Marlex Mesh as a Prosthesis in the Repair of Thoracic Wall Defects *

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TRAUMATIC or surgical interference with the thoracic cage may predispose to serious paradoxical motion, concomitant with disturbances of respiratory physiology and inadequate ventilation of lung tissue.

When reviewing the literature it becomes apparent that adequate reconstruction of chest wall defects has been a difficult yet interesting problem for many years. Various methods have been employed, and within the past decade a number of prosthetic materials have been used.

Where an adequate surgical resection is done, resulting in a large chest wall defect, a stable thoracic wall reconstruction, employing the available autogenous tissues, may not be possible. Numerous methods of repair using only autogenous tissues have been devised.

The earliest recorded repair of a lung hernia was that accomplished by Tuffiier [45] in 1891. Vulpius [58] in 1900 used an osseoperiosteal technic advocated by Volger [57] in 1898. In 1922 Graham [22] successfully treated a patient with a cervical lung hernia by packing the region with iodoform gauze. Goodman [20] in 1933 developed periosteal flaps from adjacent ribs and sutured the free edges of the flaps together over a thoracic wall defect. In 1936 Gadzhiev [18] prepared and utilized musculoperiosteal-osseous flaps. Maurer [35] in 1946 employed periosteal and rib segments and Bisgard [6] corrected a sternal defect by using mortised rib grafts. Kinsella [29] employed split tibial grafts, and both Heaney [26] and Stephenson [47] have used free anterior rib grafts.

During World War I Keller [28] employed fascia lata in chest wall reparative procedures. Winkel,[61] Mayer,[36] and others [2, 30, 46, 50, 59] have reported using fascia lata in thoracic wall reconstruction. Southwick [46] has also used rectus sheath for this purpose. Maier [32] employed a fascia lata graft combined with a contralateral breast flap. Davis [11] and Campbell [8] combined fascia lata grafts and sliding flaps of lattismus dorsi muscle, whereas Pickrell [42, 43] and McManus [34] have used fascia lata and sliding flaps of pectoralis major muscles.

Dunavant [12] successfully employed a full thickness skin graft technic, but the thoracic wall remained unstable. Pickrell [42] and Vianna [56] utilized sliding skin grafts following extirpation of mammary cancer, and Proleau [44] combined a full thickness skin flap closure with paravertebral thoracoplasty.

While the employment of autogenous tissues is desirable, these may not be readily available at the site of excision.

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Small defects may be adequately repaired by using periosteum or combined periosteum and osseus flap technics. but larger defects often do not lend themselves to this method of repair. Fascia lata or rectus sheath grafts, though perhaps adequate for closure of the defect, will not stabilize the chest wall. Campbell [8] and Maliniac [33] have stressed that the vascular supply to large muscle and skin flaps may be precarious. Mobilization of muscle flaps and procuring fascia lata adds considerably to the extent of the operative procedure. Thoracoplasty is mutilating and inhibits or destroys the physiological function of underlying lung tissues.

Attempts have therefore been made to secure a suitable prosthetic material which can be made readily available, is easily sterilized, becomes incorporated in living tissues, adds stability to the thoracic wall, and does not interfere with physiological chest wall movement. It should not potentiate infection, should be physiochemically inert, should not elicit a foreign body reaction, or cause delay in wound healing.

Metal prostheses were first advocated by Gangolphe [19] in 1909. Paulsen [41] and others [3, 9, 14, 21] used tantalum plates. The plates became loose and began to extrude through the chest wall tissues causing pain, discomfort, and hemorrhage. They provoked the production of copious amounts of serum, and their presence in the tissues potentiated the development and maintenance of infection. Serum production ceased, and infection could be readily controlled when the tantalum plates were removed. Tantalum mesh for thoracic wall defects was used experimentally by Morrow [39] in 1950. Rider,[45] Morrow,[40] and others [1, 4, 5, 13, 27, 37] report the successful clinical use of tantalum mesh in chest wall reconstruction. Urban [49] employed tantalum mesh and a contralateral breast flap, and Brodkin [7] used diced cartilage between two layers of tantalum gauze. Late fragmentation and disintegration of tantalum mesh occurs, and in some instances slivers of steel have pierced the chest wall tissues causing pain, discomfort, and draining sinuses.[13, 37, 46]

Stainless steel mesh was used by Cotton [10] and Milwidsky.[37] Stephenson [47] reports fragmentation of stainless steel mesh when buried in the abdominal wall of rabbits.

Teflon mesh was used by Hardin [25] in 1957 and was considered the most inert synthetic material available at that time. In large defects additional support is required. Ravelling occurs at the edges when the Teflon mesh is under tension.[25]

Preformed lucite plate was employed by Hardin.[23] Although this material can be employed satisfactorily in chest wall reparative procedures, preoperative cutting, shaping, and drilling holes for sutures make its use inconvenient.

Hardin [24] later used Fiberglas cloth. Apart from fraying at the edges and exerting a foreign body reaction in the presence of infection, this material appeared admirably suited for chest wall prostheses. Where infection developed, the Fiberglas had to be removed.

The use of Ivalon in chest wall reconstruction has been reported by Southwick [46] and Fitch.[16] This material is particularly troublesome in the presence of infection; and where infection develops, complete healing is unlikely until the Ivalon sponge is removed (Southwick,[46] Milwidsky [37]).

A series of cases is presented in which Marlex mesh has been used in reconstruction of surgically produced thoracic wall defects (Fig. 1).

Marlex polyethylene (Usher [51]) is a relatively new plastic material developed by Phillips Petroleum Company, Bartlesville, Oklahoma. It is a high-density polyethylene produced from ethylene gas in a carrier solution by catalytic action at relatively low pressures. This new plastic possesses a highly crystalline molecular structure affording an unusually high softening tem-

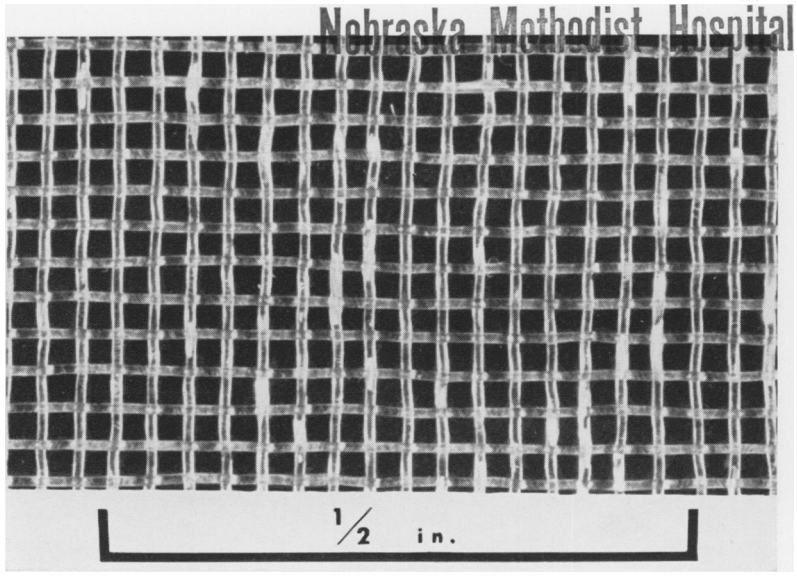

FIG. 1. Marlex mesh. Thread count 33 by 33 to the inch. Low-power magnification demonstrating open weave.

perature and high tensile strength as compared with that of conventional polyethylene. Its tensile strength is 50,000 to 150,000 pounds per square inch. It is readily made into a monofilament by hot-melt extrusion, and mesh made from this filament is nonwettable and possesses outstanding chemical resistance. It has a softening temperature of 126.6° C. Usher [51] has compared the tissue reaction of implanted Marlex to that of Dacron, Orlon, Nylon, and Teflon. He found that when implanted intraperitoneally in dogs, according to the method described by LeVeen,[31] Teflon and Marlex exhibited less foreign-body reaction than did Dacron, Orlon, and Nylon.

Because Marlex was well tolerated in living tissues and because of its desirable physical-chemical properties, Usher [52, 55] embarked on further experimental studies using Marlex as surgical prostheses. Large surgical defects in the abdominal wall, chest wall, and diaphragm of 31 dogs were replaced by Marlex mesh, and the dogs sacrificed at intervals of six, 12, and 24 weeks (Fig. 2). At autopsy macroscopic and microscopic examination of the grafts confirmed that the grafts were well infiltrated with pliable fibrous tissue which

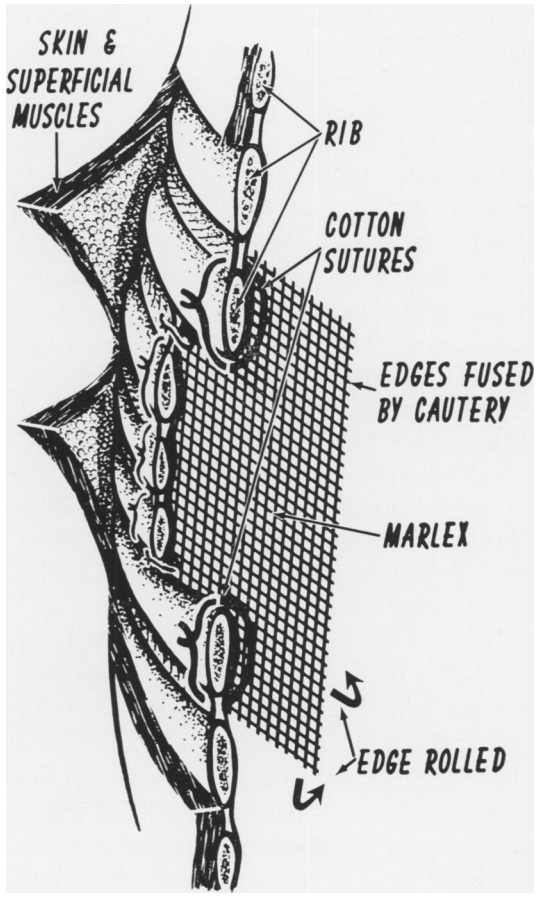

FIG. 2. Artist's conception of intrapleural fixation of Marlex.

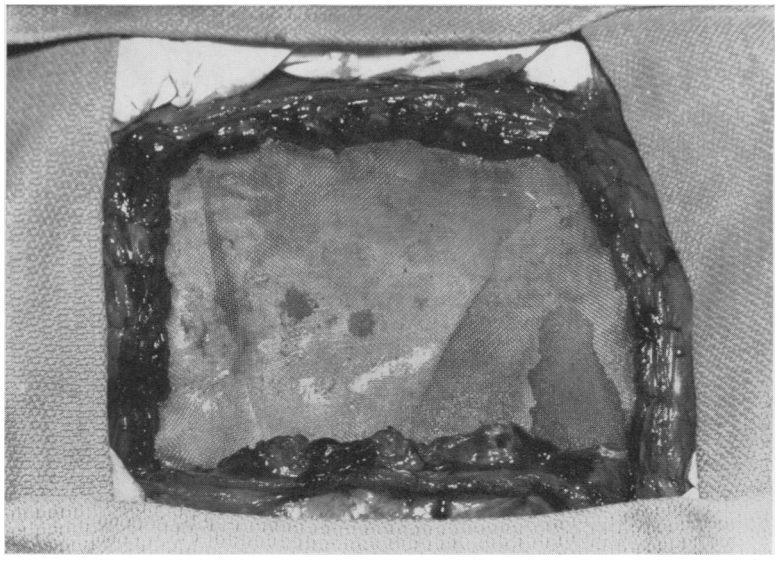

FIG. 3. Intrapleural technic of chest wall replacement with Marlex mesh demonstrated in a dog. An *en bloc* resection of five ribs including muscle and pleura has been replaced by the mesh.

varied from 3 mm. to 5 mm. in thickness. The mesh from the six-month specimens showed no fragmentation and no decrease in tensile strength.

Infection studies, where infection was deliberately induced, revealed that, although the wound healed rather more slowly, healthy granulation tissue would grow through the Marlex in the presence of purulent infection.[52, 55] The fibrous tissue was 3 mm. to 4 mm. thick and, as in the noninfected cases, well bonded to the surrounding tissues. Where similar grafts of Teflon and Marlex had been implanted simultaneously in a dog, autopsy at the six-weeks' interval revealed that very little fibrosis had taken place through the Teflon, and the Teflon was not well bonded to the surrounding tissues.

Usher[53] has reported on the clinical use of Marlex mesh in a series of 78 cases presenting with hernias and other defects of the abdominal and chest wall. From the experience gained in this series, it was decided that the intraperitoneal type of repair is the most satisfactory. Situated on the inside of the open defect and sutured to the inner aspect of the abdominal wall (peritoneum), the graft appears to have greater mechanical advantage than it would have placed externally and sutured over the defect.

Usher[53] further reports on 34 patients with incisional hernias repaired with Marlex. Wound abscesses occurred in three of the cases, but these responded to open drainage and administration of the appropriate antibiotic. In none of the infected cases was it necessary to remove the Marlex mesh.

A suitable prosthetic material for thoracic wall reconstruction should have certain attributes; Marlex mesh appears to fulfill most, if not all, of the necessary requirements. Its high tensile strength allows it to be stretched tightly across the surgical defect, thus ensuring a stable thoracic wall repair. It is readily incorporated in the chest wall tissues by infiltration of its interstices with fibrous tissue. It appears to elicit very little foreign body reaction, is inert in the presence of infection, and does not cause undue delay in wound healing. Marlex mesh can be made readily available at short notice, as it requires no preoperative preparation apart from sterilization, which can be easily and effectively accomplished by boiling for thirty minutes.

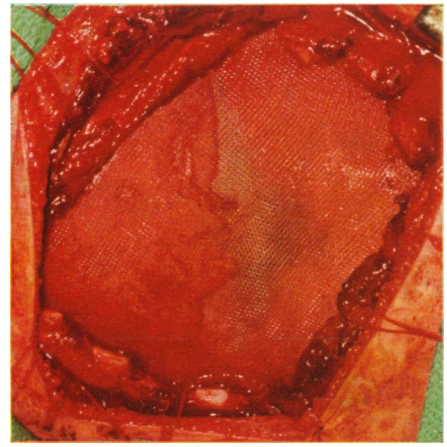

FIG. 4. Case 3. 14 by 8 cm. defect closed by Marlex prosthesis.

The mesh can then be cut to the desired size and shape. The cut edges can be seared with cautery, thus a seal is obtained which permits sutures to be placed within one-eighth inch of the edge without pulling through.

Thirteen cases are here presented in which Marlex mesh prostheses have been used in the repair of thoracic wall defects. Arising out of the success of the intraperitoneal technic,[53, 55] all but one case have been treated by what has been designated the intrapleural technic (Fig. 3, 4).

The prosthesis is closely applied to the relatively rigid externally placed pleura, ribs, and intercostal muscles surrounding the thoracic defect. In all thirteen cases the edge of the Marlex sheet was turned over to give a one-half inch margin of double thickness around the entire periphery of the prosthesis. If this is done, it is advisable to have the cut edge externally placed particularly when lung tissue is adjacent to the prosthesis because Usher[52] in experimental studies noted that lung tissue became firmly adherent to the Marlex.

In some cases stainless steel wire sutures were employed throughout; in others cotton was used; in one case black silk was used; and in the remainder both stainless steel wire and 3.0 cotton were employed simultaneously to attach the Marlex to the periosteum, pleura, ribs, and intercostal muscles. Stainless steel wire is less likely to produce a foreign body reaction, and it has the advantage of outlining the prosthesis in subsequent x-ray studies (Fig. 5, 6). Reference to the case reports will show that more than one method of catheter draining has been used. Probably the wound should be closed without drainage; and if a seroma develops, it should be aspirated.

Case Reports

Case 1. A. L. J. A 32-year-old woman had a large elliptical chondrosarcoma involving the third, fourth, and fifth ribs of the left anterior chest wall. An extensive block resection of the third, fourth, and fifth ribs was performed. The resulting defect was repaired by a 24 by 12 cm. sheet of Marlex mesh sutured over the defect with interrupted silk sutures. The thoracotomy incision was closed in the usual fashion, and the pleural cavity drained by a water seal system. Convalescence was complicated by a wound seroma which was opened and drained. A wound infection which developed responded to appropriate antibiotic therapy, and by the third postoperative month the wound had healed. No postoperative paradoxical chest motion developed; and when last seen on October 18, 1958, one year postoperative, the chest wall was strong and stable, and the patient active and well.

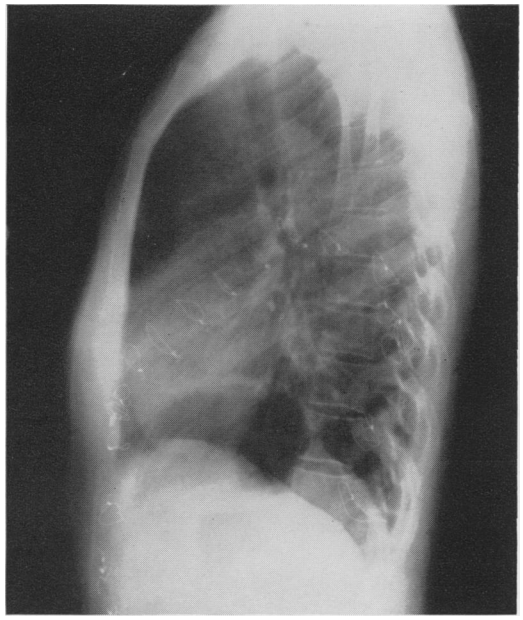

FIG. 5. Case 2. Lateral x-ray film demonstrating metal sutures outlining the prosthesis.

Case 2. M. F. A 49-year-old woman had a large osteochondrosarcoma involving the seventh, eighth, and ninth ribs of the left lateral chest wall with attachment to the lower lobe of the left lung and to the diaphragm. A block resection which included fifteen cm. segments of the seventh, eighth, and ninth ribs sectioned immediately beyond the transverse processes, a 5 by 4 cm. elliptical portion of the diaphragm, and 5 by 5 by 4 cm. "V" excision of the left lung was performed. The defects of the lung and diaphragm were repaired by approximation of their incised edges. The thoracic wall defect was repaired using a 22 by 17 cm. sheet of Marlex sutured intrapleurally with steel wire. The pleural cavity was drained by a water seal system and wound drainage accomplished by two catheters placed between the Marlex and the superficial chest wall tissues. The total wound drainage was approximately 75 cc. and the intrapleural drainage 240 cc. in five days. No paradoxical chest motion developed. A mild respiratory infection responded to Achromycin therapy, and the patient was discharged on the twenty-second postoperative day with a well-healed wound and stable chest wall. When last seen on March 17, 1959, one year postoperative, the chest wall was strong and stable, and there was no evidence of recurrent disease.

Case 3. E. M. P. An eight and half-year-old boy had an unclassified sarcoma 4 by 3 by 2.7 cm. in direct connection with the periosteum of the seventh left rib in the mid axillary line. A block resection including 11 cm. of the fifth, sixth, and seventh ribs was done. The surgical defect was repaired by the intrapleural technic using a 14 by 8 cm. Marlex mesh prosthesis. The pleural cavity was drained by a water seal system and the wound drained by two rubber catheters placed between the Marlex and the superficial chest wall tissues. Total pleural drainage was 320 cc. and wound drainage approximately 100 cc. No paradoxical respiration and no immediate postoperative complications developed. The patient was discharged on the fourteenth postoperative day with a soundly healed thoracotomy wound. He died of metastatic disease within six months.

Case 4. J. H. P. A 64-year-old man. X-ray examination revealed a lytic lesion of the right ninth rib in its middle third. Bone survey was otherwise negative. Intravenous pyelogram was negative. Blood chemistry values were normal; Bence Jones test, negative. The tumor, a plasma cell myeloma 8 by 6 by 2 cm. was resected along with the ninth rib and 10 cm. of the mid portion of the tenth rib. The surgical defect was repaired by a 12 by 6 cm. Marlex mesh prosthesis sutured intrapleurally using interrupted cotton sutures. Catheter drainage was accomplished by two catheters, one placed intrapleurally deep to the Marlex, the other between the Marlex and the superficial chest wall tissues. Both catheters were attached to a water seal system. Total drainage was 75 cc. Convalescence was uncomplicated, and the chest wall was strong and stable with no evidence of

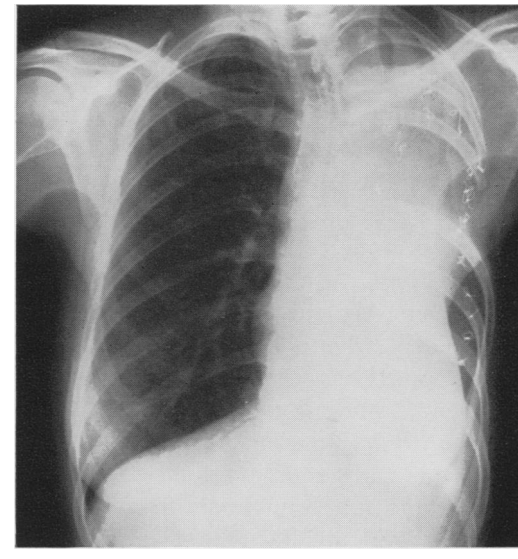

FIG. 6. Case 6. A.P. chest x-ray film demonstrating metal sutures outlining the prosthesis.

paradoxical movement. Bone survey at the last routine review on January 15, 1959, eight months postoperative, was negative. There was no clinical or radiological evidence of residual disease, and the chest wall was firm and stable.

Case 5. M. E. W. A 45-year-old woman. The referring surgeon had removed a lesion 4 by 3 by 3 cm. from the right inframammary fold. Frozen section pathological examination report indicated a benign lesion. The wound was closed. A revised pathological diagnosis of fibrosarcoma desmoid type, grade 1, was made, and the patient was referred to The University of Texas M. D. Anderson Hospital and Tumor Institute for further evaluation and treatment. A block resection of the anterior seven inches of the fifth, sixth, seventh right ribs was performed. The surgical defect was closed with a 25 by 24 cm. Marlex prosthesis using wire sutures and the intrapleural technic. Two thoracotomy drainage tubes were used, and catheters were employed to drain the wound. Pleural drainage was 200 cc. and wound drainage 50 cc. in five days. No paradoxical movement developed, and the chest wall was firm and stable when the patient left the hospital on the tenth postoperative day. When seen February 16, 1959, six months postoperative, there was no clinical or radiological evidence of residual disease and the thoracic wall was stable and strong.

Case 6. A. C. A 43-year-old woman had a bronchogenic carcinoma of the left upper lobe extending from near the hylum of the lung to the chest wall where it was adherent over a 15 by 10 cm. area in the mid axillary line. *En bloc* resection included the second and sixth ribs, partial resection of the third, fourth, and fifth ribs, and pneumonectomy, followed by a mediastinal node dissection. A 22 by 17 cm. Marlex prosthesis was placed intrapleurally and sutured with interrupted wire and cotton sutures. The wound was drained by two catheters placed external to the Marlex. The total wound drainage was 500 cc. in five days. No paradoxical movement developed, and the chest wall repair was strong and stable when the patient left the hospital on the tenth postoperative day. When seen, March 12, 1959, three months postoperative, the chest wall was stable, exhibited no paradoxical movement, and there was no clinical or radiological evidence of extension of the malignant disease.

Case 7. C. C. C. A 72-year-old man had a diagnosis of bronchogenic carcinoma of the left upper lobe. The lesion involved the third, fourth, and fifth ribs. *En bloc* resection included the second and sixth ribs and resection of 12 cm. portions of the third, fourth, and fifth ribs (in the left antero lateral thoracic wall), pneumonectomy, followed by a mediastinal node dissection. A 25 by 18 cm. Marlex prosthesis was placed intrapleurally and sutured with interrupted cotton sutures. Drainage was accomplished by two thoracotomy tubes, one placed intrapleurally, the other placed external to the Marlex, and both attached to a water seal system. Marked paradoxical movement lasting 24 hours developed on the evening of the operation and had to be controlled by external pressure. Total chest and wound drainage was 2,600 cc. in three days. On discharge from the hospital on the fifteenth postoperative day, the thoracic repair was sound and exhibited minimal paradoxical movement. When seen for review on March 2, 1959, two months postoperative, the patient's chest wall was stable and exhibited no paradoxical movement. He had no chest wall pain and no radiological or clinical evidence of recurrent disease.

Case 8. J. M. C. A 57-year-old man had an undifferentiated carcinoma of the left upper lobe extending to involve the antero lateral chest wall and with associated severe chest wall pain. Block resection included the first and fifth and partial resection of the second, third, and fourth ribs, pneumonectomy, followed by mediastinal node dissection. The surgical defect was repaired by a 22 by 15 by 8 cm. Marlex mesh graft sutured intrapleurally with interrupted cotton sutures. Wound drainage was accomplished by a rubber catheter placed between the Marlex and superficial chest wall tissues. The total drainage was approximately 2,500 cc. in five days. The patient was extremely weak following operation, was constantly supine, and on the sixth postoperative day, an area of pressure necrosis was observed in the thoracotomy wound posterior to the Marlex prosthesis. The area of necrosis healed slowly by granulation, and pinch grafts were successfully applied. Slight paradoxical movement was present for three postoperative days. The patient left the hospital on the fifty-ninth postoperative day with a stable chest wall exhibiting no paradoxical movement. He was fully ambulant and grateful to be free from chest wall pain.

Case 9. E. Y. A 66-year-old man with left chest wall pain of two months' duration had a bronchogenic carcinoma of the left upper lobe with extension to the second, third, and fourth ribs in the paravertebral region. The tumor, 8 cm. in diameter, was removed by block resection of the second, third, fourth, and fifth ribs directly adjacent to the transverse processes and anteriorly divided 7 cm. from the sternal border and pneu-

monectomy, followed by mediastinal node dissection. Following a frozen section pathological report of the excised tissues, the posterior margin of resection was extended to include the transverse processes of the second, third, and fourth thoracic vertebrae. The surgical defect was repaired by a 23 by 22 by 12 cm. Marlex prosthesis and sutured intrapleurally with interrupted cotton sutures. The wound was drained by two catheters placed external to the Marlex prosthesis. The immediate postoperative drainage was approximately 4,000 cc. over four days. The wound continued to drain approximately 30 cc. daily, and three cotton sutures were extruded. The patient's convalescence was protracted because of postoperative weakness. He left the hospital on his 54th postoperative day. Wound drainage ceased on the 67th postoperative day, and his wound is now healed and the chest wall stable with no detectable paradoxical movement, and he is completely free from chest wall pain.

Case 10. H. T. A 57-year-old man attended The University of Texas M. D. Anderson Hospital and Tumor Institute, August 27, 1958, with marked edema and pain of the left arm and with a history of having had a squamous cell lesion of the left hand treated by surgical excision and a metastasis to the left axilla treated by radium in 1952 and 1956, respectively. No active treatment was advised on August 27, 1958. When seen on March 26, 1959, he pleaded to have a very painful and swollen arm removed. On examination extensive nodular metastases were found in the left axilla. An interscapulo thoracic amputation was performed which included removal of the first and second ribs and a 4 by 6 by 3 cm. wedge of the apex of the left lung. The thoracic wall defect was repaired with a 12 by 10 cm. Marlex mesh prosthesis sutured with steel wire using the intrapleural technic. The pleural space was drained by a rubber catheter connected to a water seal system. The wound was drained by two catheters placed between the Marlex and the superficial chest wall tissues. Total intrapleural drainage was 1,050 cc., and wound drainage was 150 cc. in five days. The patient left the hospital on the 18th postoperative day with a stable chest wall and very grateful for complete relief of chest wall pain. When seen on May 8, 1959, two months postoperative, there was no clinical or radiological evidence of extension of the malignant disease. The chest wall was stable with no detectable paradoxical movement.

Case 11. J. E. B. A 71-year-old man with severe right upper chest wall pain had a bronchogenic carcinoma of the right upper lobe with extension to ribs two, three, and four in their mid axillary portions. The tumor, nine cm. in diameter, was removed by *en bloc* resection which included portions of the second, third, and fourth ribs, the entire fifth rib, and right upper lobectomy. The surgical defect was repaired by a 21 by 17 cm. Marlex mesh graft sutured intrapleurally with interrupted wire and cotton sutures. No system of drainage was deemed necessary apart from routine thoracotomy tube drainage by two catheters attached to a water seal system. The total drainage was 700 cc. Convalescence was uncomplicated, the thoracic wall stable from the outset and exhibiting no paradoxical movement. The patient left the hospital on the 15th postoperative day fully ambulant and grateful to be rid of the crippling preoperative pain. On May 12, 1959, one month postoperative, his wound was well healed and his chest wall stable with no detectable paradoxical movement. There was no clinical or radiological evidence of early recurrence or metastases.

Case 12. E. L. A. A 52-year-old man gave a history of pain in the right mid axillary line and with radiological evidence of a pathological fracture of the sixth rib enclosed in a tumor mass which extended to the fifth and seventh ribs in the mid axillary region. The lesion measuring approximately 9 by 4 by 3 cm. and extending to involve pleura was removed by *en bloc* resection. The 25 by 15 cm. surgical defect was repaired by a 27 by 15 cm. Marlex mesh prosthesis sutured with interrupted steel wire employing the intrapleural technic. The total pleural drainage from two thoracotomy tubes was 350 cc. in five days. The convalescence was uneventful, and no paradoxical movement developed. The pathological report was that of metastatic squamous cell carcinoma, primary unknown. The patient left the hospital on the eighth postoperative day. When seen by appointment on June 5, 1959, one month postoperative, the chest wall was stable, and the patient felt well and had returned to his duties as a barber.

Case 13. K. H. A 60-year-old man gave a history of severe pain in the mid zone of the right chest wall and with a radiological diagnosis of bronchogenic carcinoma involving the right hilum, upper lobe, and extension to the right fourth rib. An *en bloc* resection included a partial resection of the third, fourth, and fifth ribs in the mid axillary portions and pneumonectomy was done. The thoracic wall defect was repaired by a 27 by 18 cm. Marlex mesh graft sutured with interrupted steel wire and cotton sutures using the intrapleural technic. Drainage was accomplished

by one intrapleural and one wound catheter, the latter placed external to the Marlex mesh and both attached to a water seal system. Pleural drainage was 1,000 cc. and wound drainage, 300 cc. No paradoxical movement developed, and the patient was discharged on the tenth postoperative day free from chest pain and with a stable chest wall repair. On May 30, 1959, one month postoperative, he was readmitted critically ill, cyanosed, but afebrile. His pulse was rapid and of poor quality, and within a few hours of admission he expired. Autopsy revealed a diffuse bronchopneumonia.

Summary

Marlex mesh has been used as a prosthesis in thirteen patients for the repair of thoracic wall defects resulting from surgery. The Marlex mesh used is woven from a monofilament with a thread count of 33 by 33 to the inch and denier of 280. This mesh can be readily penetrated by granulation tissue; and because of its high tensile strength, it can be firmly stretched across the tissue defect ensuring a strong and stable repair. It is readily sterilized by boiling for thirty minutes without damage to the mesh. The mesh is easily cut to the desired shape and size, and its edges can be turned under and heat-sealed at the edges.

The intrapleural technic was used in all but one case, and it is the method recommended. Palpation of the wounds four to six weeks after operation revealed a sound chest wall repair; and paradoxical movement, if present, was found to be minimal by the third postoperative day.

Infection developed in one case, but it responded to appropriate antibiotics, and the Marlex mesh did not have to be removed. The wound healed satisfactorily, and the chest wall repair remained stable.

From the clinical experience gained in the use of this new polyethylene mesh, it would appear that Marlex mesh is admirably suitable as a prosthetic material in the repair of thoracic wall defects.

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