difference in the breaking strength data of Group 2 samples (5 days) compared to data from Group 3 samples (10 days) with either suture pattern. There was a trend for the breaking strength to be slightly greater in Group 2 samples (5 days). This observation suggests that precautions should be taken during this period to avoid sudden stresses on the incision which could occur for example during loading or trailer transport of a surgical patient, early in the postoperative period. Horses should perhaps remain hospitalized during this period to prevent premature exposure to risk of incisional stress and potential disruption of the incision. Group 4 samples (21 days) of either pattern had significantly greater breaking strength than either Group 1 or 2, which was expected.

Statistical analysis of breaking strengths at different locations along the incision revealed a tendency for the caudal aspect of the incision to have a greater breaking strength than the cranial position. This difference was significant only in data from Group 1 samples (time 0). Perhaps with a larger sample size, a similiar difference could have been demonstrated in all groups. This observation supports the clinical impression that most incisional hernias occur along the cranial portion of the incision.

Clinically, the most significant finding of this study was that there was no significant difference found between the breaking strength values of incisions closed with simple interrupted or simple continuous suture patterns at 5, 10, or 21 postoperative days. The breaking strength of the simple continuous pattern was, in fact, significantly greater than the simple interrupted pattern in segments tested acutely (Group 1, time 0). The acute phase of wound healing may be the most critical time period in which to assess breaking strength since acute incisional failure in the immediate postoperative period is associated with catestropic complications and patient mortality. There are tremendous amounts of force which are exerted on the midline surgical incision as the horse attempts to stand. In cases of violent recovery secondary to emergence delerium, a phenomen of recovery from general anesthesia, the forces and the problem are magnified. If the suture line fails at this point, the result could likely be a catastrophic eventration.

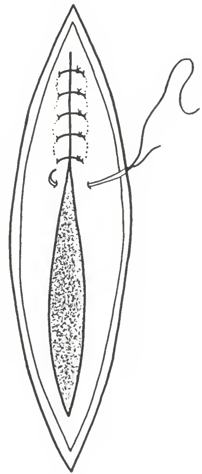
The simple continuous suture pattern has the advantages of requiring less time to apply. Because equine anesthetic morbidity appears to be directly correlated to duration of general anesthesia[38], the use of techniques which reduce operative time are highly desireable. A smaller amount of suture material is left within the wound, so there is less chance of incisional infection with the simple interrupted pattern.

Based upon these findings as well as clinical experience with more than 290 clinical cases, the data presented in this study suggest that the use of the simple continuous suture pattern in closure of uncomplicated equine ventral midline incisions is an acceptable technique. This is based on the findings of comparable or superior strength in similiar post operative periods and a lack of histologic evidence of an adverse effect on the healing of midline incisions.

SUMMARY

Midline celiotomies were performed on forty adult horses for evaluation of incisional strength and quality of healing associated with two suture patterns at various times following surgery. A 32 cm incision on the linea alba was apposed in four equal segments using #2 polygalactin 910, placed in either simple continuous or simple interrupted suture pattern. The placement of each suture pattern was randomly assigned with respect to cranial or caudal positioning. Horses were randomly assigned to one of four groups for evaluation at time 0 (24), five days (6), ten days (6), and twenty-one days (4) postoperatively. Breaking strength of each suture pattern was compared by time period and by incisional position. Samples of each pattern were collected from each position for histologic evaluation. No significant difference was found in the postoperative breaking strength between suture patterns at five, ten, or twenty-one days. In the acute group, the simple continuous pattern was significantly stronger than the simple interrupted pattern and the breaking strength of the caudal position significantly greater than the cranial. There was no significant effect of position on breaking strength of various suture patterns at five, ten, or twenty-one days. Histological evaluation revealed no significant difference in healing parameters. These findings suggest that the use of the simple continuous suture pattern is an acceptable technique for closure of equine ventral midline incisions.

FIGURE 1
The schematic drawing of simple interrupted and simple continuous suture patterns.


Simple Interrupted

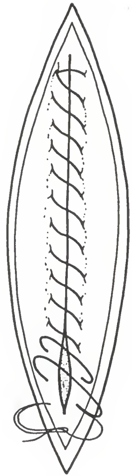

Simple Continuous

FIGURE 2
The schematic drawing of the ventral midline following closure of the linea alba.

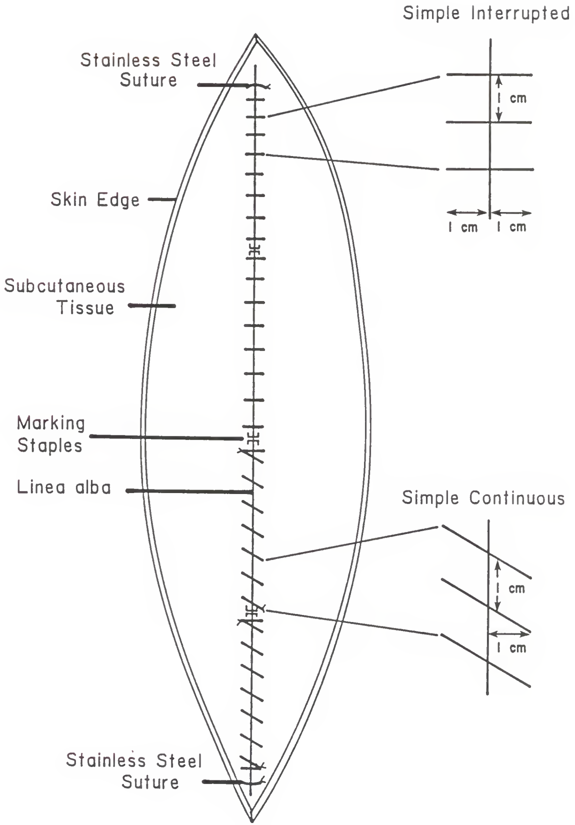
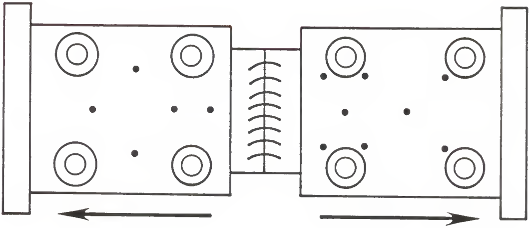

Simple Interrupted
Stainless Steel Suture
I cm
Skin Edge
I cm
I cm
Subcutaneous Tissue
Marking Staples
Linea alba
Simple Continuous
I cm
I cm
Stainless Steel Suture

FIGURE 3
The schematic drawing of the custom grips
used in sample testing.



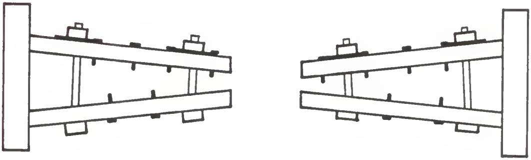


FIGURE 4
Histologic view of sample from Group 2, simple continuous suture pattern.

FIGURE 5
Histologic view of sample from Group 2, simple interrupted suture pattern.

FIGURE 6
Histologic view of sample from Group 3, simple continuous suture pattern.

FIGURE 7
Histologic view of sample from Group 3, simple interrupted suture pattern.

FIGURE 8
Histologic view of sample from Group 4, simple continuous suture pattern.

FIGURE 9
Histologic view of sample from Group 4, simple interrupted suture pattern.

FIG. 4

FIG. 5

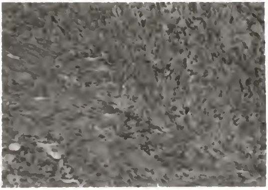


FIG. 6

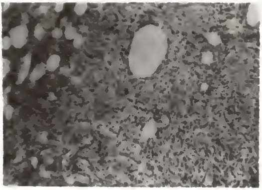


FIG. 7

FIG. 8

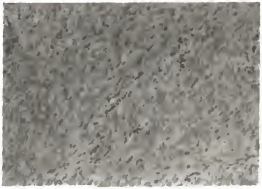


FIG. 9

FIGURE 10
Histogram of the mean breaking strength of the simple continuous vs. the simple interrupted suture pattern in each group.

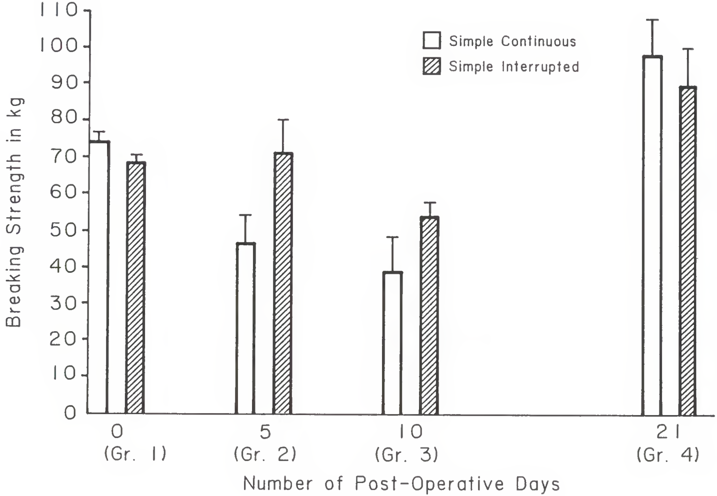

Breaking Strength in kg
110
100
90
80
70
60
50
40
30
20
10
0
Simple Continuous
Simple Interrupted
0
(Gr. 1)
5
(Gr. 2)
10
(Gr. 3)
21
(Gr. 4)
Number of Post-Operative Days

FIGURE 11
Histogram of the mean breaking strength values of cranial vs. caudal incisional location in each group.

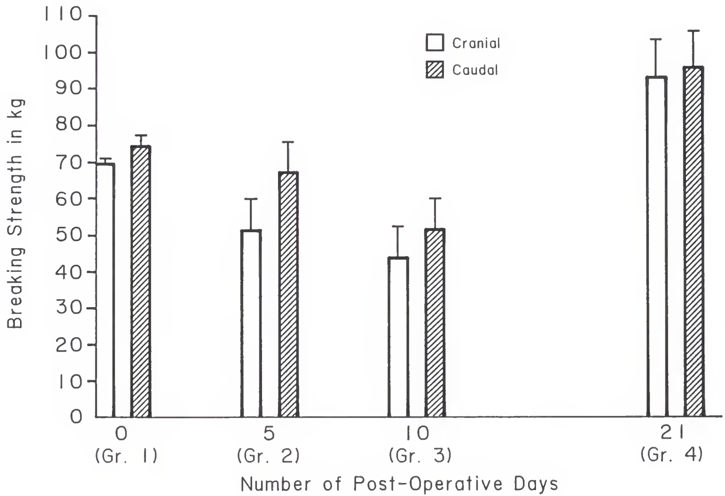

Breaking Strength in kg
110
100
90
80
70
60
50
40
30
20
10
0
Cranial
Caudal
0
(Gr. 1)
5
(Gr. 2)
10
(Gr. 3)
21
(Gr. 4)
Number of Post-Operative Days

FIGURE 12
Histogram of the mean breaking strength values for each group.

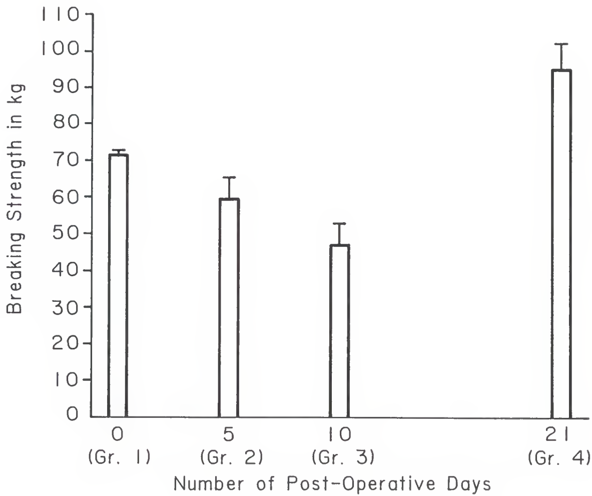

Breaking Strength in kg
110
100
90
80
70
60
50
40
30
20
10
0
0
(Gr. 1)
5
(Gr. 2)
10
(Gr. 3)
21
(Gr. 4)
Number of Post-Operative Days

TABLE 1

The breaking strength values comparing the simple interrupted and simple continuous suture pattern in each horse.

TABLE 1

GROUP 1 (time 0):

Horse No.	Force in Kilograms Interrupted	Continuous
1	51.4	66.5
2	77.1	81.5
3	60.9	76.9
4	86.4	100.0
5	78.4	67.6
6	61.1	70.1
7	64.6	75.6
8	81.8	98.2
9	79.6	73.5
10	56.5	58.0
11	63.6	67.3
12	67.8	81.3
13	58.7	70.0
14	95.5	74.9
15	58.7	57.3
16	52.0	71.1
17	75.5	70.2
18	65.9	51.4
19	70.0	71.8
20	86.2	82.9
21	65.7	77.5
22	75.1	67.8
23	44.0	84.0
24	75.0	98.2
mean	68.8	74.7
error	1.8	1.8

GROUP 2 (5 days):

25	72.5	59.6
26	101.8	13.6
27	75.5	79.6
28	61.5	68.7
29	55.9	31.5
30	64.0	26.0
mean	71.9	46.6
error	8.3	8.3

TABLE 1 (cont´d)

GROUP 3 (10 days):

Horse No.	Force in Kilograms Interrupted	Continuous
31	64.0	19.6
32	63.2	18.2
33	38.4	49.6
34	52.5	29.1
35	36.9	29.5
36	73.9	92.7
mean	54.8	39.8
error	8.3	8.3

GROUP 4 (21 days):

37	82.4	90.0
38	74.4	75.7
39	88.2	92.7
40	117.3	135.5
mean	90.5	98.5
error	10.1	10.1

TABLE 2
The breaking strength values comparing the cranial and caudal incisional location in each horse.

TABLE 2

GROUP 1 (time 0):

Horse No.	Force in Kilograms Cranial	Caudal
1	51.4	66.5
2	77.1	81.5
3	76.9	60.9
4	100.0	86.4
5	67.6	78.4
6	61.1	70.1
7	75.6	64.6
8	81.8	98.2
9	73.5	79.6
10	58.0	56.5
11	67.3	63.6
12	67.8	81.3
13	58.7	70.0
14	74.9	95.5
15	58.7	57.3
16	52.0	71.1
17	70.2	75.5
18	65.9	51.4
19	70.0	71.8
20	82.9	86.2
21	77.5	65.7
22	67.8	75.1
23	44.0	84.0
24	75.0	98.2
mean	69.0	74.5
error	1.8	1.8

GROUP 2 (5 days):

25	72.5	59.6
26	13.6	101.8
27	79.6	75.5
28	61.5	68.7
29	55.9	31.5
30	26.0	64.0
mean	51.6	66.8
error	8.3	8.3

TABLE 2 (cont´d)

GROUP 3 (10 days):

Horse No.	Force in Kilograms	
	Cranial	Caudal
31	19.6	64.0
32	18.2	63.2
33	38.4	49.6
34	52.5	29.1
35	36.9	29.5
36	92.7	73.9
mean	44.4	51.6
error	8.3	8.3

GROUP 4 (21 days):

37	90.0	82.4
38	74.4	75.7
39	92.7	88.2
40	117.3	135.5
mean	93.6	95.4
error	10.1	10.1

TABLE 3

The mean breaking strength values of each group, regardless of pattern or location.

TABLE 3

Group No.	Mean (kg)	Error
1	71.8	1.3
2	59.3	5.8
3	47.3	5.8
4	94.5	7.1

FOOTNOTES

a. Eqvalan, MSD AGVET, Merck and Co., Inc., Rahway, NJ 07065

b. Unitox, Coopers Animal Health, Inc., Kansas City, MO 64108

c. Rompun, Mobay Corp., Animal Health Division, Shawnee, KS 66201

d. Glyceryl Guaiacolate, Summit Hill Labs, Avalon, NJ 08202

e. Surital, Winchrop Laboratories, Inc., New York, NY 10016

f. Halothane, Halocarbon Laboratories, Inc., Hackensack, NJ 07601

g. Vicryl, Ethicon, Inc., Sommerville, NJ 08876

h. Butazolidin, Jensen Salsbery Laboratories, Burroughs Wellcome Co., Kansas City, MO 64141

i. T-61, American Hoechst Corp., Animal Health Division, Sommmerville, NJ 08876

j. Reihle Universal Testing Machine, Kansas State University, Manhattan, KS 66506

k. Gomori´s Trichrome Stain and hemotoxylin and eosin, Armed Forces Institute of Pathology

BIBLIOGRAPHY

1. Vaughn,JT: Surgical management of abdominal crisis in the horse. JAVMA 161(11): 1199-1212, 1972.

2. Kohn,CW, Bramlage,LR, Vaughn,JT: The ailmentary system. In Mansmann,RA, McAllister,ES, ed: Equine Medicine and Surgery. Santa Barbara, Am Vet Pub, 1982: 437-644.

3. Shires,GM: Equine colic surgery. In Jennings,PB, ed: The Practice of Large Animal Surgery. Philadelphia, WB Saunders Co., 1984: 664-670.

4. Turner,AS, McIlwraith,CW: Ventral midline laparotomy and abdominal exploration. In: Techniques in Large Animal Surgery. Philadelphia, Lea and Febiger, 1982: 204-210.

5. Pearson,H, Messervy,A, Pinsent,PJ: Surgical treatment of abdominal disorders of the horse. JAVMA 159: 1344-1352, 1971.

6. Schumacher,J, Hanselka,D, et al: Stainless steel closure of the equine linea alba. Eq Prac 3(2): 47-52, 1981.

7. Milne, FJ: Equine abdominal surgery in retrosfspect. Eq Vet J 4: 175-181,1972.

8. Knecht, CD, Allen,AR, et al: Suture patterns. In: Fundamental Techniques in Veterinary Surgery. Philadelphia, WB Saunders, Co., 1981: 52-68.

9. Rosin,E: Single layer, simple continuous suture pattern for closure of abdominal incisions. JAAHA 21: 751-756, 1985.

10. Crowe,DT: Closure of abdominal incisions using a continuous polypropylene suture: clinical experience in 550 dogs and cats. Vet Surg 7: 74-77, 1978.

11. Turner,AS, Yovich, JV, et al: Experience with continuous absorbable suture pattern in the closure of ventral midline abdominal incisions in horses. Unpublished 1988.

12. Fretz,PB, Hamilton,GF, et al: Management of umbilical hernisa in cattle and horses. JAVMA 183(5): 550-552, 1983.

13. Sloop,RD: Running synthetic absorbable suture in abdominal wound closure. Am J Surg 141: 572-573, 1981.

14. Coles,JC, Caroll,SE, Gergely,N: An improved method of abdominal closure. Can J Surg

15. Peacock,EE, VanWinkle,W: Fascia and muscle, the

biochemistry and environment of wounds and their relation to wound strength. In: Wound Repair. Philadelphia, WB Saunders Co., 1984: 129-169, 425-435.

16. VanWinkle,W: The tensile strength of wounds and factors that influence it. Surg Gyn Ob 129(4): 819-842, 1969.

17. Slauson,DD, Cooper,BJ: Healing and repair. In: Mechanisms of Disease. Baltimore, Waverly Press, Inc., 1982: 223-249.

18. Howes,EL Sooy,JW, Harvey,SC: The healing of wounds as determined by their tensile strength. JAVMA 92(1): 42-45, 1929.

19. Lee,AH, Swaim,SF, Pedersoli,BS, et al: A newly designed tensiometer. Am J Vet Res 47(3): 683-686, 1986.

20. Botsford,TW,: The tensile strength of sutured skin wounds during healing. Surg Gyn Ob 72: 690-697, 1944.

21. White,WL, Brody,GS, et al: Tensiometric studies of wounded and unwounded skin. An Surg 173(1): 19-25, 1971.

22. Nagy,E, Zingg,W: Simple standardized method for studying the tensile strength of healing incisions in animals. Can J Surg 14(2): 136-140,1971.

23. Fast,J, Nelson,C, Dennis,C: Rate of gain in strength in sutured abdominal wall wounds. Surg Gyn Ob 84: 685-688, 1947.

24. Forrester,JC, Zederfeldt,DH, Hunt, TK: A bioengineeering approach to the heling wound. J Surg Res 9(4): 207-212, 1969.

25. Wolarsky,E, Prudden,JF: A new method of woound tensiometry. Arch Surg 85: 404-409, 1962.

26. Dellmann,HD, Brown,EM: Connective and supportive tissues. In: Textbook of Veterinary Histology. Philadelphia, Lea and Febiger, 1981: 38-50.

27. Ellis,H, Gajraj,H, George,CD: Incisional hernias: when do they occur? Br J Surg 70: 290-291, 1983.

28. Johnson,JH: Surgical approaches to the abdomen of the horse. Vet Med Sm An Clin 65: 836-840, 1970.

29. Messervy,A: Surgical approach to abdominal surgery. Eq Vet J 2: 52-53, 1970.

30. Sisson,S: Equine myology. In: Sisson,S and Grossman,JD,

ed: The Anatomy of the Domestic Animal. Philadelphia, WB Saunders Co., 1975:407-412.

31. Allen,RW: In vitro tensiometric studies of the sutured ventral abdominal incision in the horse. Unpuplished thesis, Cornell U, 1974.

32. Blessing,CE: Prevention of postoperative eventrations in large animal abdominal surgery. Unpublished research, Cornell U, 1971.

33. Tulleners,EP, Donawick, WJ: Secondary closure of infected abdominal incisions in cattle and horses. JAVMA 182(12): 1377-1379,1983.

34. Barham,RE, Butz,GW, Ansell,JS: Comparison of wound strength in normal, radiated, and infected tisues closed with polyglycolic acid and chromic catgut sutures. Surg Gyn Ob 146: 901-907, 1078.

35. Wasiljew,BK, Winchester,DP: Continuous absorbable suture closure of abdominal incisions. Surg Gyn Ob 154: 378-380, 1982.

36. Malt,RA: Abdominal incisions, sutures, and sacrilage. NE J Med 297(13): 722-723,1977.

37. Adams,SB: Surgical approaches to and exploration of the equine abdomen. In: McIlwraith,CW, ed: The Veterinary Clinics of North America - Equine Gastrointestinal Surgery. Philadelphia, WB Saunders Co., 1982: 98-99.

38. Jochen,RF, Roth,DT, Burdette,BJ: Clinical evaluation of coated polygalactin 910 synthetic absorbable suture material. Mod Vet Prac 63(7): 555-557, 1982.

39. Bellenger,CR: The purpose of sutures and available suture materials. Comp 4(6): 507-518,1982.

40. Fischer,JD, Turner,FW: Abdominal incisional hernias: a ten year review. Can J Surg 12: 202-204, 1974.

41. Bucknall,TE, Cox,PJ, Ellis,H: Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. Br Med J 284: 931-933, 1982.

42. Irvin,JT, Stoddard,CJ, et al: Abdominal wound healing: a prospective clinical study. Br Med J 274: 351-352, 1977.

43. Preston,DJ, Richards,CF: Use of wire mesh prostheses in the treatment of hernia. Surg Clin NA 53(3): 549-554, 1978.

44. Woo,SL, Camp,MD, et al: Comparison of the biomechanical

properties of fresh and frozen ligaments. Unpublished research, U of CA, San Diego, Div of Orth Surg and Rehab: 98-99.

45. Matthews,LS, Ellis,D: Viscoelastic properties of cat tendon: effects of time after death and preservtion by freezing. J Biomechanics 1: 65-71, 1968.

COMPARITIVE EVALUATION OF SIMPLE CONTINUOUS AND SIMPLE INTERRUPTED SUTURE PATTERN IN THE EQUINE LINEA ALBA

by

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D.V.M., Kansas State University, 1986

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MASTER OF SCIENCE

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Manhattan, Kansas

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ABSTRACT

Ventral midline celiotomy is a commonly utilized surgical technique for the management of cases of equine acute abdominal crisis. Wound dehiscence represents a potentially devastating complication following treatment of surgical lesions by celiotomy. Dehiscence may result from several causes, including the failure of the sutured closure. Simple interrupted suture patterns have predominated in closure of the equine abdomen, primarily because of their alleged security and strength of closure. Clinical experience suggests that simple continuous suture patterns are equally acceptable and may be advantageous for several reasons. The objectives of this study were to compare the postoperative breaking strength of abdominal midline incisional closures following simple interrupted or simple continuous suture apposition; to evaluate and compare histologically, the effect of suture pattern in the closure of midline celiotomies at various postoperative times; and to evaluate the postoperative breaking strength of each suture pattern in relation to its location (cranial vs. caudal) along the incision.

Forty mature horses were randomly divided into four groups for suture pattern evaluation at time 0 (Group 1, n=24), five days (Group 2, n=6), ten days (Group 3, n=6), and twenty-one days (Group 4, n=4). A ventral midline celiotomy was made in each horse. The lineal incision was

then closed in four equal segments using #2 coated polygalactin 910. Two of the segments were apposed with a simple continuous suture pattern and the remaining two with simple interrupted pattern utilizing a standard fashion of suture placement. Pattern type and incisional segment position were randonly assigned preoperatively.

Following surgery, all surviving horses (Groups 2,3,4) were monitored daily for signs of abdominal pain, incisional infection, dehiscence, or other clinical abnormalities. Phenylbutazone was administered orally every twelve hours for 72 hours postoperatively. Animal care was in compliance with standard animal welfare guidelines for use in education and research. At the appropriate postoperative interval the animals were humanely euthanized and the abdominal wall segments collected. One segment of each pattern from the animals in Groups 2, 3, and 4 was collected and preserved in 10% formalin for subsequent histological evaluation. The remaining segments were evaluated for breaking strength.

Results of the histological examination indicated no significant difference in standard healing parameters between the two patterns in any of the groups evaluated. There were individual variations within each group.

The data on breaking strength were statistically evaluated by analysis of variance with a two factor treatment structure (location within the suture line and the suture pattern used). Results of Groups 2, 3, and 4 suggested that there was no significant difference in postoperative breaking strength of either pattern in relationship to its location (cranial vs. caudal) along the incision. In Group 1 the breaking strength of segments in the caudal location was significantly greater than that of the cranial location. Although there was individual variation in breaking strength within groups, there was no significant difference in breaking strength between simple continuous and simple interrupted suture patterns at 5, 10, or 21 days postoperatively. There was a significant difference in breaking strength in the acute group (Group 1) with simple continuous greater than simple interrupted. Breaking strength of either pattern exhibited a nonsignificant trend to decrease at 5 and 10 days postoperatively.

This study suggests that the use of simple continuous suture patterns in closure of uncomplicated equine ventral midline incisions is an acceptable technique.