Comparative Reaction of Mersilene and Silk Sutures Implanted Within the Heart *

CLARENCE I. BRITT, M.D., EDWARD M. MILLER, JR., M.D.,
MARTIN E. FELDER, M.D., HOWARD D. SIRAK, M.D.

From the Cardiovascular Service, The Ohio State University Health Center, Columbus, Ohio

OPEN-HEART procedures require permanent implantation of suture material within the heart for closure of atrial and ventricular septal defects and the repair of cardiotomy incisions. These sutures, acting as foreign bodies, may induce thrombus formation or provoke excessive edema which, if near the ventricular conduction system, may predispose to heart block. Inflammatory changes following suture implantation may result in endocarditis, myocarditis, pericarditis or abscess formation.[1]

Mersilene ** suture has been shown to be less reactive than silk when implanted in the skin, subcutaneous tissues and fascia.[1-3, 5] Also, it provides greater tensile strength with a smaller caliber.[2, 7] Therefore, it seemed worthwhile to compare experimentally the reactions of Mersilene and silk sutures in heart tissue. Early and late, gross and microscopic changes were studied. The tensile strength of the two materials was determined after varying intervals of implantation.

Experimental Method

Using proximal inflow occlusion and right atriotomy, interrupted sutures of atraumatic 3–0 silk and 3–0 Mersilene were placed in the atrial septum of dogs (Fig. 1 A). These two sutures were placed in the same dog, far enough apart in the atrial septum to prevent overlapping of the cellular reaction so that each could be studied separately. In this way, each dog served as his own control for the two materials. To avoid crushing tissue, each suture was tied loosely. The atrium was closed with a continuous atraumatic 3–0 silk suture.

The remainder of each Mersilene and silk suture was implanted in the chest wall muscle during closure. This provided a means of comparing the tensile strength of each suture after varying intervals of implantation.

Forty-six dogs were prepared as described. The findings at the time of sacrifice were classified into *early, intermediate* and *late* groups. In the *early* group, four dogs were sacrificed at 24, 48, 72 and 96 hours, and one week after operation. In the *intermediate* group, four dogs were sacrificed at two weeks and at one, one and one-half, and two months. In the *late* group, two dogs were sacrificed at three, three and one-half, four, four and one-half and six months.

Gross Observations. At the time of sacrifice, the atrial septum was inspected for the presence of thrombi on the suture (Fig. 1 B, C, D). Subendocardial hemorrhage near the suture was assigned a 1-to-4-plus according to the number of quad-

* Submitted for publication May 20, 1960.

** Mersilene sutures are Dupont's dacron polyester fibre. Supplied by Mr. C. W. Norman, Ethicon, Inc., Somerville, New Jersey.

Supported by grants from the Bremer Foundation of Youngstown, Ohio, and Ethicon, Inc., of Somerville, New Jersey.

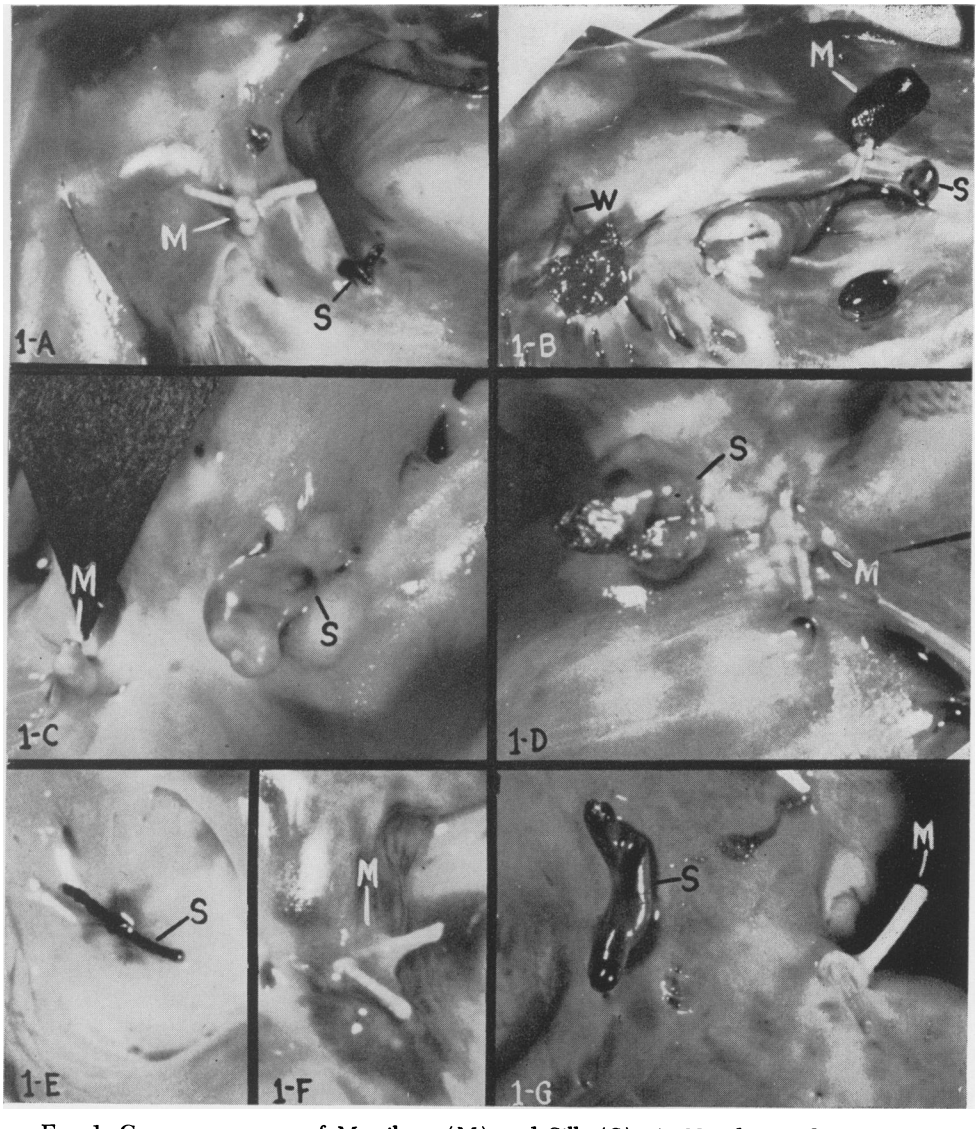

FIG. 1. Gross appearance of Mersilene (M) and Silk (S). A. No abnormal reaction after 12 weeks. B. At 6 weeks, fresh clot present on septal and wall (W) sutures. C. At 14 weeks, organized thrombus on both septal sutures. D. Organized clot on silk only. E. At 4 weeks, 2+ (2 quadrants involved) endocardial sclerosis around silk. F. at 48 hours, 3+ 3 quadrants involved) endocardial hemorrhage around Mersilene. G. At 16 weeks, endothelioid coating of silk, but not of Mersilene.

rants involved (Fig. 1 F). The white zone of endocardial sclerosis noted in the myocardium near the suture was similarly quantitated (Fig. 1 E). The thickness of the endothelioid coating (fibrin, platelets and leukocytes) on the exposed suture surface was noted (Fig. 1 G).

Microscopic Observations. A block of tissue containing each suture was obtained for microscopic examination. The amount of edema was estimated according to the amount of separation of the myocardial bundles near the suture material (Fig. 2 A, B, C, D). Microscopic hemorrhage or red cell infiltration of the tissue adjacent to the suture was quantitated according to its

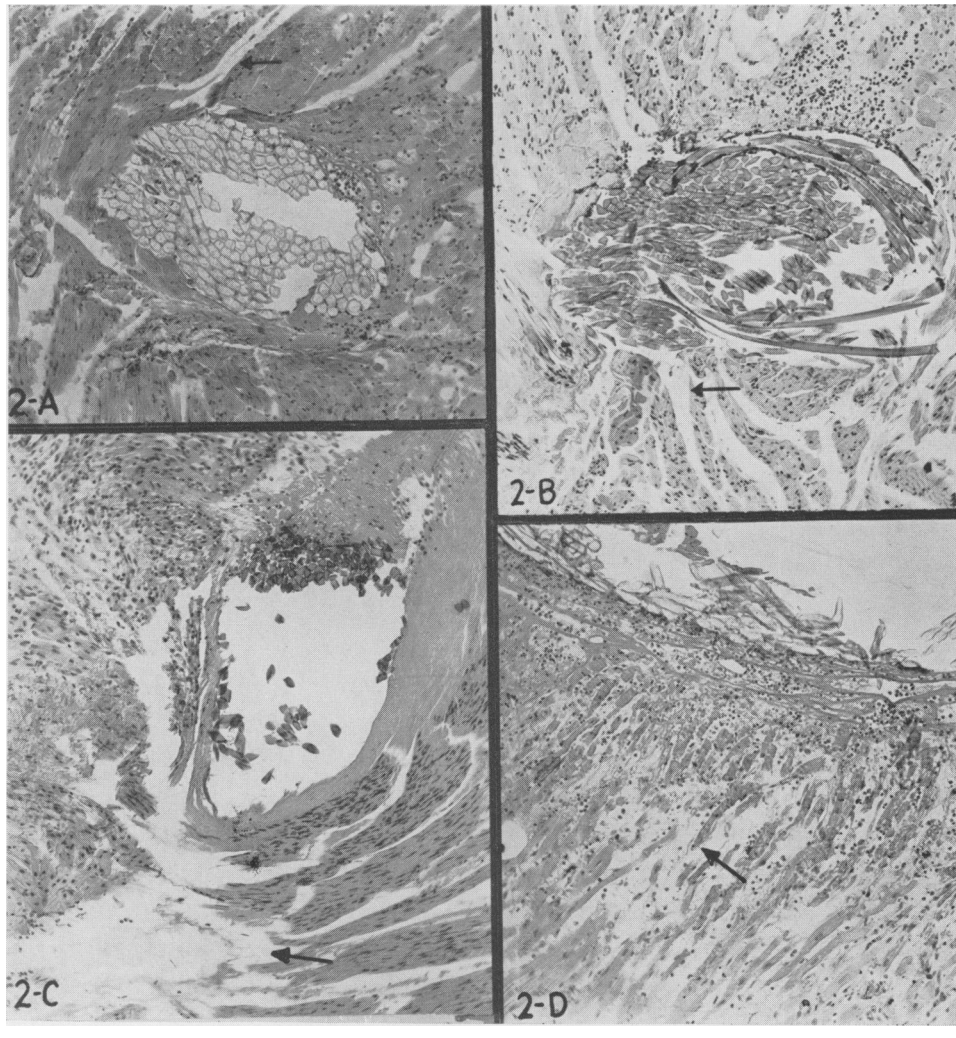

FIG. 2 A, B, C, D. *Acute* microscopic appearance of Mersilene and silk. A. At 24 hours, 1+ edema and 1+ acute inflammation around the Mersilene. B. Same animal with 2+ edema and 2+ inflammation around the silk. C. At 72 hours, 3+ edema around the silk. Note fragmention of muscle (arrow). D. At 48 hours, 4+ edema and 3+ inflammation around the Mersilene.

depth and the number of quadrants involved (Fig. 2 E, F).

The degree of acute inflammation was estimated by determining its depth, concentration and the number of quadrants of polymorphonuclear infiltration (Fig. 2 A, B, D). The presence of early granulation tissue and the presence or absence of chronic inflammatory cells was also taken into consideration.

Chronic inflammation was estimated from its depth, concentration and the degree of lymphocyte, macrophage, fibroblast and plasma cell infiltration (Fig. 3 A, B, C, D). The amount of collagen and granulation tissue present influenced this estimate. The presence of scar formation, the tendency toward encapsulation (Fig. 3 F) of the suture material, and the degree of fragmentation (Fig. 3 E) of the suture were studied. Incidental findings, such as the formation of suture abscesses (Fig.

4 A), myxomatous degeneration (Fig. 4 B, C), cartilage formation (Fig. 4 C, D), calcification (Fig. 4 D, E, F) and ossification (Fig. 4 F) were noted.

Results

Gross Findings. In this series of 46 dogs, the sutures and atrial wall closure were free of thrombus formation in 28 dogs (60%—Fig. 1 A). An organized thrombus was found twice as frequently on the black silk suture in the atrial septum (12 dogs) when compared to the Mersilene (6 dogs). There was an equal incidence of clot formation on silk placed in the atrial septum (12 dogs) and on the silk in the atrial wall closure (11 dogs), but thrombi on the atrial wall were consistently larger (Fig. 1 B). In three dogs, a clot was present on all three suture sites (Fig. 1 B) (atrial septum Mersilene, atrial septum silk, and atrial wall silk), but the thrombus was smaller on the Mersilene in two of the three animals. In two animals, a thrombus was present on the atrial septal silk and the Mersilene and the clot was smaller on the Mersilene in one (Fig. 1 C). In the atrial septum, clot formation was most commonly found on the silk only (4 dogs—Fig. 1 D). One preparation had a clot on the Mersilene only. The remainder of the dogs had clots on the atrial wall only (5 dogs). Three dogs had a clot on both the septal silk and the atrial wall closure. Organizing clots were found on silk and Mersilene more commonly during the *early* period of the study, but were found as long as six months after implantation.

There was little difference between silk and Mersilene in the frequency and amount of gross hemorrhage near the sutures (Fig. 1 F), of endothelioid coating of the free surfaces of the suture material (Fig. 1 G), and of endocardial sclerosis adjacent to the site of implantation (Fig. 1 E).

Microscopic Observations—Acute Changes. Edema was greatest on the second and third days around both suture materials. In the *early* group (24 hours to 1 week), edema of slightly greater intensity appeared earlier around the Mersilene than around the silk (Fig. 2 A, B, C, D), but subsided sooner around the Mer-

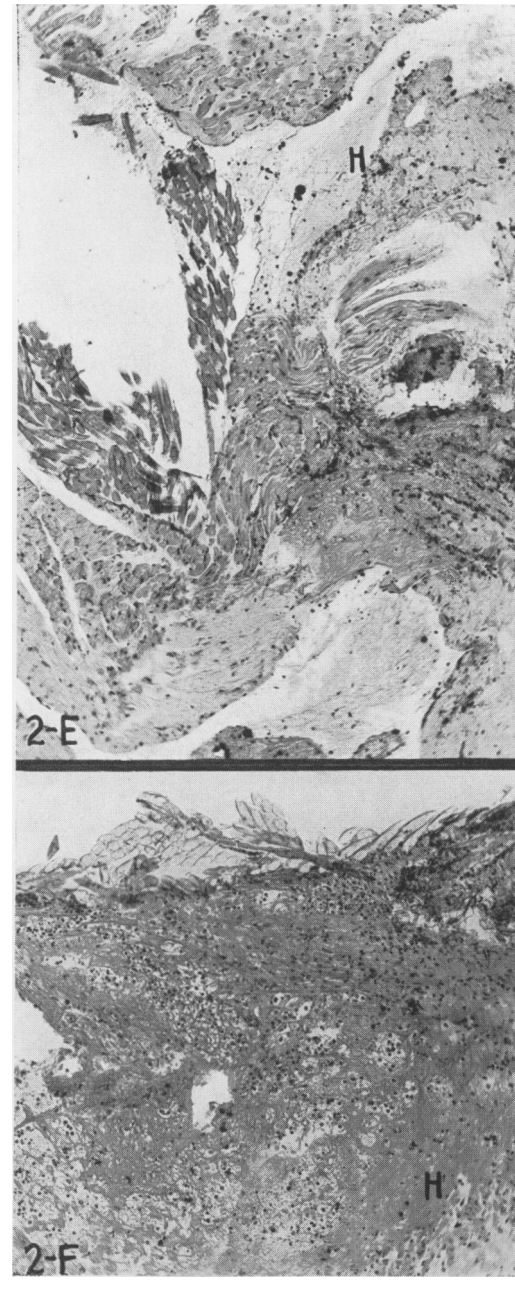

FIG. 2 E, F. *Acute* microscopic appearance. E. At 24 hours, 1+ hemorrhage (H) around the silk. F. At 48 hours, 3+ hemorrhage near the Mersilene.

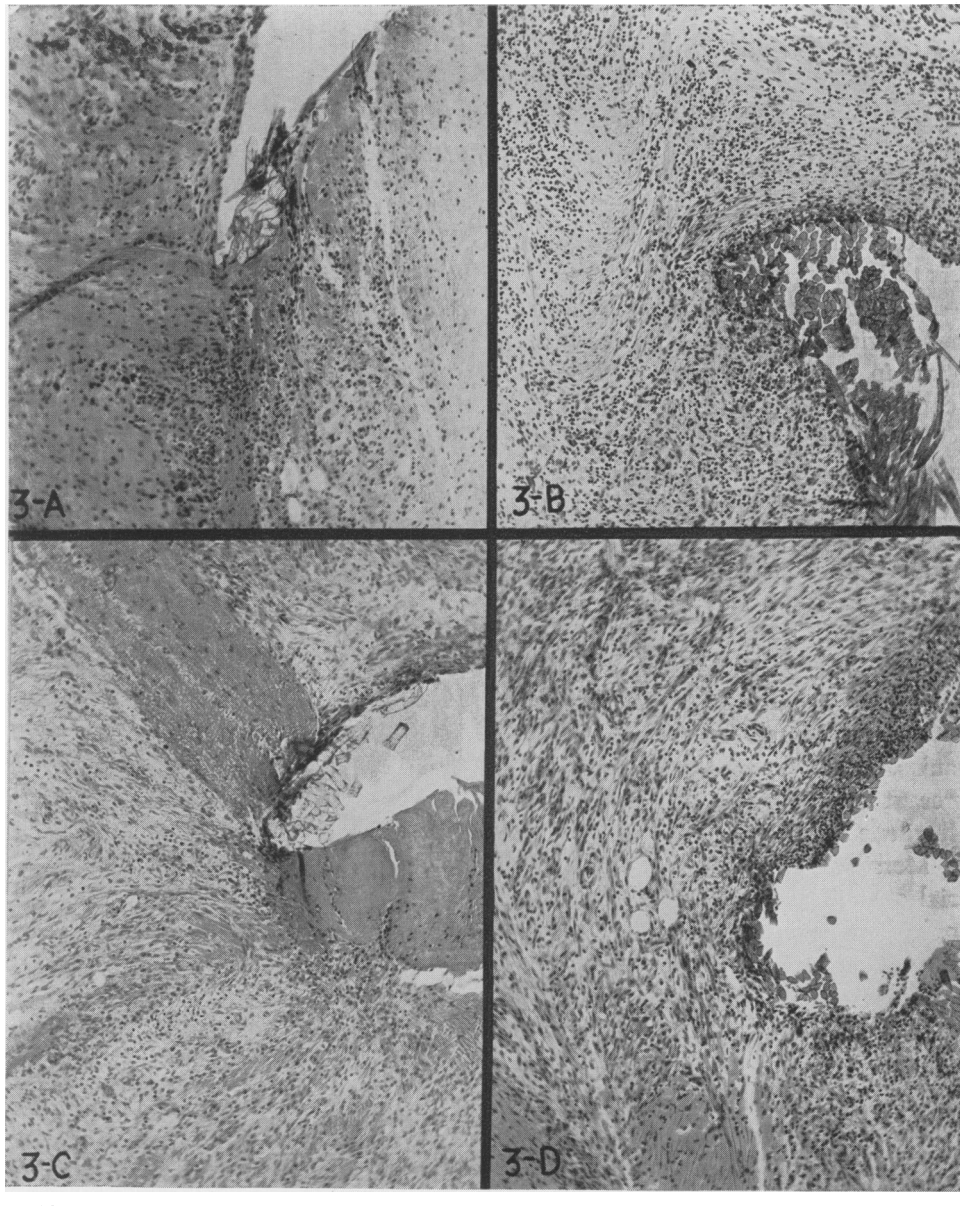

FIG. 3 A, B, C, D. *Chronic* microscopic appearance of Mersilene and silk. A. At 4 weeks, 1+ chronic inflammation near the Mersilene. B. Same animal, 2+ acute and 2+ chronic inflammation near the silk. C. At 1 week, 3+ chronic inflammation near the Mersilene. D. Same animal, 4+ chronic inflammation and 2+ acute inflammation near the silk.

silene. An equal amount of edema was still present around both sutures one month after operation. No edema was noted in later specimens.

Microscopic hemorrhage (Fig. 2 E, F) was greater on the second postoperative day around both sutures and completely subsided in two weeks. It seemed slightly greater around the Mersilene than the silk in the *early* group.

Acute polymorphonuclear leukocytic infiltration was greatest on the first and second days and completely subsided in four weeks. Consideration of all dogs in

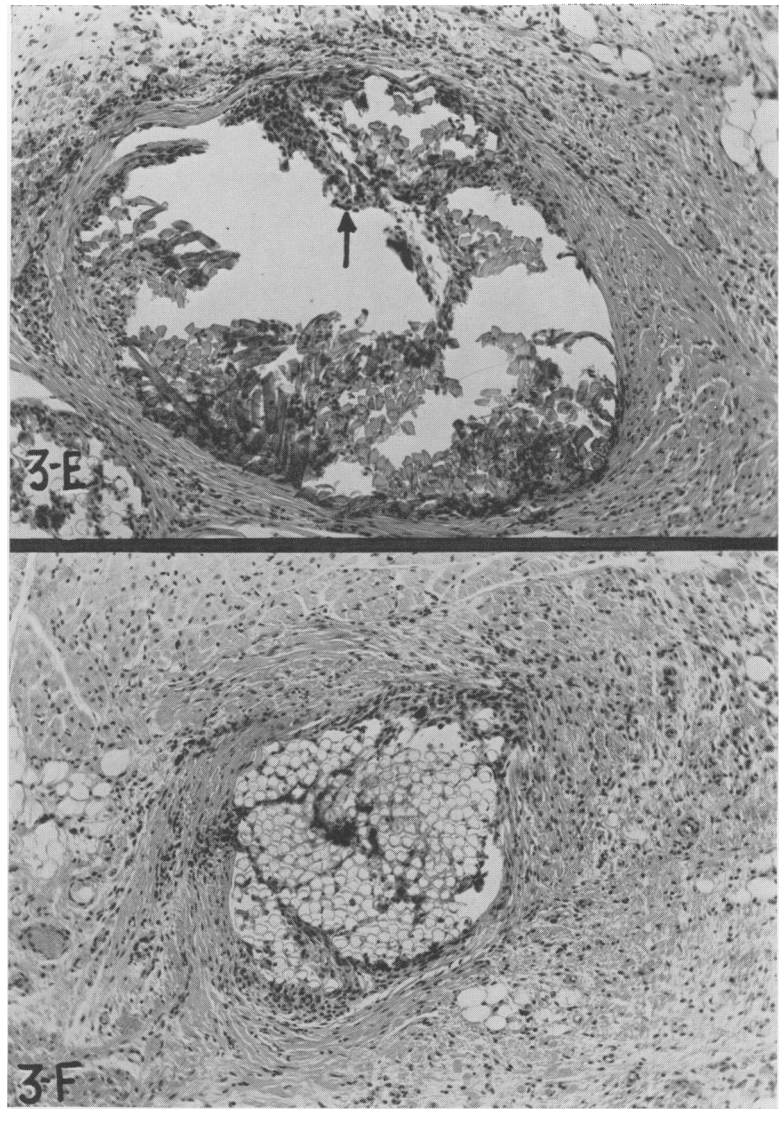

FIG. 3 E, F. *Chronic* microscopic appearance. E. At 4 weeks, fragmentation of silk suture by cellular ingrowth (Arrow). F. Same animal, encapsulation and minimal fragmentation of Mersilene.

both the *early* and *intermediate* groups indicates that there was less polymorphonuclear infiltration around the Mersilene than around the silk suture (Fig. 2 A, B, D). However, in the *early* group (24 hours to 7 days), acute inflammatory reaction was slightly greater around the Mersilene. In the *intermediate* group (2 weeks to 2 months), the inflammatory reaction around the Mersilene subsided earlier while the leukocytic infiltration around the silk suture persisted longer.

Microscopic Observations—Chronic Changes. Chronic cellular inflammation characterized by lymphocyte, monocyte and plasma cell infiltration, appeared 48 hours after operation and was followed by the appearance of macrophages, foreign-body giant cells, fibroblasts and collagen. This persisted to some degree for the 24 weeks of the study. Chronic cellular reaction was greatest seven days after suture implantation. Fibroblasts and foreign-body giant cells were most numerous at 14 days.

Chronic inflammation was greatest around the silk suture (Fig. 3 A, B, C, D) when all three groups were considered. Chronic cellular reaction appeared equal in the *early* group, but these changes significantly decreased near the Mersilene in later groups. Inflammatory changes persisted longer and were of greater intensity around

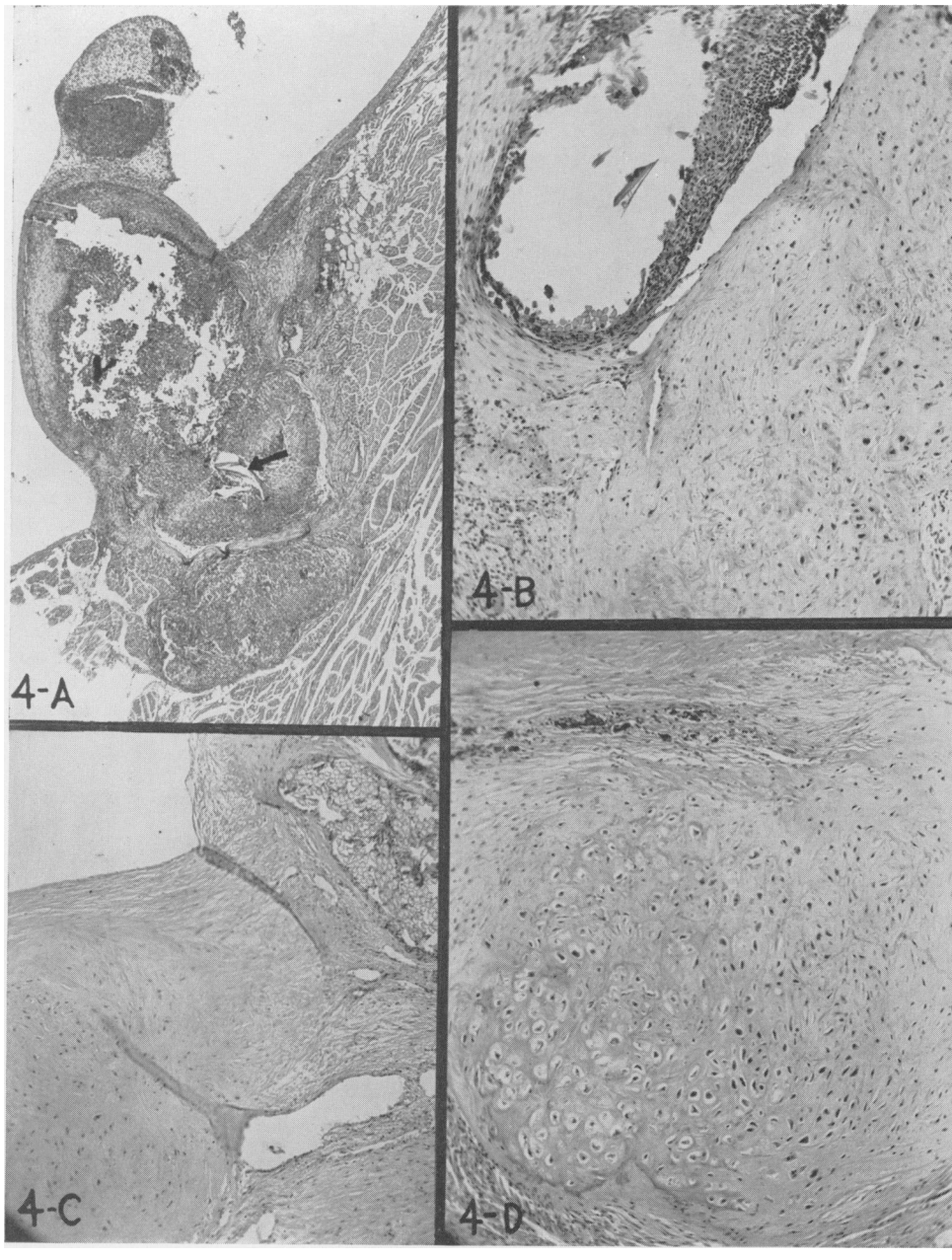

FIG. 4 A, B, C, D. Unusual late findings. A. At 14 weeks, a suture abscess with myocardial extension and silk fragmentation (arrow). B. At 14 weeks, myxomatous degeneration near a Mersilene suture. C. At 18 weeks, myxomatous degeneration and early cartilage formation near a Mersilene suture. D. At 18 weeks, typical cartilage formation and overlying metastatic intracellular calcification near the silk in the atrial wall closure.

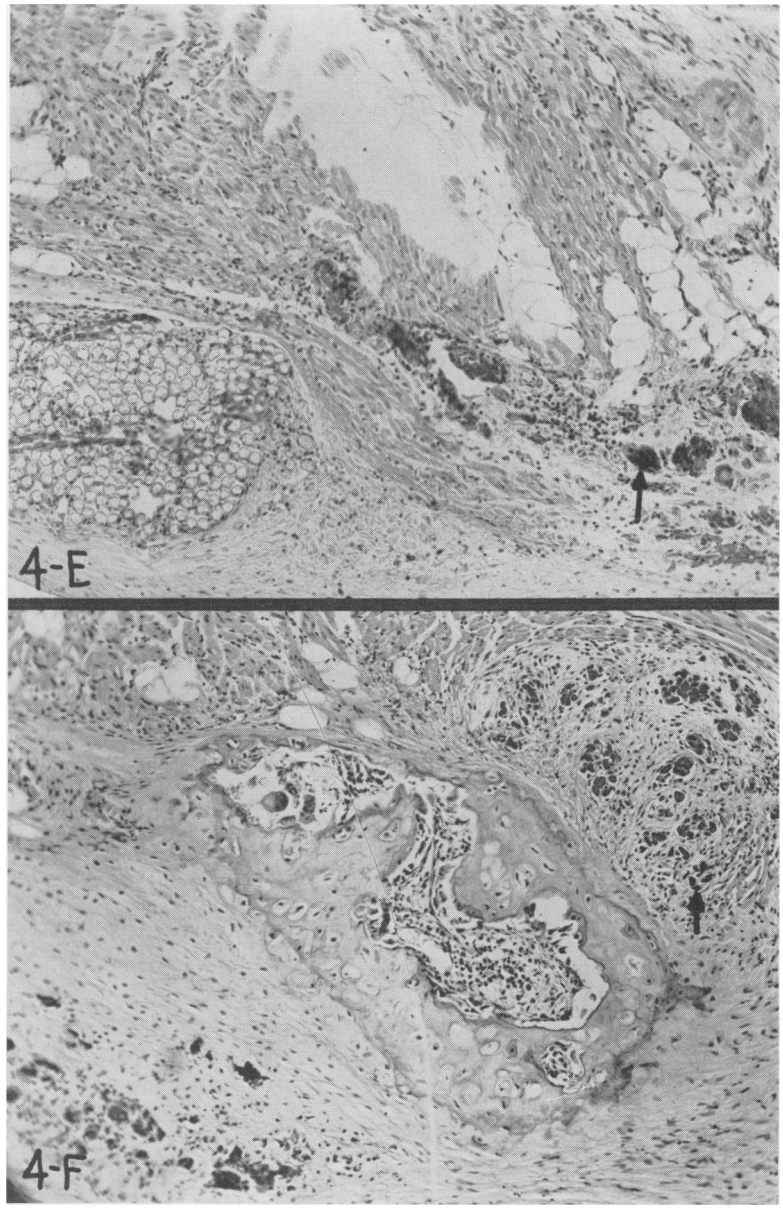

FIG. 4 E, F. Unusual late findings. E. At 18 weeks, ectopic calcification near a Mersilene suture. F. At 18 weeks, ossification of cartilage and ectopic calcification in the atrial wall silk closure.

the silk sutures in the *intermediate* and *late* groups.

Microscopic suture abscesses with central suppuration (Fig. 4 A) were found in three dogs about the silk septal suture and in two dogs near the atrial wall silk closure. None were found with the Mersilene. No bacteria were present in any of the suture abscesses. The suture abscesses involved the atrial septal myocardium and the free end of the suture material. The five suture abscesses near the silk suture were present in animals in which a clot had been found grossly.

Collagen began to appear at seven days, became prominent by 14 days and formed organized scar by four weeks. The collagen and scar tissue tended to form a capsule completely walling off the suture in some cases. Complete encapsulation (Fig. 3 F)

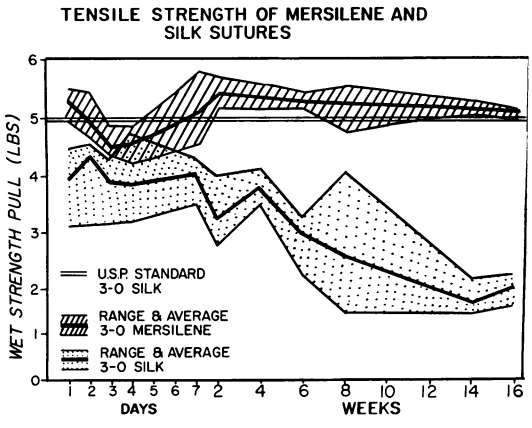

FIG. 5. Tensile strength of Mersilene compared to silk. Silk undergoes a gradual loss of tensile strength with increasing time. The tensile strength of Mersilene is constant and approximates U.S.P. standards. The range of tensile strength of each silk suture varied widely and that of Mersilene was more uniform.

occurred more often about the Mersilene. Fragmentation of the suture material by ingrowth of macrophages, fibroblasts and chronic inflammatory cells appeared at four weeks (Fig. 3 E). The incidence and degree was equal for the two suture materials.

Unexpected pathologic findings were noted in the surrounding soft tissue in several instances. Myxomatous degeneration was found in the *late* group of animals adjacent to the Mersilene suture in two dogs (Fig. 4 B, C) and in the atrial wall silk closure in two dogs. None was found in the septum near the silk suture. Cartilage formation was found in large quantities around the silk suture in one dog and around the atrial wall silk closure in seven dogs (Fig. 4 D). One dog showed ossification of the cartilage (Fig. 4 F) that had developed in the atrial wall closure. No cartilage formation or ossification was seen near the Mersilene suture. There were small areas of ectopic intracellular calcification (Fig. 4 D, E, F) near the Mersilene suture in four dogs, near the silk in one dog and in the atrial wall silk closure in one dog.

A comparison was made between the tissue reaction of the silk in the atrial wall closure and that of the two kinds of suture loops in the atrial septum. The method of placing the septal sutures was designed to minimize trauma. Atraumatic needles were used and inserted carefully in the atrial septum and the sutures tied loosely. A continuous 3–0 atraumatic silk suture was used in the atrial wall closure which had to be pulled tight enough to obtain hemostasis. The incidence of clot formation on the atrial wall closure was the same as that observed for the silk sutures in the atrial septum. The size of the clots on the atrial wall was uniformly larger than those on the septal sutures. The microscopic findings in the atrial wall closure were much more intense. The degree of acute and chronic inflammation was much greater in the atrial wall than that observed adjacent to either suture in the atrial septum. The incidence of cartilage formation in the atrial wall was significantly higher.

Tensile Strength

The tensile strength and diameter of each Mersilene and silk suture placed in the chest wall muscle was determined at the time of sacrifice. Eight to 24 weeks after implantation, the diameter of the Mersilene varied from 9.1 to 10 mils, while the diameter of the silk sutures varied from 9.5 to 11.85 mils (U.S.P. 8 to 10 mils). The diameter of the silk was consistently larger than that of the Mersilene by values ranging from 2 per cent to 27.4 per cent. In two specimens the diameter of the silk suture exceeded U.S.P. standards (8 to 10 mils) for 3–0 silk suture.

Tensile strength of the two suture materials was determined as straight pull after wetting and was compared to the expected standards for black braided 3–0 silk (U.S.P. 5.0 lbs.) (Fig. 5). The implanted Mersilene compared quite favorably with the standard, the tensile strength of the speci-

mens ranging from 4.35 to 5.83 pounds. The duration of implantation did not appreciably affect the Mersilene during the 24 weeks of the study. The tensile strength of the Mersilene suture was consistently much greater than that of the silk which varied from 4.65 to a low of 1.3 pounds at 14 weeks. The tensile strength values for the silk showed a consistent decline from the original U.S.P. standard after six weeks. There was a wide variation in tensile strength of silk sutures with the same interval of implantation.

Discussion

Mersilene, a polyester fibre condensation product of ethylene glycol and dimethyl terephthalate, is known to be well tolerated in skin and other soft tissues.[3, 5] It can be sterilized by autoclaving without loss of tensile strength or change in its chemical properties. It is considered to be noncarcinogenic because it is not a coal tar derivative.

It is desirable that the nonabsorbable suture material used within the heart produce minimal gross and microscopic tissue reaction during the immediate post implantation period. It is also important that it evoke minimal chronic inflammatory changes.[2, 4] These factors may have greater significance in open-heart procedures because they are foreign bodies whose free ends are possible sites of thrombus formation. Also, they are frequently placed near important conduction pathways where an exaggerated tissue reaction could eventuate in heart block. Because prosthetic materials are frequently placed near important conduction pathways where an exaggerated tissue reaction could eventuate in heart block. Because prosthetic materials are frequently necessary to close defects, and because healing to prosthetic materials occurs more slowly, it may be important to have a suture with greater durablity.

TABLE 1. *Relative Advantages of Mersilene over Silk Suture*

Thrombus formation	††
Chronic inflammatory changes	††
Suture abscess	††
Tensile strength	††
Suture size	††
Acute inflammatory changes	†
Encapsulation	†
Cartilage formation	†
Ossification in myocardium	†

† Slightly superior.
†† Markedly superior.

This experimental study indicates that the early gross and microscopic changes appear to be primarily related to the trauma of placing the suture rather than to a specific response to the suture material. During the first seven days after implantation, the tissue response to silk and Mersilene in the form of edema and inflammatory changes are essentially the same. However, Mersilene has several distinct advantages (Table 1) over silk when implanted within the cardiac chambers: 1) Thrombus formation occurs less frequently on the Mersilene than on the silk suture. When a clot developed on both sutures the thrombus on the Mersilene was smaller. 2) The amount and duration of chronic inflammatory reaction persisted longer and was more severe around the silk than around the Mersilene. 3) Sterile abscesses, associated with a thrombus, were found on the silk sutures three to six months after implantation, emphasizing the high incidence of granuloma formation with silk. Abscesses were not seen around the Mersilene. 4) The size and tensile strength of Mersilene is more uniform and constant than silk after varying periods of implantation.

Summary

1. Loops of Mersilene and silk suture were placed in the atrial septum by proximal inflow occlusion in 46 dogs. The animals were sacrificed at varying intervals

from 24 hours to 24 weeks to study the gross and microscopic reactions to the implanted suture material.

2. Mersilene appeared to be superior to silk when implanted within the heart because thrombus formation was considerably less, chronic inflammation was less intense and subsided earlier and suture abscess formation did not occur.

3. The tensile strength of Mersilene, unlike silk, was unaffected by implantation.

Bibliography

1. Bahnson, H. T., F. C. Spencer and I. L. Bennett: Staphylococcal Infections of the Heart and Great Vessels Due to Silk Sutures. Ann. Surg., **146**:399, 1957.
2. Deterling, Jr., R. A. and S. B. Bhonslay: An Evaluation of Synthetic Materials and Fabrics Suitable for Blood Vessel Replacement. Surg., **38**:71, 1955.
3. Dettinger, G. B. and W. F. Bowers: Tissue Response to Orlon and Dacron Sutures; A Comparison With Nylon, Cotton and Silk. Surgery, **42**:325, 1957.
4. Madsen, E. T.: An Experimental and Clinical Evaluation of Surgical Suture Materials III. Surg. Gynec. & Obst., **106**:216, 1958.
5. Narat, J. K., J. P. Cangelosi and J. V. Belmonte: Evaluation of Dacron. Suture Material for General Surgery. Surgical Forum, **7**:176, 1959.
6. Phelan, J. T., W. P. Young and J. W. Gale: The Effect of Suture Material on Small Artery Anastomoses. Surg. Gynec. & Obst., **107**:79, 1958.
7. Postlethwait, R. W., J. F. Schauble, M. L. Dillon, and J. Morgan: Wound Healing II; An Evaluation of Surgical Suture Material. Surg. Gynec. & Obst., **5**:555, 1959.
8. Wolstenholme, J. T., H. Lotman and M. Malament: The Reaction of Human Sometic Tissue to Implanted Dacron Fabric: Report of Five Cases. Plastic and Reconstructive Surg., **19**:156, 1957.