EVALUATIONS OF SURGICAL IMPLANTS OF POLYPROPYLENE MESH IN THE ABDOMINAL WALL OF THE EQUINE SPECIES

by

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INTRODUCTION

Large abdominal wall defects in the equine species are difficult to repair surgically. Most large defects in the abdominal wall result from trauma, with the remainder caused by improper development. Surgical repair is difficult because there is insufficient tissue to allow a simple closure by opposing or overlapping the tissue. A simple closure is always the method of choice if the defect can be corrected without excessive suture tension. If too much tension is applied, the sutures will pull through the relatively soft tissue.

An implant material that adapts to surgical manipulation and is not rejected by the animal's body would be useful in abdominal surgery. This implant could be used to correct large defects in the abdominal wall and it also could be used as an onlay graft to strengthen laparotomy incisions.

In man, many plastics and metals have been utilized in the closure of abdominal wall defects. Many implanted materials have had to be removed post-operatively because they were rejected by the patient or surgical complications developed (Koontz and Kimberly, 1960). A polypropylene (Marlex)[1] mesh has been used successfully in man (Usher, 1961, 1962). This material has not been critically evaluated in the equine species. The purpose of this study was to evaluate the surgical implantation of Marlex mesh and to study the macroscopic and microscopic tissue reactions in the abdominal wall of the equine species.

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[1]Phillips Petroleum Company, Bartlesville, Oklahoma

LITERATURE REVIEW

Koontz and Kimberly (1960) stated that tantalum gauze has probably been more widely used than any other prosthetic implant. During a ten year period these workers have implanted experimentally: dacron fabric, dacron and nylon cloth, fiberglass, fortisan fabric, mylar, nylon mesh, orlon cloth, polyvinyl sponge, teflon fabric, teflon and nylon cloth, vinyon - N cloth, stainless steel gauze and loosely woven stainless steel mesh. None of these materials were comparable to tantalum gauze implants. Adler (1962) stated that tantalum would fragment two months to a year after implantation. He reported a few cases in which tantalum fragmented and penetrated the skin necessitating removal.

Koontz and Kimberly (1953, 1960) reported that tantalum had an advantage over stainless steel in that it caused a proliferation of fibrous tissue after implantation so that it could not be removed except by sharp dissection. Stainless steel, an inert material, was lifted out of the tissue because of a lack of fibroplasia. In hernia repair, this was a distinct disadvantage. Fortisan and orlon caused strong fibroplasia and soon became infiltrated with fibroblasts provided no infection occurred. If infection occurred fortisan and orlon were removed.

Stock in 1954 thought that nylon would replace tantalum because nylon was flexible and did not break, but his conclusions were drawn on ten cases. Sandford et al., (1956) compared orlon to tantalum gauze. The orlon implant wrinkled and predisposed to infection more frequently than the tantalum implants.

Schwartz and Erich (1960) used a polyvinyl-formal (Ivalon) sponge as a replacement for living tissue in dogs. This material formed a good matrix for fibroplasia provided there was no infection. However, it did shrink approximately 20 to 30% and calcium was deposited in this implant between the sixth and twelfth month after surgical implantation.

Gibson and Stafford (1964) repaired 25 difficult defects in the abdominal wall in man using teflon implants. Out of these 25 patients, fifty percent developed wound complications and five percent required removal of the mesh. The wound complications were mostly from infection and seroma formation. In the five percent that required removal of the teflon, the sinuses stopped draining and the wounds healed after complete removal of the mesh. However, more than one surgical attempt was necessary to remove all of the mesh.

Gibson and Stafford used teflon mesh to repair large abdominal wall defects in 25 patients. Twelve patients' wounds healed per primam. Five patients formed seromas that required repeated draining and eight cases developed wound infections. Six of the eight cases with wound infections had the teflon removed.

Since 1958, Usher has been using a polypropylene (Marlex) monofilament mesh in the repair of abdominal hernias. At first, Marlex mesh was sutured to the tissues with silk, cotton or stainless steel sutures. Quite often the silk and cotton sutures caused a persistent draining sinus that could be corrected by removal of the sutures (Usher, 1962). The mesh would then remain in place and correct the abdominal wall defect.

Usher (1961) began using a braided polyethylene suture (Marlex braided suture). Marlex braided suture has eliminated the persistent draining sinuses that were associated with cotton and silk sutures.

Usher and Wallace (1958) conducted experimental studies on dogs comparing nylon, orlon, dacron, teflon and Marlex. Fifteen dogs were used, 3 for each material in which 10 grams of plastic in pellets or undyed shredded yarn was placed in the peritoneal cavity. Seven days after placing the plastic in the peritoneal cavity of the dogs, the animals were sacrificed and the intra-abdominal viscera examined grossly for adhesions and other evidence of inflammary reaction. Microscopic studies were also conducted on the tissues for confirmation of the gross findings.

Experimental studies with Marlex mesh were conducted by Usher and Gannon (1959). These experimental studies were conducted in 31 dogs, four in which the abdominal wall was replaced with Marlex mesh. Three dogs survived the surgery and these were sacrificed at six weeks, three months, and six months. At autopsy, the abdominal wall replacement was intact, quite pliable and uniformly infiltrated with fibrous tissue to a thickness of 4 to 5 mm in all three dogs. The intestines and omentum were adhered to the mesh but there was no intestinal blockage. After removal of the graft the fibrous tissue was digested from the mesh. No fragmentation was noted and the mesh tensile strength was not decreased.

Infection studies were conducted on ten dogs out of 31 used by Usher and Gannon (1959). A 10 X 10 cm segment of the rectus abdominis muscle was removed leaving the peritoneum intact. The defect in the rectus muscle was bridged with Marlex mesh using an unsterile technique. Following skin closure a dilute solution of feces was injected into the wound. Three of the ten dogs died because of an overwhelming infection. In the remaining seven dogs, the incision was opened on the third day to drain the wound abscesses. Penicillin and dihydrostreptomycin were given daily for seven days to control the infection. The wounds on the seven dogs were then left to granulate with no further care. One dog chewed out the mesh but the wounds healed in the remaining six dogs without slough of the graft or sinus formation. Three or four months were required for these wounds to heal completely but healthy granulation tissue grew through the mesh and covered it by post-operation day 14 to 21. At autopsy of these six dogs, the gross and microscopic examinations appeared identical with the tissue response to Marlex mesh in the non-infected dogs.

Ponka et al. (1959) duplicated some of the work reported by Usher and Gannon (1959) using dogs and guinea pigs. Ponka et al. (1959) removed a 6 cm X 8 cm portion of the rectus abdominis muscle and the peritoneum. This defect was closed using Marlex mesh to replace the 6 cm X 8 cm section that was removed. In all cases, the wounds healed without infection. Six months after implantation, the animals were sacrificed at which time cross section microscopic examinations revealed little foreign body reaction to the material. Usher et al. (1958, 1959, 1960, 1961, 1962) reported the use of Marlex mesh in 541 hernias in man. There were a total of 54 wound complications. Twenty-one of these wound complications were seromas which yielded to repeated aspirations or were drained and healed in less than 4 weeks. There were 22 wound infections. In six of the infections the surgeon later removed the mesh, and in 11 other cases, exploration of persistent sinus tracts was necessary to remove silk or cotton sutures.

Of the 541 hernia cases reported, 358 cases were incisional hernias. The operating surgeon one year or more post-operatively examined 156 of the 358 cases. The remaining 202 cases had been operated upon less than one year or lost for follow-up. There were 16 recurrences among the 358 incisional hernias. One recurrence resulted from the surgical removal of the mesh because of infection. The other 15 occurred lateral to the edge of the mesh. Nine of these 15 recurrences were due to insufficient coverage in which the mesh was used as an onlay graft. Six cases recurred because the mattress sutures cut through the tissue. In these six cases, the mesh was used to bridge the defect.

Ochsner (1965) stated that the uses of Marlex are many and the limitations few. The ability to withstand infection is its paramount advantage.

Jacobs et al. (1965) reported on 20 ventral hernias in man repaired with Marlex mesh. Complications included nine instances of serum accumulation that required aspiration and one patient developed skin necrosis with secondary infection. The average follow-up period on these 20 hernia patients was 15 months.

Johnson (1966) reported on 31 patients with incisional herniorrhaphies repaired with Marlex mesh. One wound infection was encountered out of the 31 inguinal herniorrhaphies that necessitated the removal of the mesh. All of the incisional herniorrhaphies were drained by catheters connected to continuous suction for several days.

Schmitt (1967) reported the use of Marlex mesh in repairing very large defects of the abdominal wall resulting from infected war wounds. Granulation tissue was allowed to infiltrate through the mesh and then the area was covered with a split thickness skin graft.

Marlex mesh has been used for defects in the throacic wall. Graham et al. (1960) reported on 13 thoracic wall defects in man that resulted from surgery. Marlex mesh was used intrapleurally to repair these surgical defects. One patient developed a wound infection but the mesh did not require removal.

Numans and Wintzer (1964) reported on 299 cases in animals in which nylon, a polyamide fiber (Perlon) and mersilene mesh was implanted. These mesh implants were used when the abdominal hernia could not be corrected by ordinary means. Two hundred and sixty-five of the 299 abdominal hernias were in cattle in which 256 were corrected and 9 recurred. Thirty-four of the 299 abdominal hernias were in horses in which 32 were corrected and 2 recurred. Most of the tissue reactions to the mesh occurred up to 3 weeks post-operation. In some horses as late as 1 year post-operation, a serous discharge from the operated area was observed. This was attributed to the sutures used to hold the mesh in position. Fibroplasia would proliferate more extensively through the mersilene mesh than the nylon and perlon mesh. Mersilene mesh was found to be the better of the three implanted materials.

Many methods for implanting prosthesis in the abdominal wall of man are recorded. Early attempts were made to close the peritoneum and the hernia ring and then reinforce the closure with an implant or prosthesis.

The disadvantage in this procedure was that too much tension was put on the sutures and the hernia would recur. In more recent work, the implanted material was used for reinforcement over the external fascial sheath after the peritoneum was closed. Still later workers did not advocate the closure of the peritoneum but instead placed the mesh in the peritoneal cavity and sutured the mesh in place by placing horizontal mattress sutures through the mesh, peritoneum, and both fascial planes of the muscle as well as the muscle belly after approximately 4 cm of the retroperitoneal fat had been removed. This technique (when used with the Marlex mesh) had more advantages than other techniques reported. The advantages were that the Marlex mesh in man will stimulate a certain amount of fibroplasia and the adhesions produced in dogs were comparable to the adhesions produced following a laparotomy.

Later studies by Usher et al. (1959, 1960, 1961) on abdominal wall defects and hernia repair, were conducted in which two layers of mesh were implanted. One layer of mesh was implanted in the peritoneal cavity while another layer was implanted over the external muscle fascia. These two pieces of mesh were sutured together through the peritoneum, muscle fascia, and muscle belly using a horizontal mattress pattern. This method had the advantages of distributing the stress more evenly. It gave more mechanical strength, and caused a thicker replacement of fibrous tissue.

Seroma formation following surgical repair of the abdominal wall was a very frequent complication because of the dead space that was left in the tissue following extensive surgery. Repeated drainage of a seroma only increased the chance of infection and the serum served as an ideal culture media for most contaminants. Lattimore and Koontz (1954) used four small catheters placed around the surgical area through stab incisions. These catheters were connected to a continuous suction when the patient was returned to his room. This method helped the healing process by preventing seroma formation and it also kept the bandage dry.

MATERIALS AND METHODS

Implant Materials

Marlex mesh

A high molecular weight homopolymer of ethylene has been developed and designated Marlex 50 ethylene polymer. This polymer is a tough, white, opaque, rigid material having a high melting point and density (Jones, 1956). The chemical structure of Marlex 50 ethylene polymer is unbranched polymethylene chains that terminate at one end in a vinyl group and at the other end in a methyl group (Smith, 1956). Marlex 50 ethylene polymer is readily made into a monofilament by hot-melt extrusion at 400° to 600° F through an orifice. Cloth made from this fiber is impervious to water and possesses outstanding chemical resistance.

Marlex mesh was changed to polypropylene in 1964 (Blecharczyk)[1] allowing it to be sterilized by autoclaving. The Marlex mesh used in this project was of a knit weave (Figure 1). The mesh was knitted using 6 millimeters in diameter monofilaments of polypropylene.

Marlex braided suture

Marlex suture is made by braiding 8 strands of 6 millimeter diameter monofilament polyethylene (Figure 1). Braiding gives the suture sufficient roughness to provide knot pull breaking strength of 7 pounds which corresponds in strength to a U.S.P. size 2 suture. Marlex braided suture can

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[1] Blecharczyk, W. J., Chief Chemist, Davol Rubber Co., Providence, Rhode Island. 1967.

be sterilized by boiling for 30 minutes or cold sterilization by ethylene oxide.

Experimental Animals

Eleven ponies of primary Shetland Pony breeding were purchased from a local dealer. These ponies were approximately 2 years of age and were geldings. History was not available on the ponies other than they had been obtained through a local auction barn. Ponies were used for this project because they could be purchased and housed cheaper than adult horses.

Immediately after purchase, the ponies were treated twice, at 10 day intervals for internal parasites. Each pony also received two injections of equine encephalomyelitis vaccine and one injection of tetanus toxoid. Immediately following each surgical procedure, another injection of tetanus toxoid was administered.

Pre-operatively, a hemogram was determined by the clinical laboratory. This hemogram included a hemoglobin determination, packed cell volume reading, erythrocyte count, leucocyte count and differential leucocyte determination. Serum glutamic oxaloacetic transaminase (Reitman and Frankel, 1957) values were determined the day of the surgery and intermittently for 14 days post-operation (See Table 1).

Preparations for surgery

Pre-operatively, all of the ponies received promazine[1] and atropine.

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[1]Sparine, Wyeth Laboratories, Inc., Philadelphia, Pa.

Table 1. Serum glutamic oxaloacetic transaminase determinations (measured in units per millimeter of serum)

Day of surgery	Pony number									
	1	2	3	4	5	6	7	8	9	10
1	0	220	216	230	204	148	180	210	120	156
2	95	215	224	240	172	160	180	210	160	176
3	95	220					300	340	148	
4	68	220	230				300	390	100	208
5	220				150	124	340	480		208
6					124	150				
7							340	440		
9							370	360		
14							370	360		

Succinylcholine chloride[1] was given to immobilize the ponies for anesthetic induction. Halothane,[2] the anesthetic, was used in a closed circuit, circle type gas machine.[3] The anesthesized pony was secured in a metal crate to maintain a dorsal recumbency.

The surgical area, xyphoid to the pubis, was clipped with an electric clipper fitted with a number 40 clipper blade. The area was scrubbed with a hexachlorophene soap[4] and rinsed with tap water until a sterile gauze sponge remained white after being rubbed over the proposed incision site. An alcohol rinse was applied followed by an ether scrub.

The Marlex mesh, surgical instruments, drapes, surgical film,[5] rubber gloves and surgical gowns used in the Marlex mesh implant surgery were sterilized in a steam autoclave. The Marlex braided suture was received from the manufacturer in a sterile packet. A surgical cap and mask were put on by the surgeon. The hands and arms of the operator were scrubbed thoroughly with a surgical scrub brush and a germicidal detergent. Following drying with a sterile towel, a sterile surgical gown and sterile surgical gloves were donned.

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[1]Sucostrin, E. R. Squibb and Sons, New York, N.Y.

[2]Fluothane, Ayerst Laboratories, Inc., New York, N.Y.

[3]National Cylinder Gas, Division of Chemetron Corporation, Chicago, Illinois.

[4]Lexard, Swift and Co., Chicago, Illinois.

[5]Vi-Drape Surgical Film, Aeroplast Corporation, Dayton, Ohio.

A thin film of sterile adhesive[1] was sprayed over the proposed operative field. This film was allowed to become tacky to the touch before a sterile surgical film was positioned. Four green, medium weave, duck material drapes were placed over the surgical film and attached to the animal with towel clamps.

Surgical procedures

A right paramedian skin incision was made from below the xyphoid cartilage to anterior to the prepuce. Any severed blood vessels in the skin layer were clamped with tissue hemostats. The subcutaneous tissue was incised down to the external fascia of the rectus abdominis muscle. A second scalpel was used to incise the external rectus abdominis fascia and blunt dissection used to separate the muscle fibers. The internal rectus abdominis fascia was incised exposing the retroperitoneal fat. The retroperitoneal fat was removed to approximately 5 centimeters from the incision edges. The peritoneum was then incised. In ponies designated one and two (Group I) the Marlex mesh was implanted in the peritoneal cavity. The mesh was sutured to the peritoneum and the internal rectus abdominis muscle sheath using an interrupted horizontal mattress suture pattern. The external rectus abdominis sheath was sutured using an interrupted horizontal mattress suture pattern. A simple continuous interlocking suture pattern was used to oppose the subcutaneous tissue and an interrupted horizontal mattress pattern was used in the skin. The incision was closed

[1]Vi-Drape Adhesive, Aeroplast Corporation, Dayton, Ohio.

in its entirety with Marlex braided suture. A tetracycline hydrochloride powder[1] was applied to the wound.

Ponies designated three and four (Group II) had Marlex mesh implanted retroperitoneally. The initial incision was the same as in Group I but the peritoneum was not opened. The mesh was sutured to the internal rectus abdominis fascia with an interrupted horizontal mattress pattern. The incision was then closed the same as Group I.

Group III were ponies designated five and six. An incision was made as in Group I down to the internal rectus abdominis sheath. Marlex mesh was sutured to the internal rectus abdominis sheath with an interrupted horizontal mattress suture pattern. The incision was closed as in Group I.

The ponies designated seven and eight made up Group IV. The incision was made down to the external rectus abdominis sheath. The mesh was sutured to the external rectus abdominis sheath with interrupted horizontal mattress sutures. The incision was closed as in Group I.

Group V were ponies designated nine and ten. An incision was made through the peritoneum as in in Group I. Mesh was not implanted in this group. Marlex braided suture was used to close the peritoneum and internal rectus abdominis sheath. These structures were incorporated together with a continuous horizontal mattress suture pattern that was interrupted in the center of the incision. The incision was then closed as in Group I.

Pony eleven was designated as Vetafil control. An incision was

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[1]Polyotic, American Cyanamid Company, Princeton, N.J.

made in this pony as in Group I and closed using a 0.40 mm synthetic suture material (Vetafil).[1] The Vetafil was sterilized in a steam autoclave.

Post operative care

All ponies were kept in the Iowa State University Veterinary Clinic for at least 10 days post operatively at which time they were trucked to a privately owned local farm. Samples for serum glutamic-oxaloacetic transaminase determination were drawn while the ponies were in the Veterinary Clinic. The ponies were kept on grass as long as the season permitted and during the winter months, they were housed in a small paddock with an access to a shelter. During the winter months their ration consisted of a clover hay supplemented with oats of an unknown quantity.

Necropsy technique

The ponies were immobilized with succinylcholine chloride and euthanasia performed by electrocution. The hair was removed from the incision site and the scar examined. A large flap of abdominal wall was reflected to see if adhesions were present between the peritoneum and the omentum.

Sections through the incision site were fixed in 10% buffered formalin, dehydrated in graded ethyl alcohol solutions, cleared with chloroform and embedded in paraffin. Sections were stained with Harris hemotoxylin and eosin y.

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[1]Bengen and Company, Hannover, Germany.

RESULTS

Clinical Results

The ponies in this study were taken from the recovery room as soon as they were coordinated sufficiently to walk. All ponies were reluctant to walk and dragged the hind limb on the side that the paramedian incision was made. The first day following surgery, pitting edema developed along the incision lines. Small seromas developed on 6 of the ponies but none of these were drained nor did they ulcerate because of skin necrosis. Massage along the incision line helped relieve the edema on the third or fourth post operation day. Without massage the edema disappeared on the seventh to the ninth post operative day. The edema was more extensive and slower to be relieved in the ponies with excessive retroperitoneal fat.

The skin sutures were removed on the seventh to the ninth post operative day. All skin incisions healed by first intention resulting in very small scars.

Post operatively, the ponies did not show any abdominal discomfort. Their appetite was good and all of the ponies gained weight during this study.

Surgical Results

Handling the Marlex mesh was accomplished with relative ease. The most difficulty was encountered in attempting to keep the mesh from wrinkling. The first two corners could be sutured in place but it was difficult to place the remaining sutures at a sufficient distance from the incision to keep the mesh wrinkle free.

The Marlex braided suture ends had to be left long, otherwise the knot came untied. A square knot or a surgeons knot slipped, but this aided in obtaining the proper suture tension. To prevent additional slipping of the sutures after proper tension was achieved, a square knot was tied over the first knot.

Macroscopic Results

The ponies in Group I were sacrificed 16 months after the mesh implantation. This group had some adhesions between the peritoneum and the omentum (Figures 2 and 3). Pony number two had approximately 3 cm of the small colon adhered closely to the peritoneum. The Marlex mesh was wrinkled in the area of the most severe adhesions. When the adhesions were dissected away the mesh was covered with peritoneum. (Figure 4).

Group II was sacrificed 16 months post operatively. There were fewer adhesions in this group than Group I. The adhesions were associated with the small holes that were torn in the peritoneum while removing the retroperitoneal fat (Figures 6 and 7).

Microscopic Results

All tissues studied revealed a similar reaction to Marlex mesh. The mesh fibers appeared unaltered. A small layer of histiocytes (1 - 3 cells deep) and an occasional giant cell surrounded each mesh fiber (Figures 14 and 15). Fibroblasts infiltrated between the mesh fibers and laid down collagen incorporating the mesh with the surrounding tissues (Figures 16 and 17). The fibroblastic and connective tissue reaction was not excessive. Plasma cells were evident in some areas and small numbers of eosinophils were widely scattered throughout the tissue adjacent to the mesh.

The mesh implanted on the peritoneum was covered with mesothelial cells. More cellular reaction was observed at the edges of the mesh strip, particularly if wrinkling had occurred. Mineralization was a part of the reaction in one area of wrinkling. Capillaries were more evident in some areas than others. This was not associated with any particular location of the mesh in the abdominal wall.

The giant cell reaction and the histiocyte layer around the Marlex suture material appeared to be greater than around the Marlex mesh. Early metaplasia to cartilage was evident in one area adjacent to the Marlex braided suture. A more severe cellular reaction occurred to Vetafil than to the Marlex mesh or Marlex suture.

DISCUSSION

Fifteen years ago, abdominal surgery in the equine species was considered to be impractical because the risk of peritonitis was considered to be too great. Restraint was a major problem in maintaining a sterile surgical field. These problems have been reduced today by the use of aseptic surgery and gaseous anesthesia. This type anesthetic allows the surgeon to position himself and the animal properly without fear of trauma or contamination to the patient.

Asepsis is a must when surgery of any area is attempted. The abdominal cavity of the horse is no exception. When peritonitis develops in the horse, the infection rapidly becomes generalized, rather than localized as in other animals. The pre-operative preparation of the patient and the surgeon must be thorough in any surgery, but especially in equine abdominal surgery.

The technique of an operator can dictate the results of surgery. A surgeon must discipline himself to follow all of the principles of aseptic surgery as well as delicate tissue handling. Manipulation of any tissue is damaging but this can be minimized by proper technique.

Post operative care should also be of great concern to the surgeon. Creating the proper environment for the healing tissue is as much a part of a surgical procedure as the active tissue manipulation. Healing of any surgical wound is dependent upon the general welfare of the patient as well as local considerations.

Adjuncts in surgery can be of great value, but should be used only when indicated. Before any material or method is employed in a surgical technique it should pass the test of not causing an adverse tissue reaction. Marlex mesh and Marlex braided suture, used in this project, were found adaptable to the abdominal wall of the equine species. This mesh, when implanted in the equine abdominal wall, caused sufficient fibroplasia for strong wound healing but no adverse tissue reactions. The mesh was easy to manipulate and properly form to the tissues without the problem of unraveling, at the time of surgery.

Surgical invasion of the abdominal cavity of the equine species is not a simple technique. The stress that is applied to the suture line in the horse is great compared to the holding power of the abdominal wall tissues. A paramedian incision allows more layers of tissue to be closed which should lessen the chance for dehiscense. Most complications are observed on the first three days following surgery.

Dorsal recumbency is required for surgery to be performed on the ventral abdomen. The horse must recover from the anesthetic and regain a standing position, since the horse normally objects to any other position. During this stage a great deal of stress is applied to the suture line and in a high percentage of cases, the suture line can be disrupted. If an onlay graft of Marlex mesh is used over a suture line in the rectus abdominus muscle sheath, the tension can be absorbed by three suture lines rather than one. If the surgeon desires, Marlex mesh can be implanted in the peritoneal cavity or any layer in the abdominal wall. This allows three suture lines and may possibly prevent post operative herniation.

If difficulty is encountered in opposing the incision edges, Marlex mesh can be sutured to the incision edges and the area between the incision edges would heal by fibroplasia. In this case more than one layer of Marlex mesh might be desirable. One layer of mesh can be implanted in the peritoneal cavity and the other placed external to the external rectus abdominis sheath. The two layer method was recommended by Usher (1959, 1960, 1961) when repairing a large tissue defect in man. This study indicates that the two layer method can be used to repair large abdominal wall defects in the horse.

Marlex mesh can be handled very easily because of its pliability. It can also be cut to fit after sterilization and it can be sterilized with steam up to six times. Any portion that is unused after a surgical procedure can be saved for another procedure. The suture material is sterile when received from the manufacturer. In contrast to the mesh, the suture can not be sterilized by steam but it can be resterilized by boiling.

Because of its 54 inch length the suture material is very difficult to handle and the suture needle is also hard to thread because the braid will unravel slightly where the suture material is cut. Another disadvantage associated with the suture is that there is poor knot retention; therefore a long end is required after the knot is tied.

Marlex mesh is pliable and conforms well to the animal's tissues. For the operator, the mesh is difficult to suture in place without wrinkling. Experience in handling the mesh results in less wrinkling.

In hernia repair seroma formation following surgery has been the most commonly observed complication. This could have been controlled by using a pressure bandage around the entire abdomen. This is very difficult to apply in an anesthesized pony and on a gelding the prepuce and penis would interfere.

Another method to control the seroma formation is to implant catheter drains as described by Lattimore and Koontz (1954). These drains work best when connected to continuous suction. This is difficult to apply to an active patient that is standing. Also, if these catheters become accidentally disconnected contamination of the surgery site results.

On necropsy, the ponies that had the most abdominal adhesions were in the groups in which the mesh was implanted in the peritoneal cavity or retroperitoneally. More adhesions between the peritoneum, omentum and intestines were associated with wrinkled mesh than the areas of mesh that were smooth. The areas of adhesions did not cause any blockage of the bowel that was adhered to the mesh. The adhesions permitted normal peristaltic waves even in pony number two in which a section of small colon was adhered tightly over the mesh. The adhesions are not considered significant other than being associated with a normal healing process. The wrinkled mesh caused more irritation and as a result the adhesions were more extensive in these areas.

In the ponies that did not have the peritoneum opened there were no adhesions between the peritoneum and the omentum. If the peritoneum was nicked, there were adhesions (Figure 7).

In all ponies the abdominal wall was slightly thicker at the surgical site. The thickened abdominal wall was caused by fibroplasia. In Group IV the imprint of the mesh could be palpated easily and seen after the hair over the area was clipped (Figure pony 7). The skin was not adhered tightly to the mesh. The tissue reaction was minimal in this area.

The tissue reaction that was associated with Marlex mesh was a minimal foreign body reaction. Fibrous tissue proliferated through the mesh as described by Usher (1961). The foreign body reaction to the Marlex braided suture was less than the foreign body reaction incited by Vetafil. There was more foreign body reaction where the mesh was folded. The wrinkled mesh caused more irritation during normal tissue movement.

This project did not include infective studies as described by Usher (1959) in dogs. Marlex mesh being nonporous does not harbor bacteria and being very inert is not rejected from the body in the presence of infection. Marlex mesh can be used in the presence of infection provided the wound is irrigated and medicated to prevent the spread of infection.

Marlex mesh in this study produced a minimal tissue reaction when implanted in the abdominal wall of the Equine species. This mesh adapts itself to surgical manipulations and can be used as an adjunct to surgery.

SUMMARY AND CONCLUSIONS

In this study Marlex mesh and Marlex braided suture were surgically implanted in the abdominal wall of ten Shetland ponies and compared with one Vetafil control. The ponies were observed eight to 17 months post operatively.

The mesh adapted well to surgical manipulation and implantation. The mesh was infiltrated with fibroblasts and initiated a minimal foreign body reaction. There was no fragmentation of the mesh 16 months after implantation.

Marlex suture was found to be a useful suture material, the only possible disadvantage being a slipping of the knot. The Marlex suture caused less foreign body reaction as compared to Vetafil.

The findings of this study support the use of Marlex mesh in the repair of large abdominal wall defects and as a surgical adjunct to help support ventral abdominal incisions in the equine species.

LITERATURE CITED

Adler, R. H. 1962. An evaluation of surgical mesh in the repair of hernias and tissue defects. Archives of Surgery 85: 836-844.

Gibson, L. D. and Stafford, C. E. 1964. Synthetic mesh repair of abdominal wall defects. American Surgeon 30: 481-486.

Gorman, W. C., Flynn, G. F., Lepleu, D., Jr., and Weisel, W. 1961. Synthetic materials for bridging diaphragm and chest wall defects. Archives of Surgery 82: 863-869.

Graham, J., Usher, F. C., Perry, J. L., and Barkley, H. T. 1960. Marlex mesh as a prosthesis in the repair of thoracic wall defects. Annals of Surgery 151: 469-479.

Jacobs, E., Blaisdell, F. W., and Hall, A. D. 1965. Use of knitted marlex mesh in the repair of ventral hernias. American Journal of Surgery 110: 897-902.

Johnson, J. R. 1966. Marlex mesh in incisional and inguinal herniorrhaphy. California Medicine 105: 111-112.

Jones, R. V. and Boeke, P. J. 1956. Properties of marlex 50 ethylene polymer. Industrial and Engineering Chemistry 408: 1155-1161.

Koontz, A. R. and Kimberly, R. C. 1953. Tissue reactions to tantalum gauze and stainless steel gauze: an experimental comparison. Annals of Surgery 137: 833-840.

Koontz, A. R. and Kimberly, R. C. 1960. Tantalum and marlex mesh (with a note on marlex thread): an experimental and clinical comparison-preliminary report. Annals of Surgery 151: 796-801.

Lattimore, T. J. and Koontz, A. R. 1954. Suction drainage after implantation of tantalum gauze sheets. American Medical Association Journal 155: 1333-1334.

Numans, S. R. and Wintzer, H. J. 1964. Zur alloplastic in der hernienbehandlung bei groBen haustieren. Wiener Tierärztliche Monatsschrift 51: 433-440.

Ochsner, J. L. 1965. Editorial: Marlex mesh, the surgeon's friend. Surgery 57: 343.

Ponka, J. L., Wylie, J. H., Chailof, L., Sergeant, C., and Bush, B. E. 1959. Marlex mesh: a new plastic mesh for the repair of hernias. Henry Ford Hospital Medical Bulletin 7: 278-280.

Reitman, S. and Frankel, S. 1957. A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic tranasaminases. American Journal of Clinical Pathology 28: 56-63.

Sandford, J. P., Riley, P. A., Jr. and Sauvage, L. R. 1956. Evaluation of orlon fabric in the repair of defects in the abdominal wall. Surgery 39: 236-243.

Schmitt, H. J. and Grinnan, G. L. B. 1967. Use of marlex mesh in infected abdominal war wounds. American Journal of Surgery 113: 825-828.

Schwartz, A. W. and Erich, J. B. 1960. Experimental study of polyvinylformal (Ivalon) sponge as a substitute for tissue. Journal of Plastic and Reconstructive Surgery 25: 1-14.

Smith, D. C. 1956. Molecular structures of marlex polymers. Industrial and Engineering Chemistry 480: 1161-1164.

Stock, F. E. 1954. Repair of large hernia with nylon mesh. Lancet 1: 395-396.

Usher, F. C. 1959a. Further observations on the use of marlex mesh: a new technique for the repair of inguinal hernias. American Surgeon 25: 792-795.

Usher, F. C. 1959b. A new plastic prosthesis for repairing tissue defects of the chest and abdominal wall. American Journal of Surgery 97: 629-633.

Usher, F. C. 1961a. Knitted marlex mesh. Archives of Surgery 82: 771-773.

Usher, F. C. 1961b. A new technique for repairing large abdominal wall defects. Archives of Surgery 82: 870-877.

Usher, F. C. 1961c. Braided marlex suture. Archives of Surgery 83: 203-204.

Usher, F. C. 1962. Hernia repair with marlex mesh. Archives of Surgery 84: 325-328.

Usher, F. C. 1963. Hernia repair with knitted polypropylene mesh. Surgery, Gynecology and Obstetrics 117: 239-240.

Usher, F. C. 1964. Hernia repair with marlex mesh. Philadelphia, Pa., J. B. Lippincott Co.

Usher, F. C., Allen, J. E., Jr., Crosthuart, R. W., and Cogan, J. E. 1962. Polypropylene monofilament: a new biological inert suture for closing contaminated wounds. American Medical Association Journal 179: 780-782.

Usher, F. C., Fries, J. G., Oschner, J., Tuttle, L. L. D., Jr., and Gannon, I. P. 1959. Marlex mesh: a new plastic mesh for replacing tissue defects. II. Clinical studies. Archives of Surgery 78: 138-145.

Usher, F. C. and Gannon, J. P. 1959. Marlex mesh: a new plastic mesh for replacing tissue defects. I. Experimental studies. Archives of Surgery 78: 131-137.

Usher, F. C., Hill, J. R., and Ochsner, J. L. 1959. Hernia repair with marlex mesh. Surgery 46: 718-724.

Usher, F. C. and Matthews, J. 1964. Surgery: treatment of choice for hernia (with a note on Usher's marlex mesh). American Journal of Nursing 64: 85-87.

Usher, F. C. and Ochsner, J. L. 1960. Marlex mesh: a new polyethylene mesh for replacing tissue defects. Surgery Forum 10: 319-323.

Usher, F. C., Ochsner, J., and Tuttle, L. L. D., Jr. 1958. Use of marlex mesh in the repair of incisional hernias. American Surgeon 24: 969-974.

Usher, F. C. and Wallace, S. A. 1958. Tissue reaction to plastics: a comparison of nylon, orlon, dacron, teflon, and marlex. Archives of Surgery 76: 997-999.

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APPENDIX

Figure 1. Marlex knitted weave mesh and a single strand of Marlex braided suture. 8X.

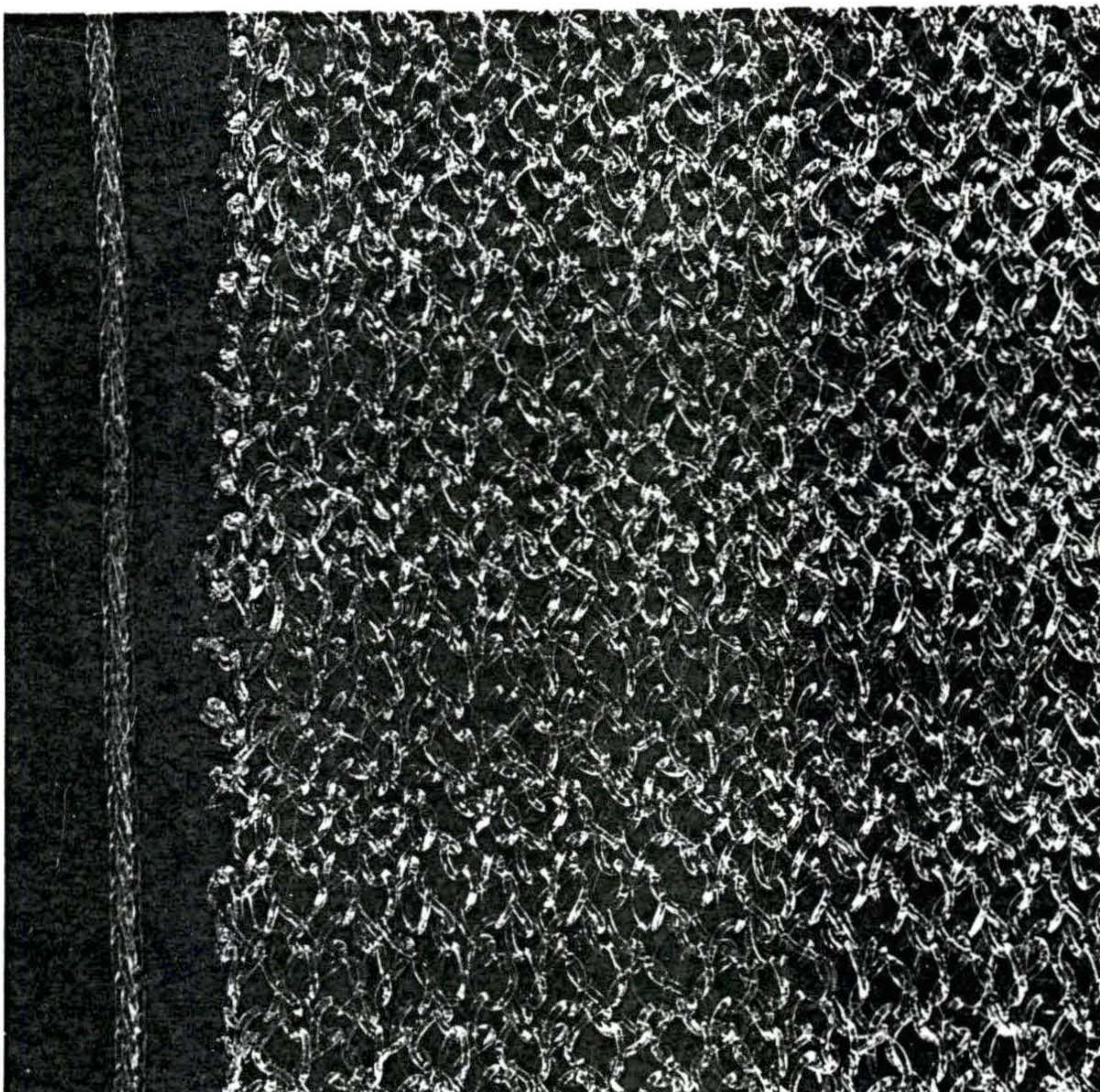
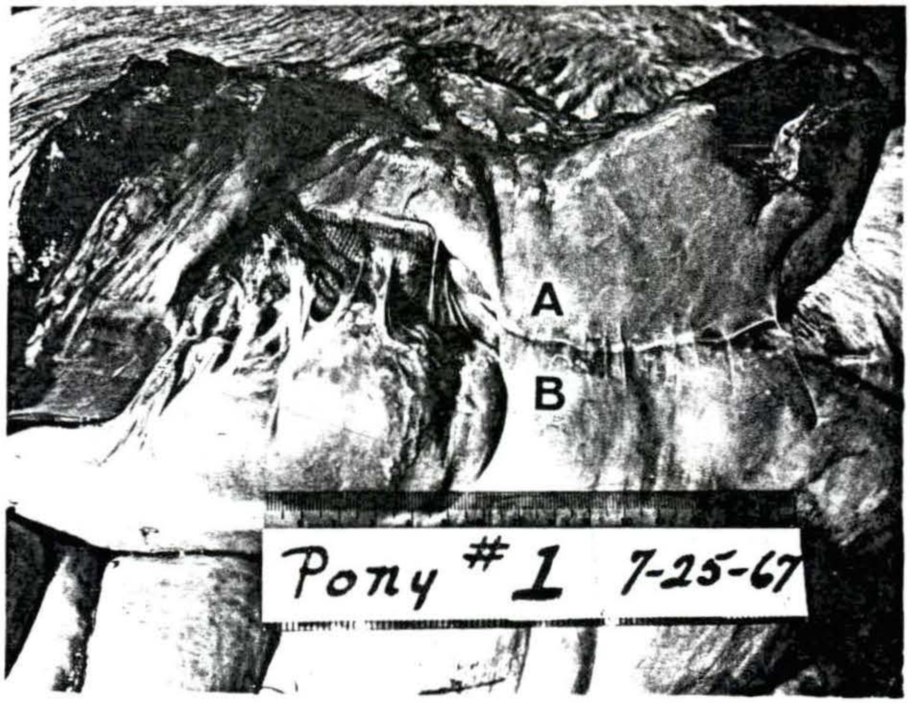


Figure 2. Pony number one with adhesions between the peritoneum (A) and the omentum (B).

Figure 3. Pony number two with adhesions between the peritoneum (A) and omentum (B). A section of the small colon is adhered to the peritoneum.


A
B
Pony #1 7-25-67

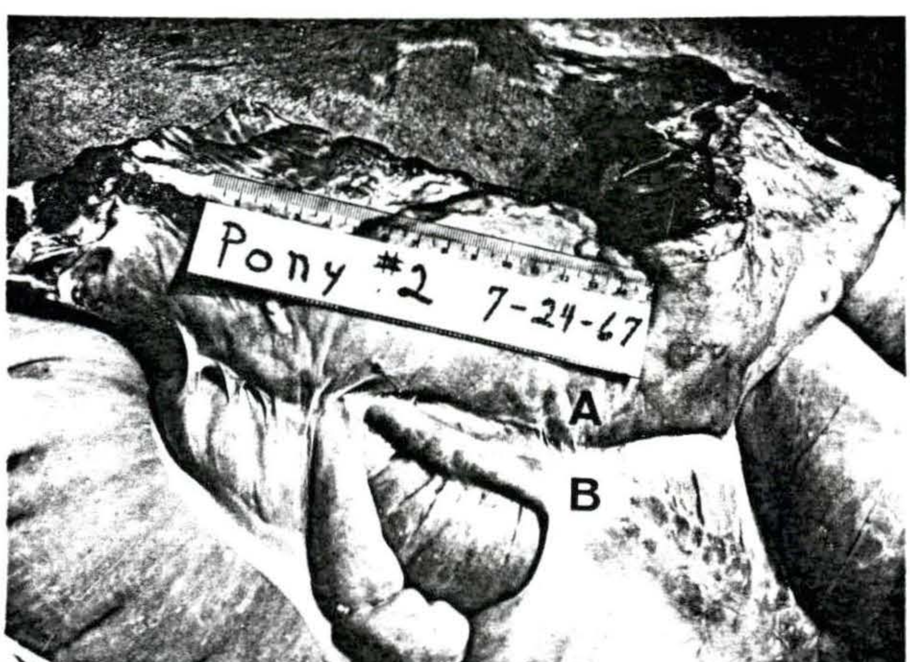
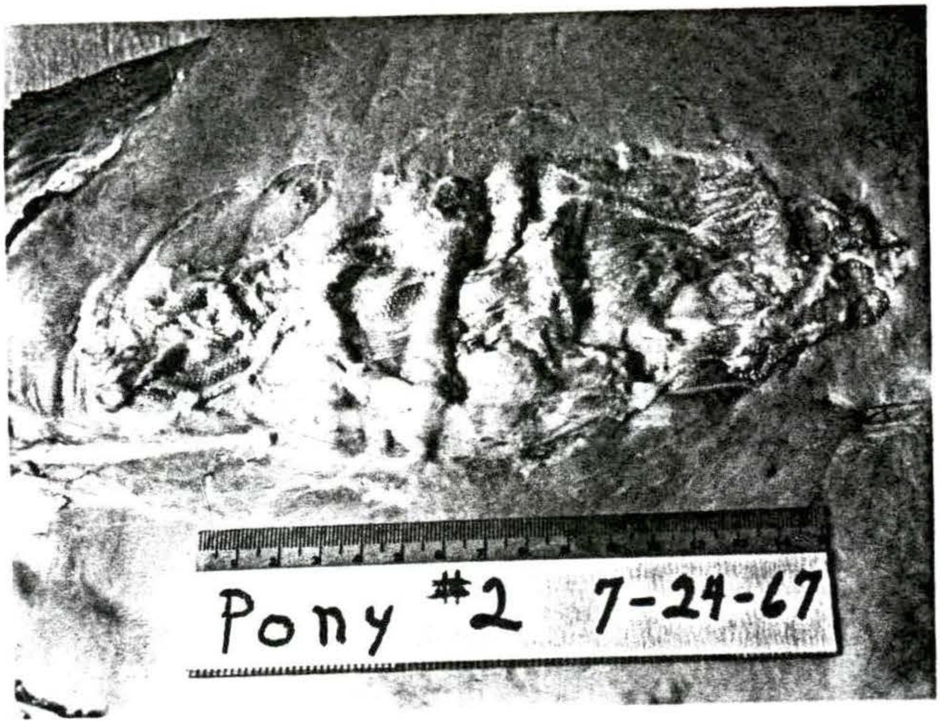

Pony #2 7-24-67
A
B

Figure 4. Pony number two with the adhesions dissected away. The mesh is covered with peritoneum.

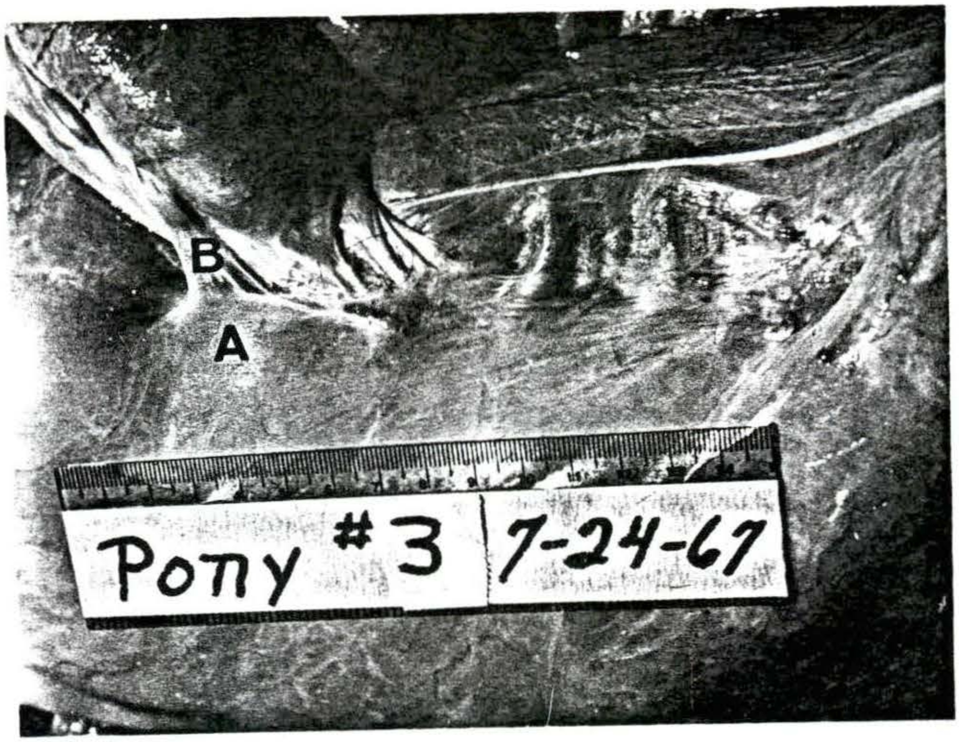
Figure 5. Pony number six with no adhesions between the peritoneum and the omentum. The incision is between the arrows.


Pony #2 7-24-67


Pony # 6 7-25-67

Figure 6. Pony number three with adhesions between the peritoneum (A) and the omentum (B).

Figure 7. Pony number four with adhesions between the peritoneum (A) and the omentum (B).


B
A
Pony #3 7-24-67

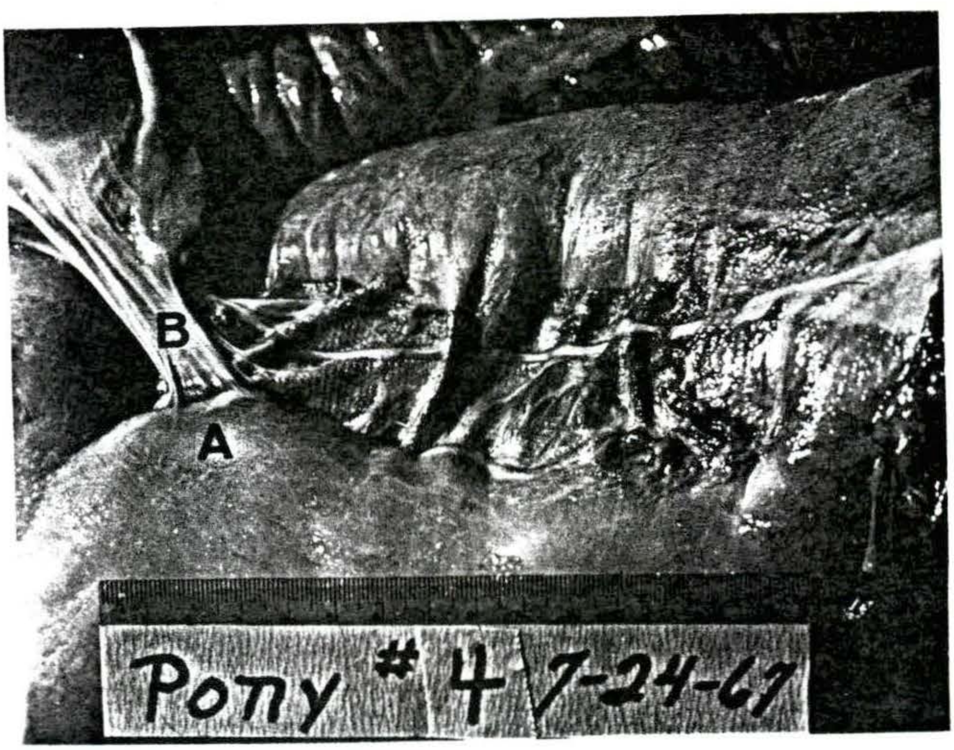
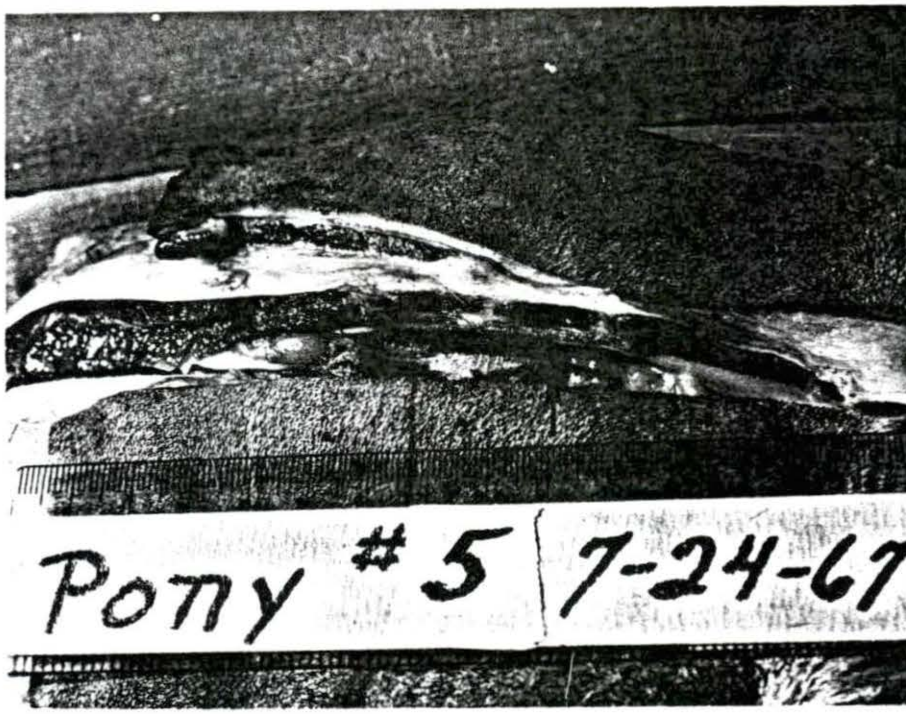

B
A
Pony #4 7-24-67

Figure 8. Cross section of the thickened abdominal wall with the mesh (arrow) from pony number five.

Figure 9. The imprint of the mesh (arrows) through the intact skin from pony number seven.


Pony #5 7-24-67

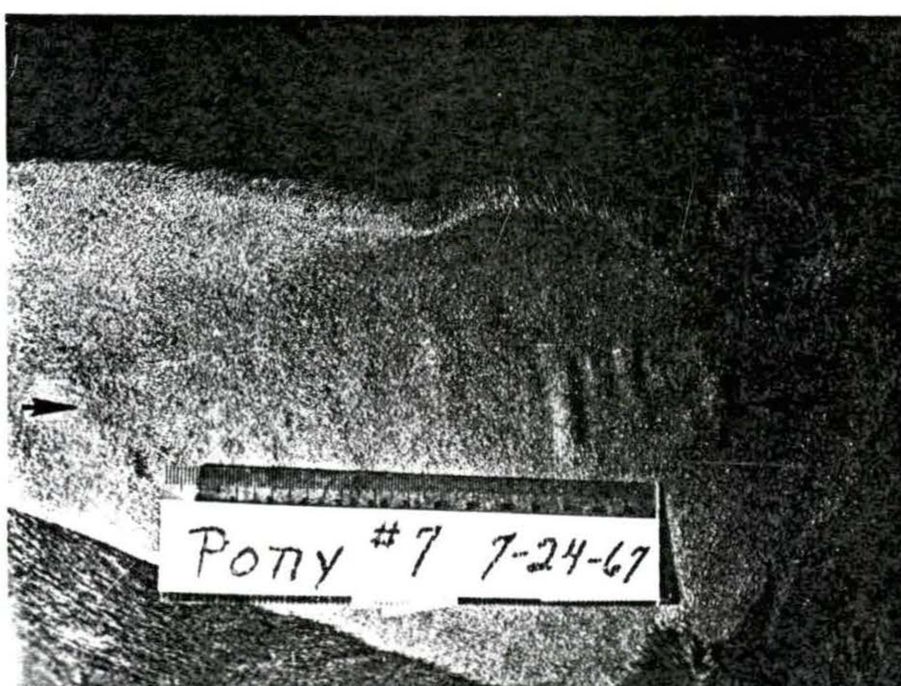
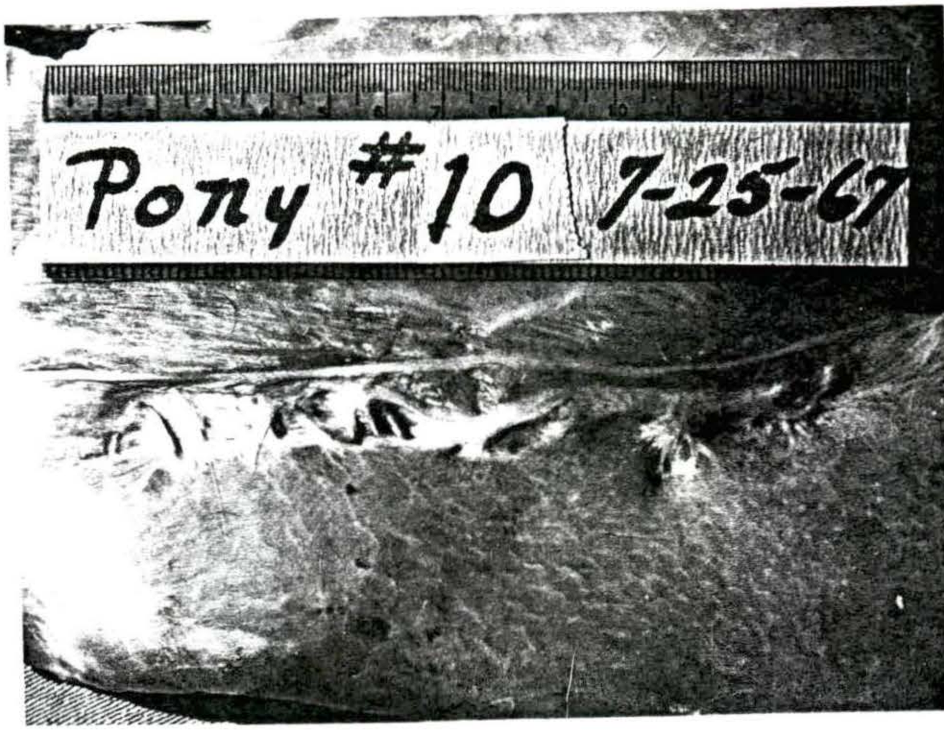

Pony #7 7-24-67

Figure 10. The peritoneum with the adhesions broken down from pony number ten.

Figure 11. Vetafil control pony with no adhesions to the peritoneal surface.


Pony #10 7-25-67

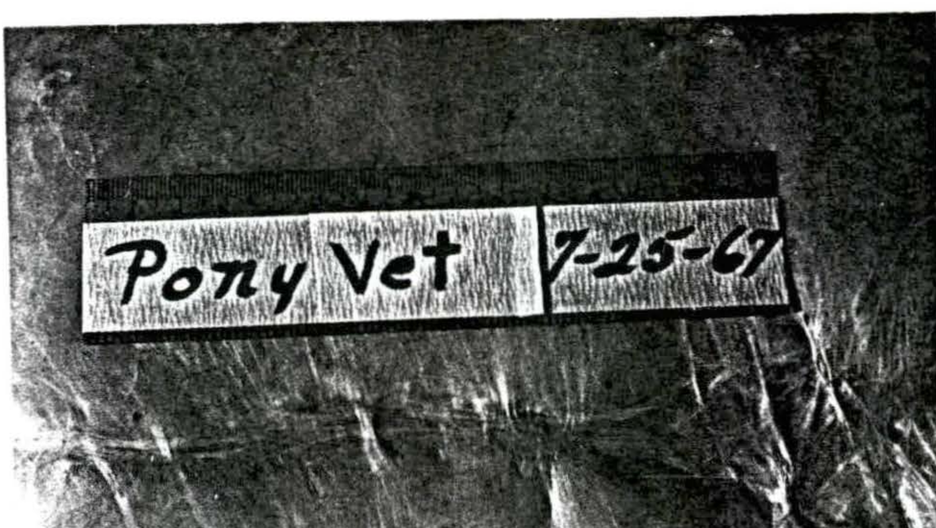
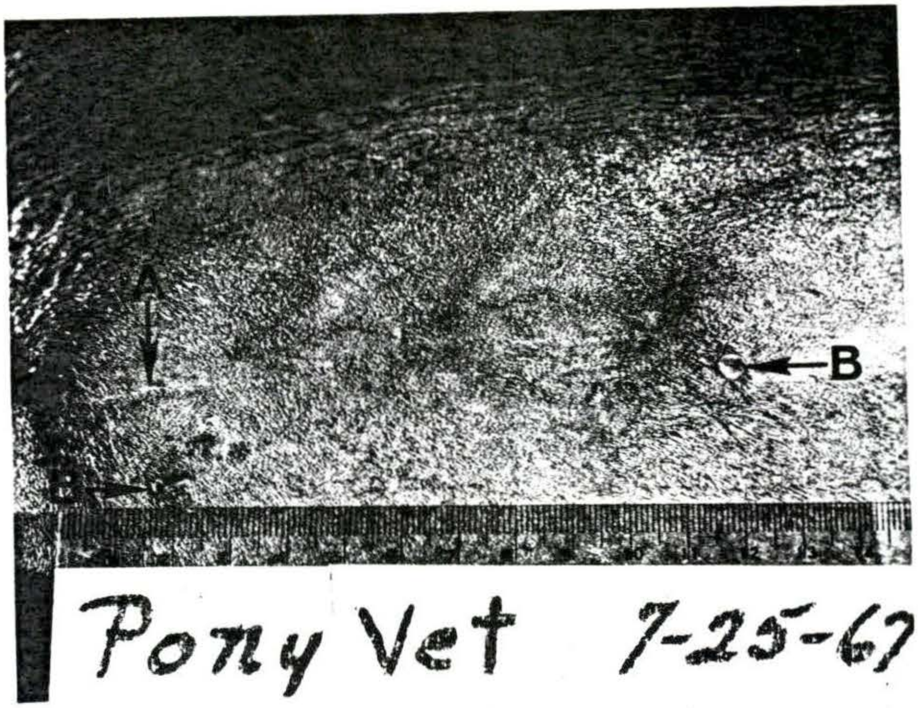

Pony Vet 7-25-67

Figure 12. Vetafil control pony with the scar in the skin (A) and the draining tracts (B).

Figure 13. Vetafil control pony with the draining tract as it opened through the skin (A) and the cysts formation (B) in the subcutaneous tissue.


A
B
Pony Vet 7-25-67

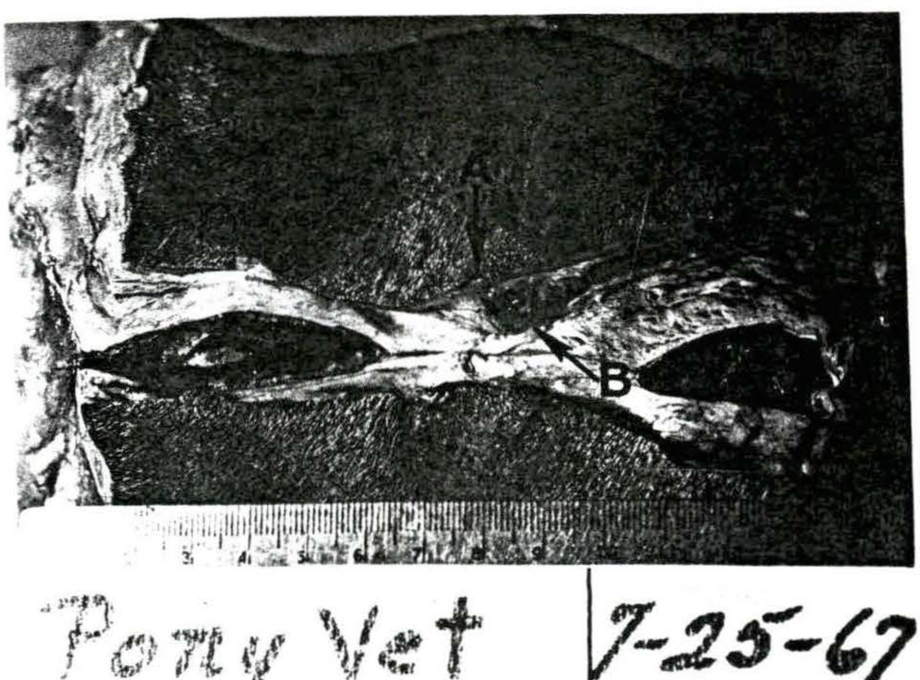

A
B
Pony Vet 7-25-67

Figure 14. The most severe reaction to the mesh fiber. Several layers of histiocytes are adjacent to the fiber with fibrous connective tissue between fibers. 225X.

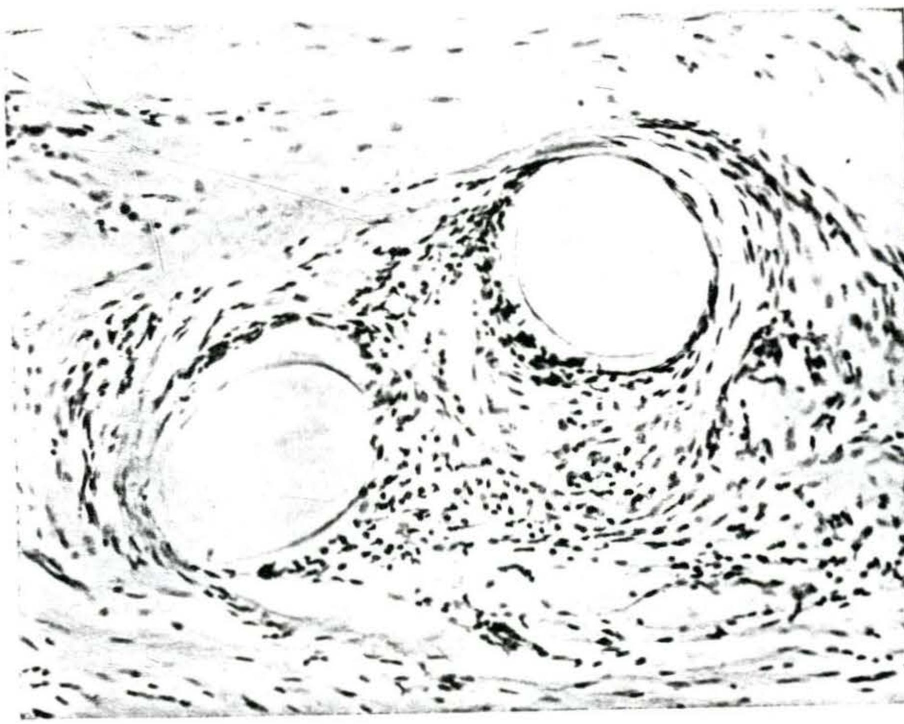


Figure 15. A mild reaction to the mesh fibers. Only a few histiocytes are adjacent to the mesh. Fibrous connective tissue is evident. 225X.

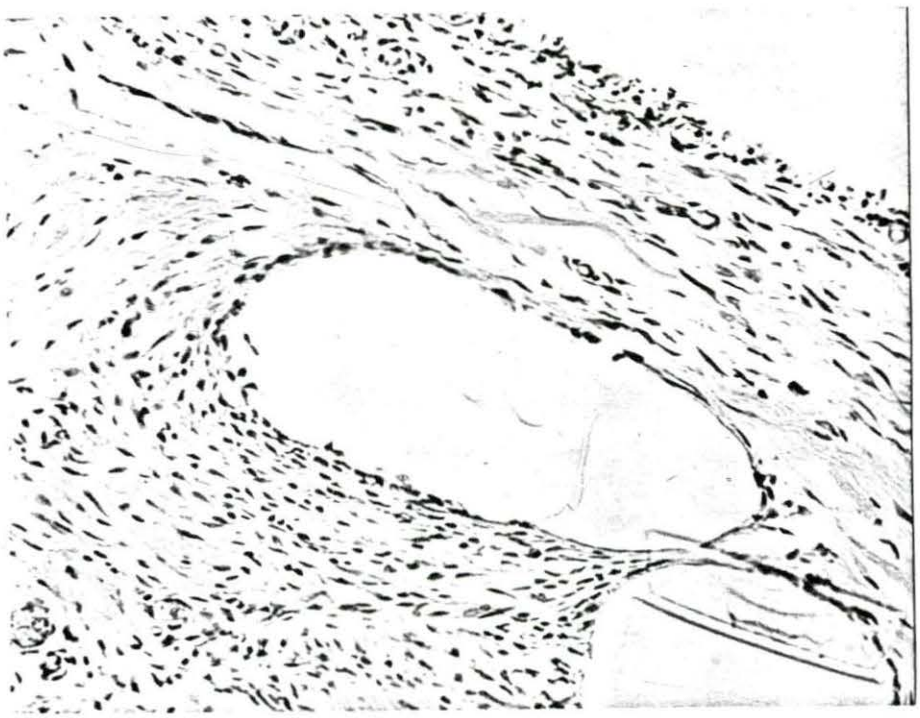


Figure 16. Fibroblastic proliferation and collagen deposition around mesh fibers. 140X.

Figure 17. Fibroblastic connective tissue proliferation between mesh fibers. 65X.