

CUTIS GRAFTS

CLINICAL AND EXPERIMENTAL STUDIES ON THEIR USE AS A REINFORCING PATCH IN THE REPAIR OF LARGE VENTRAL AND INCISIONAL HERNIAE

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SINCE LOEWE'S REPORT, in 1913, cutis grafts have been sporadically adopted for two purposes: (1) In the field of plastic surgery where the cutis is utilized to fill in tissue defects; and (2) in the operative treatment of hernia where patches of cutis are applied to strengthen the repair.

Cutis may be defined as the deeper layers of the skin which have been stripped of their epidermal covering. Anatomically, this includes approximately the deeper three-quarters of the thickness of the skin, the entire skin averaging about 1 mm., or 40/1000 inches, in depth. Histologically, cutis embraces the dermal layer with no epidermal covering, but with sebaceous and sudoriferous glands and occasional hair follicles as well as some of the underlying subdermal fat.

Reports in the literature on the use of cutis grafts, particularly as applied to the repair of hernia, include the following:

1. Loewe (1913) reported the use of cutis grafts in five cases of hernia and one of tendon repair. In describing the technic for removal of the graft, this author stated that the skin was removed with a scalpel in the manner of any full-thickness graft. The epidermis was then abraded away by scraping, as one would clean a carrot. The remaining tissue was then sutured over the defect under tension and the donor area was allowed to granulate and heal by second intention.

2. Rehn (1914) reported experiments on the use of cutis material. Strips of twisted cutis were used as insert grafts in the Achilles tendon of dogs. Rehn stated that under the influence of continual tension, a gradual degeneration of epithelial elements occurred, and that the tissue assumed the appearance and functions of normal tendon in about ten weeks.

3. Loewe (1929) extended his observations on the clinical use of cutis grafts to almost 100 cases.

4. Straatsma (1932) used buried cutis grafts for saddle-nose repair.

5. Uihlein (1939) reviewed the work of Rehn and presented 104 cases done in the latter's University Clinic in Freiburg since 1928. Eighty of these operations were for hernia.

6. Cannaday (1942) was the first writer to report the use of cutis grafts in hernial repair in this country, presenting 14 such cases. In 1943, this author made a later report, adding to his original cases and bringing the total to 37, 27 of which were operations for hernia.

7. Swenson (1943) reported two incisional herniae which were repaired with cutis graft reinforcement.

8. Scola (1944) reported the use of cutis grafts in the repair of two recurrent inguinal herniae and three incisional herniae. The cutis grafts were prepared by Scola's special method (*vide infra*) and in the operations on two of the incisional herniae formed the chief support, it being stated that "the fascia could not be closed."

9. Cannaday (1944) reported a total series of 107 operations utilizing cutis grafts, 56 of which were operations for hernia. Cannaday is at present the chief advocate of this technic in this country and expresses his position by stating: "Cutis may be used for any and every purpose for which fascia has been used, with the expectation of better results. . . . After this clinical experience with the uses of cutis (derma) in repair surgery, I am convinced that it is one of the most useful autoplasmic repair materials that we have, that it is superior in strength to fascia lata and of much easier availability; that success in its use can be expected in a large percentage of cases; that it is of especial value in the surgical repair of large incisional herniae."

METHOD OF OBTAINING CUTIS

Cutis is obtained by removing a full-thickness skin graft and, in turn, separating the latter into its deep larger (cutis) and superficial layer (epidermis). The cutis is used for the hernial repair and the epidermis is either discarded (by some authors) or utilized to cover the donor area as a skin graft. These methods can be classified as follows:

1. *Original Loewe Method (1913)*: A full-thickness graft is removed with a scalpel and then the epidermis is scraped off the graft with a razor. The donor site is allowed to granulate.

2. *Rehn Method (Uihlein, 1939)*: A Thiersch graft is removed from the thigh and in the exposed bed a cutis graft of desired size is cut. The Thiersch graft is presumably resutured over the defect.

3. *Rehn's "Türflügel" Method (Uihlein, 1939)*: The cutis is cut from a portion of abdominal wall to be discarded (as when doing a lipectomy in association with the repair of an incisional hernia). This obviates all necessity for closing the donor site. The method is only applicable to obese patients with incisional herniae, and has the objection that the neighboring skin is often atrophic and contains striae.

4. *Dermatome Flap Method of Swenson and Author (1943)*: This technic is similar to the Rehn method (No. 2 above) except that the epidermis is cut off with a dermatome and one end is left attached. This saves time and allows for a neater closure of the donor wound.

5. *Method of Scola (1944)*: A full-thickness dermatome flap (0.040 to 0.050 inch) is cut and one end left attached. Fresh glue is applied to the dermatome which then shaves the epidermis off the full-thickness flap at a depth of 0.008 inch, beginning at the attached end. The underlying cutis is then detached for use and the free piece of epidermis sutured over the donor defect. This method has the advantage of cutting the cutis so that not only its superficial, but its deep surface is smooth and regular. This also represents the first

method where the cutting of the cutis is entirely mechanically controlled and where its thickness is known, at least within the limits of accuracy of the dermatome.

6. *Split-split Method*: In 1945, Zintel, of Philadelphia, reported the split-split method for increasing the yield of skin grafts from donor sites of limited size in extensive burns. The principle of the method is simply the splitting of a Padgett skin graft into two layers of equal thickness on the drum by resetting the blade. For adults the entire thickness was 0.020 to 0.028 inches and the two component halves were 0.010 to 0.014 inches. The idea presented itself to the author of utilizing Zintel's method for the preparation of cutis grafts. A thicker original setting (about 0.040 inches or more) is used and then the epidermis is cut off at a depth of about 0.010 to 0.020 inches and sutured on the donor area. The inner cutis layer is used for reinforcement of the hernia. The cutis so obtained is of known and regular thickness, but if the dermatome has a loose axle, tends to be too thin.

ANALYSIS OF CLINICAL CASES

Eleven patients, nine with ventral incisional herniae and two with epigastric herniae, were operated upon with silk closure of the fascia reinforced with an overlying patch of cutis. These operations were performed during the two-year period from May 13, 1943, to February 28, 1945. All operations except one (Case 4, done by Dr. George Duncan, Resident in Surgery at the Johns Hopkins Hospital) were performed by the author. Cases 1 and 2 were seen at the Henry Ford Hospital, and the remainder of the operations were performed at the Johns Hopkins Hospital.

Age: The patients varied in age from 36 to 56 years, with an average of 44 years.

Sex: Eight of the patients were females and three were males.

Weight: In ten cases where the weight was given all but one exceeded 205 pounds, with the heaviest patient (Case 4) weighing 263 pounds.

Previous Operation: Nine patients had previous operations as follows: Appendicectomy, with drainage—3 cases, cholecystectomy—2 cases, pelvic operations—3 cases, operation for "swallowed glass in intestines in 1919"—1 case. These operations had all been performed before 1941.

Duration of Hernia: The onset of the hernia varied from 1924 to 1943, with an average date of onset of 1936 (seven years before this series).

Previous Attempts at Repair: This had been done in five of the 11 cases, four of these operations being performed elsewhere. The exception (Case 2) deserves further explanation. On December 8, 1942, an hysterectomy and Mayo repair of a para-umbilical hernia was performed by the author. Six months later a swelling was diagnosed as a recurrence and operation was performed. Before starting the abdominal part of the operation, a strip of cutis was taken from the right thigh by the dermatome flap method. Afterwards, the abdominal operation revealed no recurrent hernia and only an aseptic serocele containing clear fluid. The wall of the serocele was excised and the cutis used

to reinforce the already strong previous repair. Two years later the patient presented no signs of recurrence and had no symptoms referable to the operation.

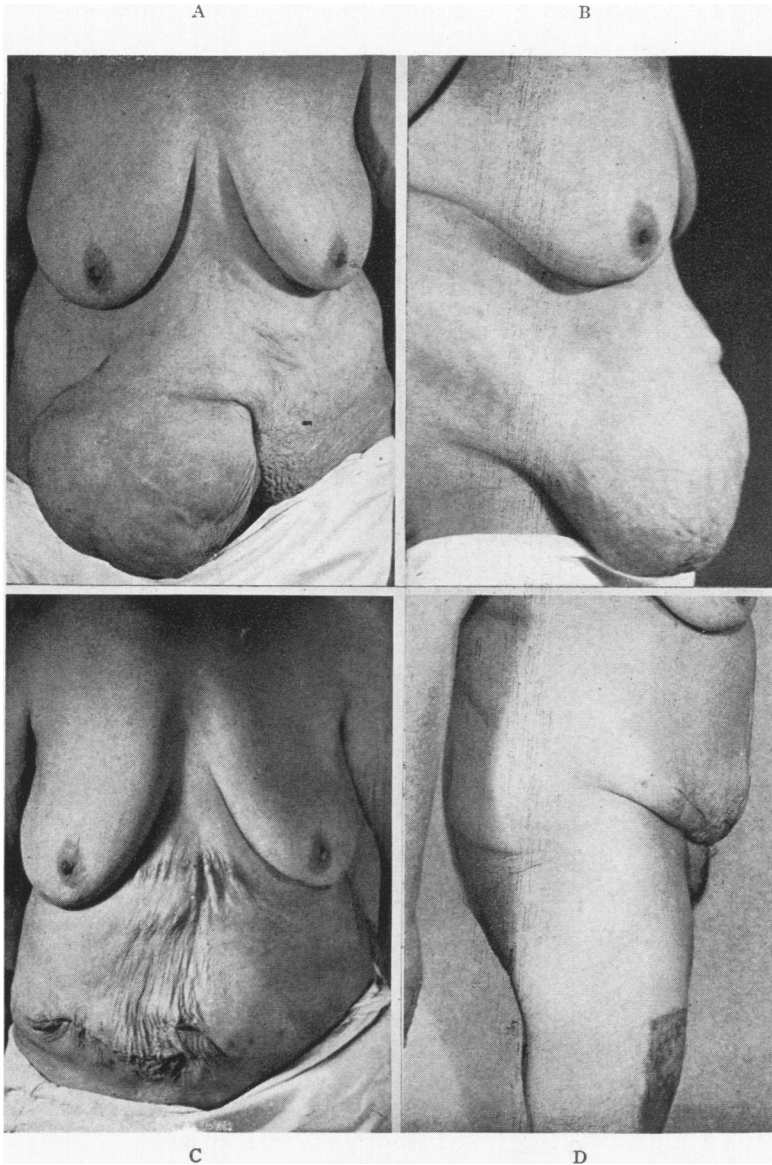


FIG. 1.—Incisional hernia in a 56-year-old female following hysterectomy in 1932. Onset in 1933, previous attempt at repair elsewhere in 1935. Cutis graft repair September 30, 1944 (Case 8). (A) and (B). Front and side views before operation. (C) and (D). Front and side views six weeks after operation. The healed donor area on the right thigh is seen in (D).

Size and Description of the Hernia: In all instances the well-known fact that incisional hernia rings are smaller than they appear to be externally was demonstrated. However, rings 6x10, 6x13, 5x5, 9x9, 6x9, 9x11, and 13x13 cm.

were noted. All sacs came straight out or pointed to the right. In two cases two rings were noted. Representative herniae with results after operation are shown in Figures 1 and 2.

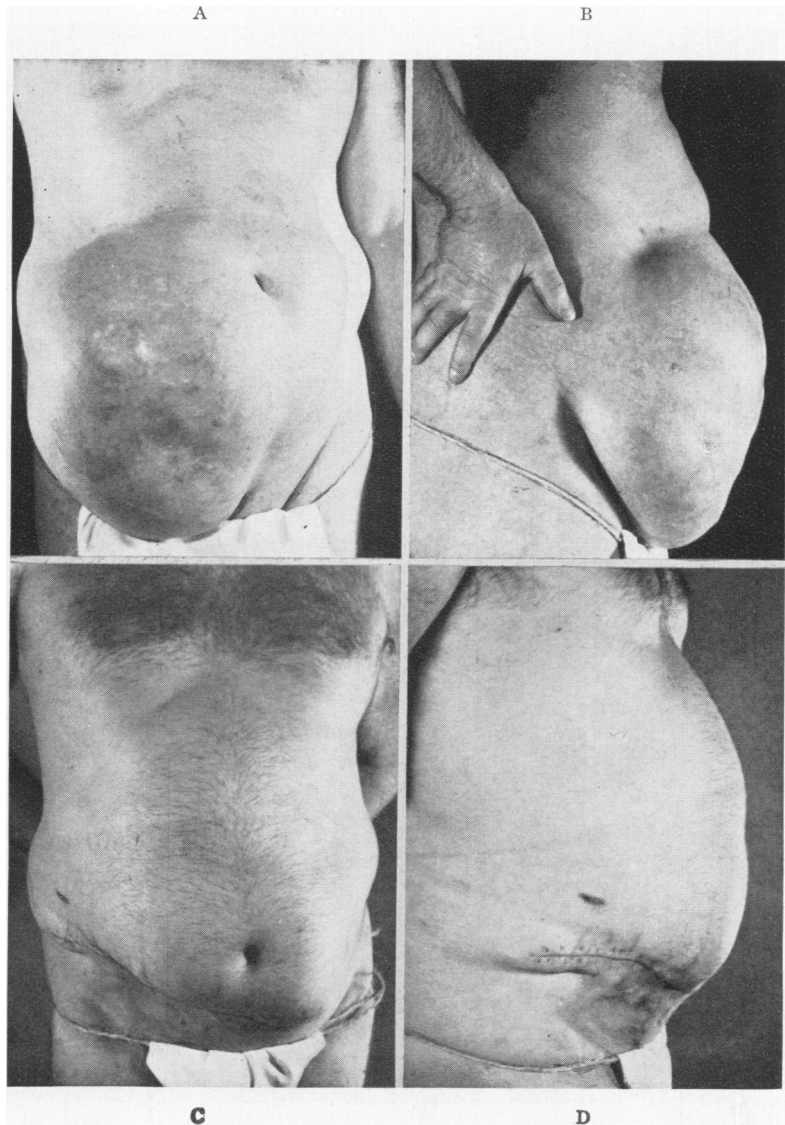


FIG. 2.—Incisional hernia in a 45-year-old male following appendicectomy, with drainage, elsewhere in 1940. Cutis graft repair February 28, 1945 (Case 11). (A) and (B). Front and side views before operation. (C) and (D) Front and side views four weeks after operation.

Anesthesia: In five cases gas-oxygen-ether was used alone, and in one case each was supplemented with pentothal and with spinal. In one case continuous spinal anesthesia was used.

Incision: In eight cases a transverse incision was used, in two, a vertical, and in one, the previous right subcostal incision was followed.

Source of Graft: The right thigh was used in ten cases and the part of the abdomen to be discarded after lipectomy was used in another case.

Associated Lipectomy: This was done in nine of ten cases where there is a statement in this regard.

Taking of the Cutis: This was done by three methods as follows:

(a) Dermatome flap method, used in Cases 1-5 and 7 and 8. This method is simpler and more rapid than any of the older technics. It is, however, more time-consuming than the two methods listed below. The under side of the cutis, being cut by hand with a scalpel, is of necessity irregular.

(b) Scola method, used in Case 6. This technic is rapid, but requires a very sharp blade and has the objection that it is difficult to cut the epidermis off the edges of the cutis, and this wastes a considerable portion of the graft.

(c) Split-split method, used in Cases 9-11. The quickest and most satisfactory method. (One of our dermatomes has an axle with considerable looseness and is not accurate enough to cut split-split grafts of any sort).

Thickness of the Epidermis: This varied from 9 to 20 thousandths of an inch, with an average of 13 thousandths in ten cases. The donor sites healed with no appreciable differences, as did the hernia wounds. A section of epidermis is shown in Figure 3.

Thickness of the Cutis: This can obviously be measured only when the Scola or split-split methods are used. In four cases it varied from 20 to 31 thousandths of an inch, averaging 24 thousandths. A section of cutis is shown in Figure 4.

Position of the Cutis Graft: In one case the cutis was placed right side up and in seven cases it was placed upside down (fat side up). In one instance (Case 7) a double thickness of folded cutis was used, the fat side being inside on each leaf. No difference in the results was noted. The reason for putting the nonfatty side down was the belief that it would unite more easily with the fascia beneath. A photograph of a patch of cutis sutured in place is shown in Figure 5.

Cultures: Cultures of the epidermis taken in four cases were all negative. These varied from the thinnest (0.009 inch) to the thickest (0.020 inch) slices of epidermis. In six cases the cutis was cultured and the results were negative in four instances (Cases 6, 7, 9 and 10). In two instances, as will be discussed later, the results were positive (Cases 8 and 11).

Closure of the Fascial Defect: This was transverse in five instances, vertical in five instances, and oblique in one instance. This corresponds to the skin incisions except that in three cases a transverse skin incision was followed by a vertical fascial closure. Transverse skin incisions were chosen because of the frequent desirability of lipectomy. Silk closure with interrupted sutures and, if possible, imbrocation of the fascial layers was used routinely. In no case did a fascial defect remain. In one case the anterior rectus sheath was split vertically on each side and folded over the suture line.

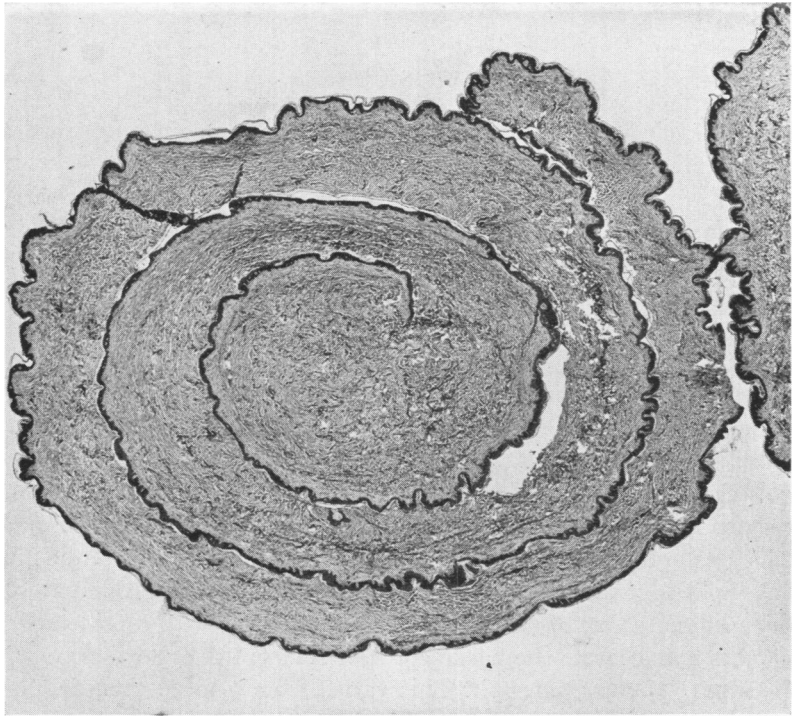


FIG. 3.—Discarded rolled-up epidermis in Case 10. The epidermis was removed at a depth of 0.020 inch by the split-split method from the portion of the abdominal wall to be discarded after lipectomy. Note the atrophic epidermis which could have been adequately removed by a more shallow excision.

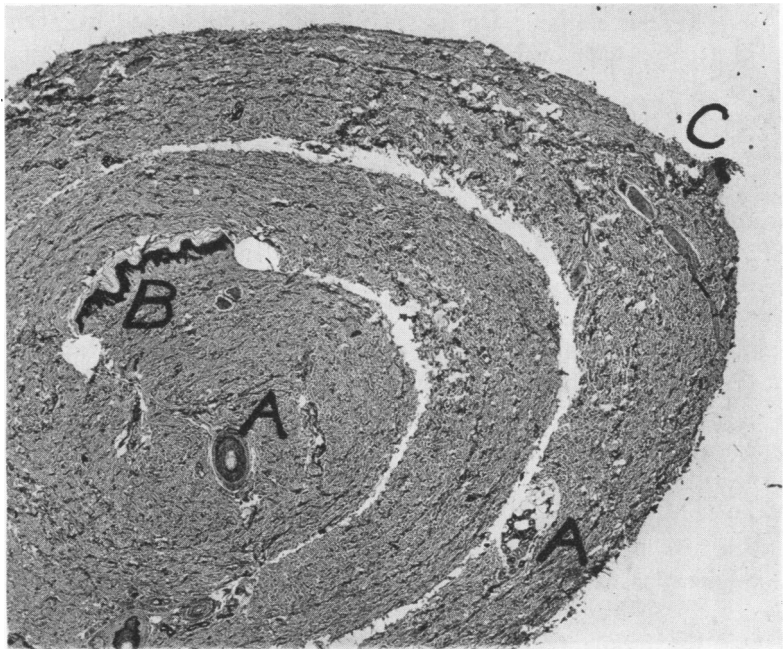


FIG. 4.—Portion of rolled-up cutis in Case 11. A full-thickness graft was removed at a depth of 0.040 inch (1 mm.) and the epidermis taken off by the split-split method at a depth of 0.014 inch, making the resultant cutis 0.026 inch thick. Note hair follicles and glands (A); border of epidermis (B) at edge of graft (such a border was removed from the piece of cutis that was buried); and an island of epidermis (C) which might have been overlooked and buried.

Histologic Examination: Sections of the epidermis removed in Case 10, at a depth of 20 thousandths of an inch, show that this depth of cutting was not necessary (Fig. 3). Sections of excess cutis in six cases all showed epithelial elements. This indicates that such an inclusion cannot be entirely avoided by cutting the epidermis deeper, unless the cutis itself is made so thin that it is of little value for supportive purposes.

Case 6.—Cutis: In a low power field several hair follicles and a few sebaceous and sudoriferous glands are identified. These occur at various depths in the cutis and are not just at the superficial edge. (Epidermis 0.009 inch; cutis 0.031 inch additional).

Case 7.—Cutis: Rather frequent hair follicles are seen at various depths in the cutis. One sebaceous gland, several sudoriferous glands and two epidermal pockets are identified. (Epidermis 0.012 inch; cutis cut by scalpel.)

Case 8.—Cutis: No hairs or hair follicles are seen, but there are numerous sudoriferous glands especially near the superficial surface of the cutis. These are, however, seen occasionally in the depths of the cutis. One sebaceous gland is identified and one patch of epidermis is seen in the surface; this latter is possibly the edge of a hair follicle. (Epidermis 0.011 inch; cutis cut by scalpel.)

Case 9.—Cutis: Few epithelial elements are present. The base of one hair follicle is seen at the outer surface and a few sudoriferous glands at various levels. No patches of epidermis or sebaceous glands are identified. (Epidermis 0.020 inch; cutis 0.020 inch additional.)

Case 10.—Cutis: There are few epidermal elements present, but one hair follicle and several sudoriferous glands are seen. (Epidermis 0.020 inch; cutis 0.020 inch additional.) It is of interest that this cutis as well as that from Case 9 both had the most (0.020 inch) epidermis removed, indicating that there is at least a quantitative reduction in the amount of epithelium left behind, even though there is not a qualitative disappearance of the same.

Case 11.—Cutis: Several hair follicles and glands are identified, as shown in Figure 4. At the edge of the cutis is a portion of unremoved epidermis. This remained attached because of rolling of the edge during the split-split process. The piece of epidermis was large enough to be visible to the naked eye and was removed from the portion of the cutis used for the operation. A smaller piece of epidermis near the center of the cutis was probably due to a glue blister on the dermatome. Such a piece might easily have been buried in the patient's wound. (Epidermis 0.014 inch; cutis 0.026 inch additional.)

Results: Ten of the 11 patients showed no recurrence of the hernia after the short follow-up of from one to 22 months (average eight months). All but one follow-up was by direct examination, the exception being by letter. Case 10 (weight 259 pounds) which at operation was more a diastasis than an hernia still has some diastasis at the upper end of the incision on straining. This patient and that in Case 9 still complain of a slight pain at one end of the incision. The other nine patients have no complaints referable to the operation. The donor site is well healed in all but the patient in Case 5 who was last seen only one month after operation.

OBJECTIONS TO THE USE OF CUTIS GRAFTS IN THE REPAIR OF HERNIAE

These can be summarized as follows:

(1) *Introduction of infection* from bacteria contained in the hair follicles

and sudoriferous glands of the cutis. In published reports of clinical cases, infection does not seem to be a frequent postoperative complication. In Uihlein's series (1939) of 104 cutis graft operations, 15 wound infections (15 per cent) developed. The personal clinical cases cited above also substantiate this experience, there being only one case of wound infection (Case 11), and in this case the wound culture when the infection had developed (*hemolytic Staphylococcus albus*) did not reveal the same organism as did the cutis culture at the time of operation (heavy growth of *beta Streptococcus*, Lancefield Group B). The results of cutis cultures in the five other tested clinical cases were as follows: Negative in four cases and positive in Case 8 (moderate growth of *hemolytic Staphylococcus albus* and *Staphylococcus aureus*). In four cases, portions of the epidermis removed from the top of the cutis were cultured with no growth resulting in any instance.

The animal experiments described below were formulated to further test this aspect of the subject:

(2) *Persistence of Epithelial Elements with Resultant Cyst Formation:* Several writers, particularly Davis and Traut (1926), and Zimches (1931), have studied the effects of burying sheets of full-thickness skin in dogs. Cysts resulted after three to four weeks, and tended to persist. Peer and Paddock (1937) studied the effects of burying fragments of cutis in human beings, with histologic observations at intervals of from one week after operation. The cutis grafts were prepared by taking a Krause full-thickness skin graft from the abdomen. "The epidermis was shaved from each section as completely as possible with a sharp No. 11 Bard-Parker knife blade, and the remaining dermis and fat were inserted beneath the skin of the chest with the dermis outermost." This method did not yield a true cutis graft because the authors admitted and their sections demonstrated that "in spite of attempted complete removal of the epidermis, some epidermis remained." This gave rise to cysts containing horny material and some hairs. Sebaceous glands were noted only in the implants of one week's duration, hair follicles only up to three weeks, while sweat glands persisted for a year, but in later sections they were in the process of degeneration and fibrous replacement. The cutis grafts fused with the surrounding connective tissue, but the granulation tissue surrounding the implant was of the chronic inflammatory type with lymphocytes, macrophages, epithelioid cells, often giant cells, and in some cases granulomatous nodules. The latter contained elements resembling hairs in some instances.

The animal experiments described below were formulated to further test the importance of persistence of epithelial elements. Furthermore, since the advent of the dermatome, there is now a means of measuring accurately the exact depth of cutis used and epidermis removed, as was not the case in Peer and Paddock's experiments.

(3) *Bridging a Fascial Defect is Seldom Necessary in the Repair of Herniae:* This objection also holds for the use of fascial grafts. The author has never seen a ventral or incisional hernia where the fascial layers could

not be brought together. The cases of Scola (1944), where large defects in the fascia remained and these were covered with cutis, seem incomprehensible or are very rare. Swenson and Harkins (1943) reported that in recurrent inguinal herniae silk gives just as good if not better results than fascia. The indication for cutis would seem to be, therefore, as a reinforcement of an already carefully executed silk (or other nonabsorbable material) repair.

(4) *Reinforcement is not Necessary in Small Herniae and Increases the already Long Operating Time too much in Large Herniae.* This objection is valid in many cases, but, on the other hand, a large group of moderate sized herniae do appear to be better supported with a reinforcing patch of cutis. When the cutis is taken by the split-split method, the additional time required is about 20 minutes. When one of the combined dermatome-manual technics is used, up to 50 minutes may be consumed in taking and applying the graft and in suturing the donor site. When two teams are available, this additional time can be cut down to almost nothing. The amount of blood lost by the additional procedure is, on the other hand, quite small.

EXPERIMENTAL STUDIES

Cutis grafts were implanted in 25 experiments upon 14 dogs. The grafts were taken by the various methods outlined in discussion of the clinical cases and sections and cultures were made of the epidermis and of the cutis. Necropsy studies were made as to the gross and histologic fate of the grafts. All experiments were undertaken under ether anesthesia, and with routine aseptic technic.

Experiment 1.—(Dog 1, female, 9.8 Kg.) October 16, 1944. *Abdominal Wall Implant:* A piece of cutis 4 cm. square was removed from beneath a dermatome graft of 0.014 inch with a scalpel and was implanted over the rectus sheath on the right side with the epidermal side up. Death occurred on the 22nd day from no apparent cause and necropsy showed no definite wound infection. There were no evident gross cysts, but histologic section revealed numerous horny clusters separated from the rectus sheath by a fatty layer.

Experiment 2.—(Dog 1) *Abdominal Wall Implant:* A similar graft was placed epidermal side down on the left rectus sheath. Gross cysts were present at necropsy and histologic examination (Fig. 6) revealed a picture similar to that in Experiment 1, except that the horny clusters pointed towards the rectus sheath rather than away from it.

Experiment 3.—(Dog 2, female, 10.2 Kg.) October 23, 1944. *Abdominal Wall Implant:* A small cutis graft similar to those in Experiments 1 and 2 was placed over the muscular fascia of the lower lumbar region with the epidermis down. The wound was well healed, as was the donor area, on September 21, 1945 (11 months) when the animal which was in good shape was sacrificed. The graft was still present, clean, and was fused with the surrounding tissues. Histologic section revealed hairs, small epithelial-lined cysts, and clusters of epithelial cells, all with practically no sign of surrounding inflammatory reaction.

Experiment 4.—(Dog 2) *Abdominal Wall Implant:* A similar graft was placed in the upper lumbar region with the epidermis up. The wound is well healed and the graft clean and similar to that in Experiment 3 except that it was less demarcated from the surrounding tissue on necropsy. Histologic section revealed numerous but scattered hairs and hair roots with no sign of surrounding inflammatory reaction.

Experiment 5.—(Dog 3, female, 9.5 Kg.) November 15, 1944. *Iliac Artery Ligation:* A cutis graft was removed with a scalpel from the back after taking off the

epidermis at a depth of 0.010 inch by the dermatome flap method. The epidermis shows numerous transected hair follicles as seen in Figure 7. Numerous hairs and glands were present throughout the cutis and, in fact, were quite numerous in the fatty tissue beneath it as seen in Figure 8. The number of epithelial elements was much larger than in the human cases (Fig. 4). Two strips of cutis were used to ligate the right common iliac artery twice. Death occurred from inanition without gross wound infection on April 9, 1945 (five months). The artery was occluded, but considerable sebaceous material was about the site of the ligature.



FIG. 5.—Cutis graft (the white patch in the wound bed) in place (Case 1). The cutis graft was taken from the right thigh by the dermatome flap method and is used as a patch over the suture line of a modified Mayo-type repair of an incisional hernia. This hernia occurred in a male 40 years of age, and was situated in the right subcostal region following a cholecystectomy in 1940. One previous attempt at repair had been made elsewhere.

Experiment 6.—(Dog 3) *Abdominal Wall Implant*: A large piece of the cutis (9 x 4 cm.) graft was placed over the right rectus sheath with the epidermal side down. At necropsy, this graft was not completely adherent to the rectus sheath.

Experiment 7.—(Dog 3) *Abdominal Wall Implant*: A smaller piece of the cutis placed over the left rectus with the epidermal side up was well healed and scarred at necropsy, but histologic sections showed hairs and chronic granulation tissue.

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Experiment 8.—(Dog 3) *Abdominal Wall Implant*: A small piece of cutis was placed between the peritoneum and the properitoneal fat with the epidermal side towards the peritoneum. At necropsy, it was puckered and sebaceous-like material was grossly present.

Experiment 9.—(Dog 4, female, 11.8 Kg.) November 20, 1944. *Iliac Artery Ligation*: A cutis graft was obtained from the back by the split-split method (epidermis 0.008 inch, and cutis 0.032 inch additional). Hairs and attached sebaceous glands as well as sudoriferous glands made up a good portion of sections of the cutis. These were just as plentiful in the middle of the cutis as on its superficial edge, but less so at its deep margin. The left common iliac artery was tied with two strips of cutis 1 cm. wide. It tied more easily than when the cutis was cut by hand (Experiment 5). The lumen of the iliac artery was quite intact and no remnant of the cutis was found when the dog was sacrificed on June 27, 1945 (seven months).

Experiment 10.—(Dog 4) *Abdominal Wall Implant*: A portion of cutis was placed under the left external oblique over the celiotomy suture line with the epidermal side out. At necropsy, a sinus came from this wound, and there was a large collection of hairs at the site of the graft, with acute infection demonstrated grossly and microscopically. There was no weakness of the abdominal wall.

Experiment 11.—(Dog 4) *Abdominal Wall Implant*: A piece of cutis was placed over the left external oblique in the upper abdomen with the epidermal side in. It was not adherent at necropsy to the external oblique, but was to the subcuticular structures. Hair, sebaceous material and granulation tissue were present, grossly and microscopically.

Experiment 12.—(Dog 5, male) November 20, 1944. *Abdominal Wall Implant*: A cutis graft was obtained from the chest by the split-split method (epidermis 0.016 inch, and cutis 0.024 inch additional) and placed epidermal side down over the right external oblique. A piece of the epidermis when sectioned showed transected hair follicles as did the cutis strip. The animal died from pneumonia on the seventh day. The wounds on the right side were infected (see also Experiment 14) but were not on the left (see Experiment 13). The cutis seemed to be attached, however.

Experiment 13.—(Dog 5) *Abdominal Wall Implant, Double Thickness*: Another strip of cutis was sutured after folding it double with the epidermal side inside beneath the left external oblique. At necropsy this graft was clean and no infection or sebaceous material was noted grossly. Microscopically, a small abscess, 0.5 x 4.0 mm., containing polymorphonuclear neutrophils was present as well as sebaceous material and hairs.

Experiment 14.—(Dog 5) *Homologous Graft, Abdominal Wall Implant, Double Thickness*: A piece of cutis obtained from another dog that died from anesthesia, and taken by the same technic, was placed without suturing over the right external oblique after folding double with the epidermal side out. At necropsy this graft was infected, but firmly attached.

Experiment 15.—(Dog 6, female, 10.5 Kg.) November 27, 1945. *Abdominal Wall Implant, Rolled Up*: A cutis graft 8 x 11 cm. was taken from the lower chest by the split-split method (epidermis 0.020 inch, and cutis 0.020 inch additional). Half of this was rolled up with the epidermal side outside under the skin of the right groin through a midline incision. Sections of epidermis and cutis were similar to those in Figures 7 and 8. The animal was sacrificed June 27, 1945 (seven months). The wound was clean and no evidence was found of the cutis graft. The donor area to which the epidermis had been resutured was well healed, but practically hairless.

Experiment 16.—(Dog 6) *Abdominal Wall Defect*: The other piece of cutis fell on the floor, but was washed in saline and was sutured in a 10 x 3 cm. excised defect of the left lower abdominal musculature (oblique muscles and rectus abdominus) against the transversalis muscle and peritoneum with the epidermal side down. At necropsy the graft was well fixed and clean. Sections showed no sign of infection or epithelial



FIG. 6.—Necropsy specimen of cutis graft from Dog 1, taken 22 days after operation. The graft was placed upside down on the rectus abdominis muscle. Note the numerous horny nests.

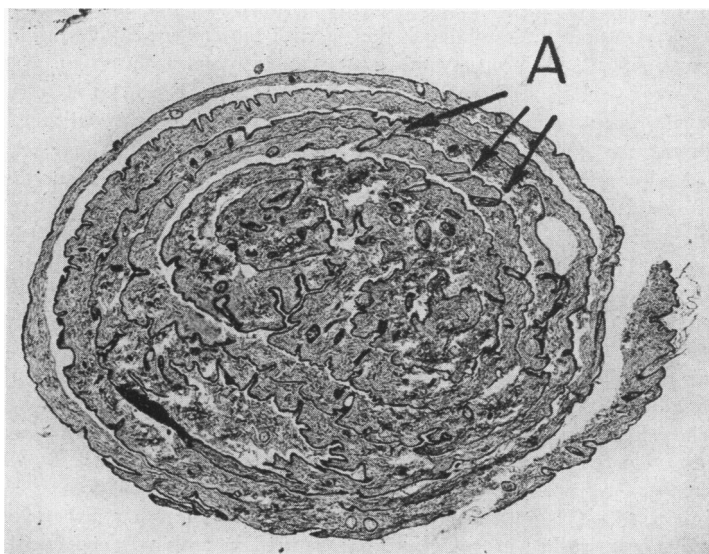


FIG. 7.—Rolled-up epidermis from Dog 3, taken at a depth of 0.010 inch. Note the numerous bisected hair follicles, some of which are seen at (A).

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remnants and only traces of hemosiderin deposits. Sections of the donor area to which the unused epidermis had been regrafted showed essentially normal skin.

Experiment 17.—(Dog 7, female, 9.8 Kg.) *Aortic Ligation:* A cutis graft 8 x 12 cm. was taken from the chest by the split-split method (epidermis 0.020 inch, and cutis 0.020 inch additional). Marcks' copper gauges were used to measure the thickness of the grafts in this and in ensuing experiments. Sections of epidermis and cutis were similar to those in Figures 7 and 8. Three strips 1 x 12 cm. were used to ligate the

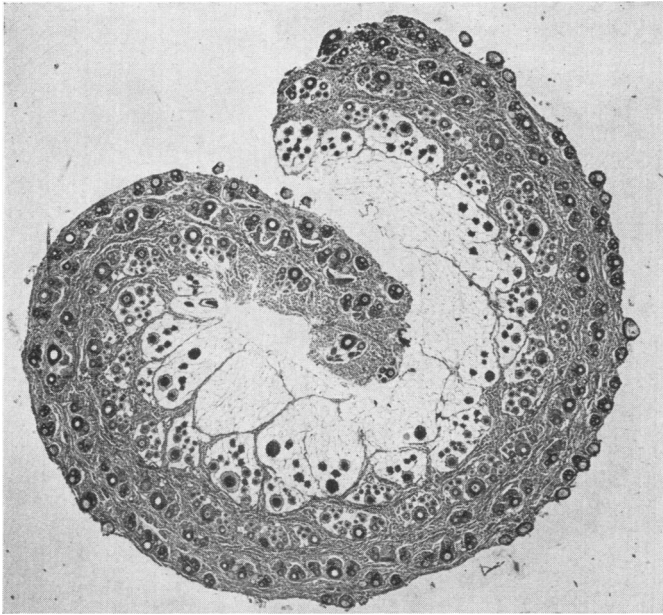


FIG. 8.—Rolled-up cutis graft from Dog 3. The epidermis was removed at a depth of 0.014 inch, and the cutis removed from the underlying bed with a scalpel. Note the large number of epithelial elements as compared to the human case seen in Figure 4.

abdominal aorta. A triple tie was used in each case and the knots were transfixed with one silk suture which did not surround the aorta. On the twelfth day the animal died of distemper. The donor area to which the epidermis had been resutured was entirely healed. All wounds were healed and clean. The aortic ligatures had atrophied and the lumen was reduced by only one-third.

Experiment 18.—(Dog 7) *Abdominal Wall Defect:* A 2.5 x 7.5 cm. area of oblique muscles was excised and the remainder of the cutis graft was fastened with interrupted silk sutures in place, epidermal side down, over the transversalis muscle. At necropsy, the graft was clean and was quite adherent on its lower (epidermal) surface, but not quite on its upper surface. A section of the cutis shown in Figure 9 demonstrates good fusion to the surrounding structures, but with contained epithelial elements including hair follicles. A section of the grafted donor area shows the graft viable and united with the underlying structures by a thin zone of granulation tissue. Sections of the abdominal wall showed the muscle quite adherent to the underlying internal oblique. A moderate number of hairs and hair follicles were fused with the surrounding tissue. Round cells were seen but no polymorphonuclear neutrophile collections were found.

Experiment 19.—(Dog 8, female, 7.7 Kg.) January 15, 1945. *Aortic Ligation:* Two strips of cutis 1 cm. wide obtained by the split-split method from the chest (epidermis 0.020 inch, and cutis 0.020 inch additional) were used for ligatures of the abdominal aorta. The knots were sutured with silk to prevent slipping but the silk

did not surround the aorta. The animal died of distemper on the 17th day. The aortic lumen was not reduced. The cutis had degenerated into a mass of sebaceous material about 12 mm. in diameter. No true pus was present. The donor areas to which the epidermis had been resutured were entirely healed.

Experiment 20.—(Dog 9, female) March 5, 1945. *Abdominal Wall Defect:* A cutis graft obtained by the split-split method from the upper abdomen (epidermis 0.020 inch, and cutis 0.020 inch additional) was sutured in a defect of the entire thickness of the abdominal wall below the subcutaneous tissue measuring 2.5 x 7.5 cm. Sections of a portion of the cutis showed it to be irregular in thickness with one side composed

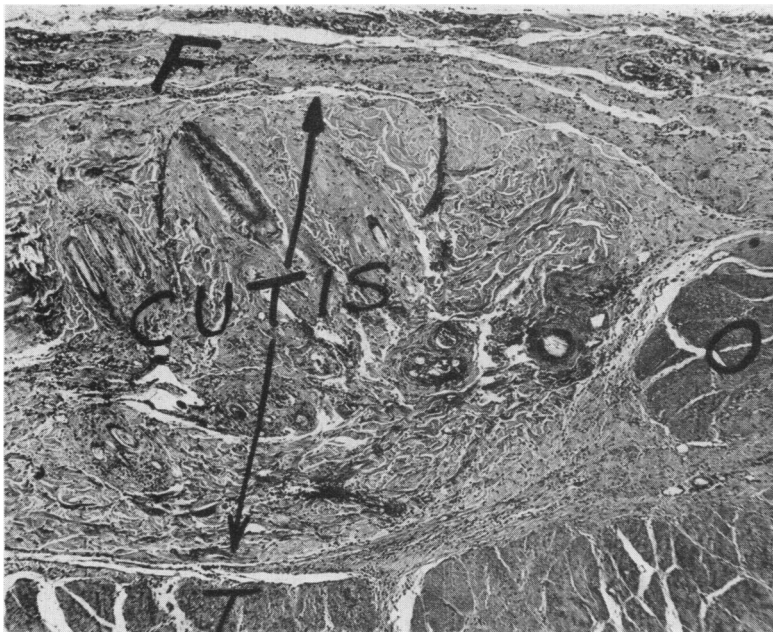


FIG. 9.—Cutis graft in place at necropsy 12 days after operation in Dog 7. A strip of cutis was obtained from a full-thickness graft of 0.040 inch by splitting it in two by the split-split method and utilizing the deeper half. An area of external and internal oblique muscles, 3 x 1 inches, was excised and the strip of cutis fastened upside down on the transversalis muscle (T). The cutis lies beneath the superficial fascia (F) and joins the oblique muscles (O) on the right. It contains epithelial elements, including hair follicles.

mainly of fat and containing practically no epithelial elements while the other side contained many hair roots and some hairs. The graft was sutured to the cut edges of the surrounding muscles with the epidermal side facing the intestines. The donor site to which the epidermis was resutured was entirely healed in one month. At the time of sacrifice on September 21, 1945 (6.5 months) the animal was in excellent condition and there was no sign of hernia. All wounds were well healed. Histologic section of the donor skin grafted area showed good epithelium with hairs and other accessory epithelial elements. A surrounding edge of second degree scar-healing showed a thin layer of epithelium with very few hairs. The graft was firm, but not as strong as the surrounding tissues and had shrunk to a size of 7.0 by 2.5 cm. Histologic section of the cutis graft scar showed many small cysts containing hairs and epithelial buds.

Experiment 21.—(Dog 10, female) March 12, 1945. *Abdominal Wall Defect:* This was exactly similar to the preceding experiment except that the epidermal thickness was 0.018 inch, and the cutis 0.022 inch, and the cutis was placed epidermal side out in the abdominal wall. Sections of a portion of the cutis showed it to be mainly fat. Few epithelial elements were present and these included hairs, hair roots, and one demon-

strable sudoriferous gland. The animal was found dead on April 4, 1945 (23 days) with minimal distemper. The donor site was only 50 per cent healed. The cutis graft was well healed and clean. The defect had shrunk to 3 x 6 cm. Sections showed that the graft was of poor quality containing considerable fat, a very occasional hair but no other epithelial elements. One small collection of polymorphonuclear neutrophils lay beneath the skin at the edge of the graft but superficial to it.

Experiment 22.—(Dog 11, female) March 21, 1945. *Diaphragmatic Defect:* A cutis graft of a thickness similar to that of the last experiment was taken from the abdomen and sutured into a full-thickness excised defect in the left diaphragm through a transthoracic approach with the epidermal side towards the chest. Sections of a portion of the cutis revealed a thin layer of muscle with fat on each side and with no epithelial elements. On July 19, 1945 (four months) the dog was well, the donor site was well healed and the wound was clean. Death occurred on August 28, 1945. Necropsy was not performed.

Experiment 23.—(Dog 12, female, 4.5 Kg.) March 28, 1945. *Abdominal Wall Defect:* A cutis graft of thickness similar to that in the last two experiments was taken from the upper abdomen and sutured into a whole-thickness defect of the abdominal wall musculature about 2.5 x 9 cm. Sections of the graft showed it to be very uneven in thickness. In one place it had practically no cutaneous elements, in another a great many. The graft was folded double with the epidermal layer inside facing itself. The animal was sacrificed on June 27, 1945. The donor area was entirely healed. The abdominal wound was entirely clean and healed and represented a perfect result. There was no weakness. The defect measured 3 x 9 cm. The intestines were not adherent to the underside of the graft but the omentum was slightly attached. The graft was well adherent in its upper surface. Histologic section showed a thick layer of relatively normal fibrous tissue containing very occasional hairs.

Experiment 24.—(Dog 13, female, 5.2 Kg.) March 29, 1945. *Diaphragmatic Defect:* A cutis graft taken from the abdomen by the split-split method (epidermis 0.014 inch, and cutis 0.026 inch additional) was sutured to a 2.5 x 4 cm. defect in the diaphragm with the epidermal side towards the chest. The animal died in four hours, and at necropsy the graft was seen to be quite intact.

Experiment 25.—(Dog 14, female, 6.0 Kg.) April 2, 1945. *Diaphragmatic Defect:* A graft similar to that in Experiment 24 was sutured to a diaphragmatic defect 4 x 6 cm. with the epidermal side towards the chest. The animal was sacrificed on June 27, 1945 (2.5 months). The donor site was entirely healed and the chest wound was clean. The graft was intact without weakness and was firmly attached to the lung and only partially attached to the liver. Sections of the cutis at the time of operation were similar to Figure 8 except that epithelial elements were not so widely distributed. Histologic examination of the graft at necropsy revealed an intact graft firmly adherent to the underlying lung and in places adherent to the liver. The graft contained a few hairs and hair roots and sebaceous cysts 0.5 mm. or less in diameter. No notable signs of inflammation were present. Sections of the donor site revealed an intact but thin epithelium with hairs and underlying glands.

RESULTS OF CULTURES

Aerobic and anaerobic cultures of the cutis obtained from the first five dogs all showed only a gram-positive anaerobic gas-forming bacillus with no spore formation or branching. In one case (Dog 3) where incidentally only a thin (0.010 inch) layer of epidermis was removed, an additional growth of *Staphylococcus aureus* was observed. At necropsy the wounds of Dogs 4 and 5 were grossly infected.

ANALYSIS OF EXPERIMENTAL DATA

A total of 25 experiments on 14 dogs included 13 abdominal implants, five bridging of abdominal wall defects, two ligations of the common iliac artery, two ligations of the abdominal aorta, and three bridging of diaphragmatic defects.

In the series of 13 abdominal wall implants at various levels and positions, all examined at necropsy, no remnant of the graft was found in one case, granulation tissue or pus was found four times, gross hairs in two instances, gross sebaceous material in two instances, sinuses once, and apparently clean healing six times. In eight experiments histologic sections were made and all revealed epithelial elements including two in which no gross hairs were evident. In 12 instances where fusion of the graft to surrounding surfaces could be noted, fusion was present on both surfaces eight times, on the fat side but not on the epidermal side of the graft twice, and the graft was not adherent at all in two instances. Of the 13 grafts observed, only six were without some complication (pus, hair, sebaceous material, entire disappearance of the graft, *etc.*).

In the series of five bridging of abdominal wall implants, all examined at necropsy, on gross examination all showed complete absence of hair, pus, cysts, *etc.* Three grafts were adherent on both surfaces and one on the epidermal surface only. Histologically, hair was present four times and absent once.

In the series of two common iliac ligations, in one there was no remnant of the graft and no occlusion of the artery, and in the other the artery was occluded, but a mass of sebaceous material was present.

In the series of two aortic ligations, in neither case was the aorta occluded. In one the graft had disappeared, in the other a sebaceous mass was present.

In the series of three diaphragmatic defects of two animals examined at necropsy no gross evidence of abnormal healing was observed (one animal, Experiment 24, died after only four hours; the other, Experiment 25, was sacrificed after 2.5 months). The graft was adherent mainly on its epidermal surface in Experiment 25, and sections in this case revealed hairs and sebaceous cysts.

NOTE ON THE USE OF WHOLE SKIN AS A SUBSTITUTE FOR FASCIA (AND FOR CUTIS)

In the January, 1945, issue of the British Journal of Surgery an article by Mair of Aberdeen, Scotland, appeared on the use of whole skin grafts as buried patches for the repair of hernia. This author reports the use of this method in 88 herniae, and studied the results of whole skin implants in rabbits. This same author has another article in a recent issue of the American Journal of Surgery. Despite the excellent results reported with this method, it would appear to be more risky than the use of cutis, but these articles deserve reading. It would seem that while one layer of cutis might be weaker than one layer of whole skin, two layers of cutis would

be stronger and still not have as many epithelial elements combined as the single layer of skin.

SUMMARY

A cutis graft reinforcement patch was used in the surgical repair of 11 cases of large ventral or incisional herniae. These herniae were in most instances chosen for this type of repair because of their large size and associated obesity of the patient. Seven cases were specifically selected from a large number of ward patients because of the magnitude of the hernia.

In all cases the fascial layers were closed with silk sutures and the cutis acted only as a supportive patch. The cutis was obtained by four methods: (1) Dermatome flap; (2) Scola double graft; (3) split-split; and (4) from tissue removed from the region of the hernia by lipectomy. In all cases, except when the fourth method rendered it unnecessary, the donor area was again covered with the removed epidermis.

The results of the operation were completely satisfactory in all but one instance (Case 10). In this instance some diastasis of the upper end of the wound recurred. It is impossible to state, however, that the basic silk repair, often by the Mayo technic with imbrocation, might not have been equally satisfactory and that the cutis graft was superfluous.

The chief objections to use of cutis grafts have been met in these clinical cases as follows: (1) Infection with drainage occurred in only one wound, and in that instance was associated with finding a different organism from that cultured from the cutis at the time of operation. (2) Cyst formation from persistent epithelial elements has to date caused no obvious trouble in any case. (3) Increased operating time has been largely obviated by use of the split-split method.

Variations in the technic whereby single and double layers of cutis were used; whereby in different cases the cutis was placed epidermal side down (seven instances) and epidermal side up (one instance); whereby the thickness of the removed epidermis and of the cutis itself was varied, all seemed to have no effect on the results.

While the results of the human cases were in general quite satisfactory, the animal experiments were accompanied by a high incidence of complications. In all cases but one of the 14 where sections of the buried graft were taken at necropsy, epithelial elements were present. Pus, hair, sebaceous material, or sinuses were observed in 18 out of 24 experiments (75 per cent) in which the graft was observed at necropsy. In four other instances no epithelial remnant of the graft was found and in the two remaining cases the intact graft was observed. Most of these complications followed the insertion of the cutis as abdominal implants or its use as arterial ligatures. The experiments where the graft was actually sutured under tension to close muscular defects in the abdominal wall or diaphragm were much better, with no gross complications of healing being observed in six such experiments.

Ligations of the abdominal aorta and common iliac arteries were not successful with cutis strips. Either the artery was not occluded or the cutis

degenerated into sebaceous material. The reestablishment of continuity of the arterial lumen is possibly attributable to the elasticity of the cutis.

The difference between the human and animal experiments would seem to be a quantitative rather than a qualitative one. It is impossible to remove all of the epithelial elements from the cutis without excising such a thick layer of epidermis that no dermis is left behind. It was one of the initial hopes of this investigation that with the modern precise methods of taking grafts at known depths the optimum thickness of cutis and of removed epidermis might be ascertained. Actually, it seems to make little difference because once the superficial epidermis is shaved off—and this can be done by a very shallow setting of the dermatome (0.008 inch, or even less)—the epithelial elements in the underlying cutis penetrate deeply. It is true that quantitatively the deeper one removes the epidermis the less the remaining cutaneous remnants, but also the less the remaining cutis. This quantitative difference is especially noticeable in the animal experiments where a large amount of epithelial material in the cutis (estimated histologically in area as 50 times as much, or more, in a section of cutis of equal size) is far greater than in a human cutis graft.

CONCLUSIONS

1. Quantitative studies on cutis grafts cut at various thicknesses indicate that superficial removal of the epidermis need be no more than 0.008 inch.
2. A relatively nonhairy donor site is desirable to avoid as much as possible the inclusion of hair follicles and attached glands. The danger of such an inclusion is essentially quantitative rather than qualitative, but is always to be considered. With adequate skin preparation infection does not seem to be a major menace.
3. The split-split method is the most useful technic for obtaining cutis grafts.
4. It seems to make little difference whether the cutis is used with the epidermal side up or down, or whether it is inserted in single or double sheets.
5. Cutis grafts should be applied under tension and when used in the surgical treatment of hernia should be fastened as a supporting patch over the suture line of an otherwise adequate repair of the fascial layers with nonabsorbable sutures.
6. Cutis grafts as used in these experiments are not suitable for ligation of major arteries.

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