

HEMOSTASIS WITH ABSORBABLE GAUZE*

(OXIDIZED CELLULOSE)

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A PRELIMINARY REPORT of our observations of tissue reactions to oxidized cellulose† appeared in the ANNALS OF SURGERY in July, 1943. This represented experimental work undertaken in 1941, and the results agreed with those of Ingraham and Bailey, reported in 1944, who checked the tissue reactions and compared them to those obtained with fibrin foam.

In the same issue of the ANNALS Dr. Tracy J. Putnam reported his clinical use of the material as a carrier for thrombin to secure hemostasis in neurosurgery. At that time further investigation was planned to determine the degree of oxidation, *i.e.*, percentage of carboxyl groups, yielding the most satisfactory product for clinical use, and a reliable method for sterilization of the material, which does not withstand the process in the autoclave. At the moment of writing, the gauze supplied for clinical investigation contains approximately 13.5–15.8 per cent COOH, and is submitted, doubly packaged, in glassine envelopes after formaldehyde sterilization, which has been checked aerobically and anaerobically, and which does not leave sufficient trace of formaldehyde to render the material irritating on this account. Cotton pledgets, similarly packaged, contain 10–12.5 per cent COOH.

When the relatively nonirritating nature of the cellulose had been established, and it had been shown that, in small amounts at least, it was absorbed in varying lengths of time from different tissues, there was an immediate demand for the release of the gauze for clinical use in cases of hemorrhage where hemostasis could not be secured by ligature or other methods, and where ordinary gauze packing, with all the well known difficulties of subsequent removal, had to be used as a last resort. There were many suggestions offered as to use of the material in traumatic surgery, naturally, with military necessity in mind, where packing of wounds with ordinary gauze, used for

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† The gauze and cotton were supplied by Eastman Kodak Research Laboratories, Rochester, N. Y. (U. S. Pat. No. 2,232,990), through Parke, Davis & Company, Detroit, Michigan.

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hemostasis, had so often resulted in sealing-up of deep contamination, with resulting serious wound infection.

Accordingly, a series of experiments were undertaken to reproduce, as nearly as possible, lacerated bleeding wounds such as those which in clinical practice might necessitate gauze packing. No adjuvant to promote clotting was used, and no immediate effect was expected other than cessation of bleeding inherently due to the presence of the packing. Standard procedures were worked out, after trial and error, in which the type and extent of bleeding



FIG. 1.—Photomicrograph showing oxidized gauze in experimental wound of kidney 48 hours after packing. The gauze is closely applied to the wound surfaces. (Low power.)

could be anticipated, and in which the effectiveness of packing could be estimated. This estimation was, needless to say, based not on any measuring or timing, but on clinical impression. With repeated observations, however, certain unexpected findings were established:

1. The oxidized gauze was easier to pack into a bleeding wound than ordinary gauze. It seemed more pliable, and, when wet with blood, slightly sticky.

2. The oxidized gauze, used dry, was observed to swell when saturated with blood, and this was a second factor which facilitated packing—the gauze easily filling all the irregular crevices in the wound (Fig. 1).

3. The combination of blood and oxidized gauze resulted almost immediately in a dark-brown or black mass and as soon as this discoloration

occurred bleeding usually ceased. (The affinity of the oxidized material for hemoglobin and its effect on this may be seen by immersing a strip of gauze in a test tube of dilute laked blood. Almost immediately the hemoglobin is drawn into the gauze, turning brown, and leaving the solution colorless (Fig. 2).

4. The hemostatic effect appears to depend *not on clotting* within the meshes of the gauze but on the *swelling* of the material and its *sticky character* when blood-soaked, so that the packing itself *takes the place of clot*. We have not studied any possible *direct* effect on the clotting process.

5. Neutralization of the material with calcium acetate resulted in the loss of the above properties, rendering it less effective as an hemostatic.

6. As early as 24 hours after packing, the oxidized gauze was so friable that it broke when an attempt was made to withdraw it, in contrast to ordinary gauze which could be withdrawn, but which, in clean wounds especially, was usually stuck, so that force was necessary for withdrawal. With ordinary gauze, removal was apt to be followed by bleeding, sometimes requiring secondary packing. With oxidized gauze, by 48 hours in an open wound, the gelatinous mass of brown material which represented the blood-soaked packing could be gently scraped away from the wound surface without renewal of bleeding (Fig. 3).

7. Oxidized gauze, even when not absorbed early, was not invaded by reparative tissue. The foreign body, therefore, was not incorporated in scar to any extent, and scarring was minimal.

8. In serous cavities where a relatively large single mass of material is surrounded by serous membrane, cysts are sometimes formed. These apparently can eventually resorb and have been in general small, not proportional to the amount of gauze used. Such cysts have not been observed in solid viscera or the supporting tissues—connective tissue, muscle, bone. (The work on serous cavities is not complete as regards the study of adhesions, but is reported here to illustrate the tissue reaction to large amounts of gauze).

The observations summarized above are based on experiments in which the wounds were made with the animals under general anesthesia, and with aseptic precautions.

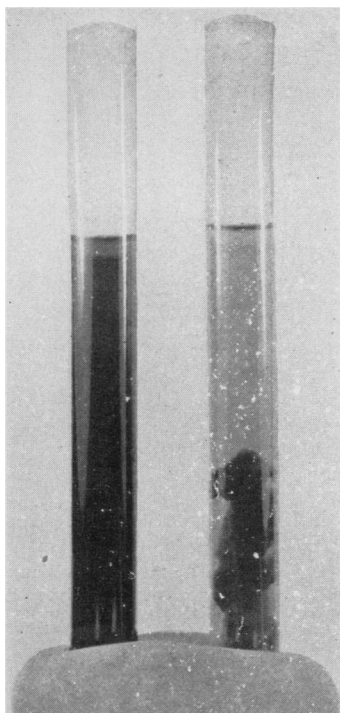


FIG. 2.—Photograph showing oxidized gauze in dilute laked blood—right; control without gauze—left. The control was bright red. The gauze was brown and the supernatant fluid almost colorless.

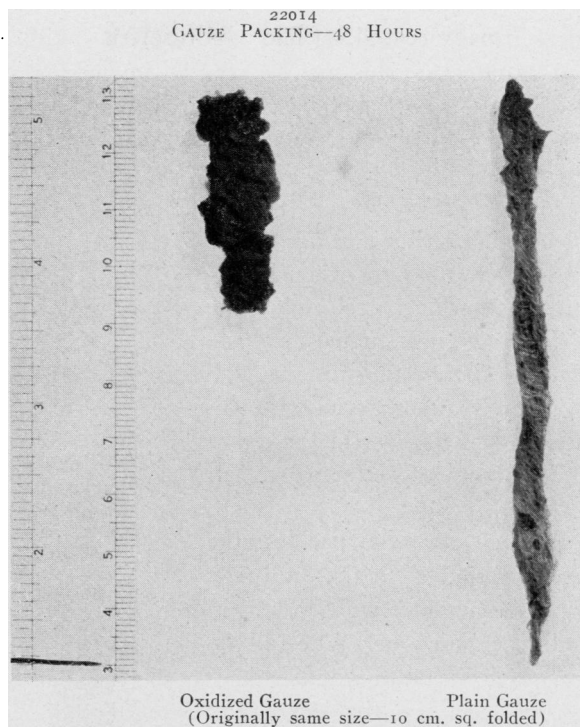


FIG. 3.—Gauze packing withdrawn from experimental wounds of kidney after 48 hours. The oxidized gauze was black and friable. The plain gauze was stained with bright red blood.

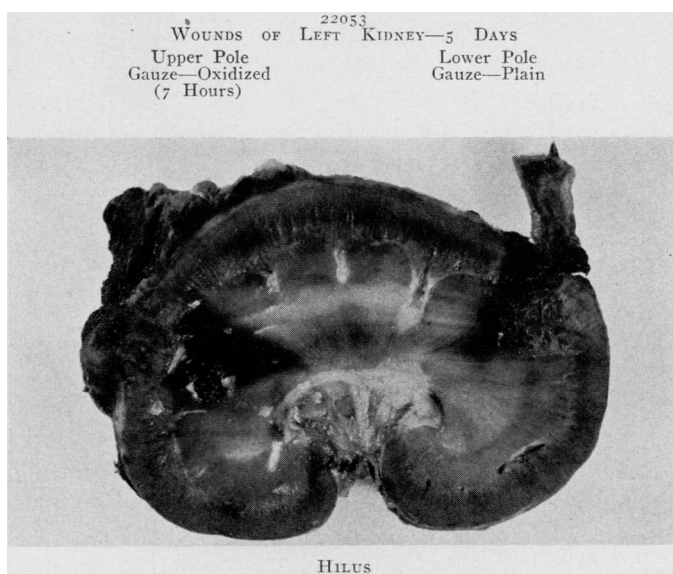


FIG. 4.—Autopsy specimen, five days after operation. See Table I, S. P. 22053. At four days an attempt had been made to remove both packings. The oxidized gauze (Eastman OR-1352-B, 7-hour oxidation sample, 13.5-13.8 per cent COOH) was too friable to be withdrawn completely. Through an error, only one of the two strips of plain gauze was withdrawn. No bleeding occurred. Twenty-four hours later the animal was sacrificed. The kidney has been sectioned through the two wounds, showing their size and the gauze packing. On the convex surface of the upper pole there is peritoneal fat.

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EXPERIMENTS WITH HEMOSTASIS WITH CLEAN WOUNDS OPEN
(Kidney, Spleen, and Liver)

The kidneys were delivered extraperitoneally, through an oblique muscle-splitting incision in the flank. Wounds were made, as nearly as possible similar in the upper and lower poles, by an incision about 1.5 cm. in the capsule, which was deepened by blunt dissection so that the medulla was reached but the pelvis was avoided, and spurting bleeding was obtained. The wound in the upper pole was then packed with oxidized gauze, various

TABLE I
HEMOSTASIS IN OPEN WOUNDS OF VISCERA
(Oxidized Gauze—Eastman OR-1352-B)

S.P. No. Animal	Organ	Time Postoper.	Result	
			Oxidized Gauze	Control Gauze
22020 Dog	Kidney	24 hours	Gelatinous. Easily expressed. No bleeding.	Stuck. Bleeding after removal. Ceased spontaneously.
22025 Dog	Kidney	48 hours	Gelatinous. Scooped out. Followed by thin brown fluid	Stuck. Bleeding after removal. Packed with oxidized gauze.
22059 Dog	Kidney	48 hours	Disintegrated. No free fluid. No bleeding.	Stuck. Bleeding after removal. Packed with oxidized gauze.
22058 Dog	Kidney	48 hours	Disintegrated. Came away with dressing; gush of thin, brown fluid.	Stuck. Bleeding after removal. Stopped spontaneously.
22021 Dog	Kidney	52 hours	Gelatinous. Loose in mouth of wound. No fluid.	Did not control bleeding at operation. Oxidized gauze used.
22052 Dog	Kidney	4 days	Gone from mouth of wound. Dressing dry.	Stuck. Bleeding after removal. Repacked with oxidized gauze.
22053 Dog	Kidney	4 days	Disintegrated. Pressure yielded gelatinous fluid.	Stuck. Only one strip removed. No bleeding. Second strip found at autopsy 5th day.
22025 Dog	Spleen	48 hours	Negligible remnant. (Infected wound). No bleeding.	Stuck. Bleeding after removal, requiring repacking.
22058 Dog	Spleen	48 hours	Gelatinous. (Infected wound). No bleeding.	Stuck. Bleeding after removal. Animal voided blood. Sacrificed.
22059 Dog	Spleen	48 hours	Negligible remnant. (Infected wound.) No bleeding.	Stuck. Moderate bleeding after removal. Animal sacrificed.
22078 Dog	Spleen	48 hours	Loose in wound. No bleeding after removal.	Stuck. Slight bleeding. Animal sacrificed.
22079 Cat	Spleen	48 hours	Gelatinous. No bleeding.	Stuck. Slight bleeding. Animal sacrificed.
22061 Dog	Liver	24 hours	Packing in place. Crumbles. No bleeding.	Stuck. Slight ooze. Animal sacrificed.

samples, and the wound in the lower pole by plain gauze (Fig. 4). In one instance, No. 22021, the kidney was badly traumatized at the lower pole and bleeding could not be controlled by packing with ordinary gauze. Oxidized gauze was, therefore, used and hemostasis secured.

In the case of the spleen exteriorization was three times accomplished through a left lumbar incision at a secondary procedure after nephrectomy of a previously injured kidney. These cases were all infected. Twice a left rectus approach was used. Only one exteriorization of the liver was performed in a survival animal, and this was accomplished through a transverse upper abdominal incision and the liver secured in the wound by tamponade. Repeated observations, however, in anesthetized animals, were made, just prior to death from overdose of anesthesia, of immediate control of

bleeding in all these viscera with various samples of material. The results are noted in Table I.

EXPERIMENTS IN HEMOSTASIS WITH CLEAN WOUNDS CLOSED
(*Kidney, Spleen, Liver, Thyroid and Bone*)

Further investigation of the late effects on the tissue of trauma and packing were then undertaken. The wounds were closed.

Kidney.—The technic used for the kidney differed from that employed for open wounds only in that the approach was transperitoneal, through a left rectus incision, and the packing was not allowed to protrude from the viscus, but was cut flush with the surface and a single marking black silk suture was tied loosely over it.

Spleen.—The spleen was also delivered through a left rectus incision. Wounds were then made by excising a rectangular piece of tissue approximately 2 x 1 x 0.3 cm. from the upper surface. Bleeding was always brisk. It was controlled by placing a 10 x 10 cm. square of oxidized gauze, folded, over the defect, and a similar folded sponge of the same material on the opposite surface, securing the two by through-and-through sutures of black silk. This "sandwich" type of packing controlled bleeding quickly. The material used was Eastman OR-1352-B, 7-hour oxidation, and Parke, Davis No. 098630, 5-6 hour oxidation, 13.5-15.8 per cent COOH. The results are noted in Tables II and III.

Liver.—Because of the difficulty of approach and the anaerobic infections, which occasionally occur in dogs following liver injuries, this organ was used only five times. Hemostasis was immediately satisfactory in all five cases, whether the gauze was packed into deep wounds in the parenchyma, or used as "sandwich" packing to staunch bleeding from a shallow surface defect. Four of the animals have come to autopsy, at 31, 35, 36, and 42 days, respectively. There was one abscess in which an *hemolytic Staphylococcus aureus* and *C. welchii* were found on culture. This was well walled-off, and there was no infection of the spleen wound in the same animal. In all four the gauze was entirely absorbed.

Thyroid.—Four cases have been studied. The right lobe of the thyroid was split along the convex border, the wound was enlarged by blunt dissection, and oxidized cotton, Parke, Davis No. 098631, packed into the cavity from which bleeding was always brisk. At two weeks the material had not been absorbed (Fig. 10). At four, five, and six weeks the material was entirely absorbed, and the injury was represented by a zone of characteristic phagocytes.

Bone.—Experiments on bone are not complete, due to the length of time required for histologic preparation. Defects have been made repeatedly in the radius, and bleeding was quickly and easily controlled by packing, which was made tight. In such rigid-walled cavities the material could be made to fill the crevices almost like gutta percha. Callus has been shown in some cases roentgenologically, but complete data are not yet at hand.

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TABLE II

KIDNEY PACKINGS—TWO EACH CASE—UPPER AND LOWER POLES

S. P. No. Animal	Time Days	Result
22125 Cat	21	Largely absorbed. Micros: Remnants. Many phagocytes.
22155 Dog	23	Partly absorbed. Micros: Many phagocytes.
22118 Rabbit	28	Grossly absorbed. Micros: Remnants. Many phagocytes.
22181 Dog	28	Partly absorbed. Micros: Some polymorphonuclears. Many phagocytes.
22248 Dog	29	Largely absorbed. Micros: Remnants. Many phagocytes.
22257 Dog	29	Almost all absorbed. Micros: Remnants. Many phagocytes.
22220 Dog	30	Largely absorbed. Micros: Remnants. Many phagocytes.
22146 Dog	31	Partly absorbed. Micros: Considerable amount. Many phagocytes.
22191 Dog	33	Almost entirely absorbed. Micros: Phagocytes.
22154 Dog	35	Almost entirely absorbed. Micros: Occasional fiber. Phagocytes.
22256 Dog	35	Lower pole—absorbed entirely. Micros: Phagocytes. Upper pole—absorbed very little. Micros: Phagocytes. Giant cells.
22157 Dog	36	Absorbed. Micros: Rare fiber in one pole. Phagocytes.
22214 Dog	37	Absorbed. Micros: Rare fiber in one pole. Phagocytes.

TABLE III

OXIDIZED GAUZE "SANDWICH" PACKING OF WOUND OF SPLEEN

S. P. No. Animal	Time Days	Result
22125 Cat	21	Omental adhesions. Gauze gelatinous. Micros: Phagocytes. Giant cells. Cicatrix.
22311 Dog	22	Omental adhesions. Some gross gauze present. Micros: Phagocytes. Giant cells. Polys. N.B. This animal had a large amount of gauze also packed in the pelvis.
22312 Dog	22	Omental adhesions. Some gross gauze present. Micros: Phagocytes. Giant cells. Polys. N.B. This animal had a large amount of gauze also packed in the pelvis.
22155 Dog	23	Omental adhesions. A little gauze in wound. Micros: Some gauze both sides. Phagocytes. Few giant cells.
22181 Dog	28	Omental adhesions. No gross gauze. Micros: Gauze remnants. Phagocytes. Giant cells.
22248 Dog	29	Omental adhesions. No gross gauze. Micros: Few fibers both sides. Phagocytes. Many giant cells.
22257 Dog	29	Omental adhesions. No gross gauze. Micros: No gauze. Few phagocytes. Slight cicatrix.
22220 Dog	30	Omental adhesions. No gross gauze. Micros: Occasional gauze fiber. Phagocytes.
22146 Dog	31	Omental adhesions. Bulk of gauze gone. Scarring. Micros: Phagocytes and polymorphonuclear leukocytes. (Liver abscess in this case.)
22191 Dog	33	Omental adhesions. No gross gauze. Micros: Remnants. Phagocytes. Moderate cicatrix.
22154 Dog	35	Omental adhesions. No gross gauze. Micros: Few fragments. Phagocytes. Marked cicatrix.
22256 Dog	35	Omental adhesions upper and under surface. No gross gauze. Micros: Remnants. Phagocytes. Giant cells.
22157 Dog	36	Omental adhesions very delicate. No gross gauze. Micros: Gauze fragments only upper surface. Phagocytes.
22214 Dog	37	Omental adhesions. No gross gauze. Micros: No gauze. Few phagocytes. Slight cicatrix.
22356 Dog	40	Omental adhesions. No gross gauze. Micros: Tiny remnant. Phagocytes.

EXPERIMENTS WITH GAUZE SPONGES WRAPPED IN OMENTUM

A sponge was made of a 10 x 10 cm. square of oxidized gauze, and this was placed on the surface of the omentum. In most instances the sponge was dry. In a few cases it was first wet with the animal's blood. The omentum was then folded over it and tacked in place with two marking silk sutures. The results are noted in Table IV.

It will be seen from study of these tables that the time of absorption is variable. There are several possible factors in this connection which may all operate together, but which may be discussed separately.

1. Amount of Material: Since disappearance of the material depends, at least in part, on solution, large amounts of gauze packed into small spaces might not readily be penetrated by tissue fluids, and absorption would be delayed. Penetration by phagocytes would also be slower the greater the bulk of the foreign body.

2. Degree of Injury: This is difficult to evaluate, but obviously the integrity of the circulation to the part would influence rapidity of absorption.

3. Amount of Blood Present: This would at least add to the bulk of material to be absorbed.

4. Nature of the Tissue: This is illustrated by the fact that in the kidney considerable delay was repeatedly found, whereas, in the omentum, for instance, absorption was, in general, more rapid. This may possibly be related to the lower p_H of the tissue fluids in the kidneys of laboratory animals (dogs and cats). On one determination upon homogenized kidney tissue of a dog the p_H was 6.63.

5. Lack of Uniform Degree of Oxidation: Occasional fibers of gauze remaining when the bulk is absorbed may, perhaps, contain a lower percentage of carboxyl groups.

These variables are all reflected in the gross and microscopic findings in the tissues which have been in contact with the material. In our earlier report in the ANNALS we submitted photomicrographs of the reaction of various tissues at varying intervals after operation. The amounts used were small, and a deliberate attempt was made to avoid all unnecessary injury and bleeding. In the present series, except in the omental implants, the tissues have been deliberately traumatized, and the gauze used for hemostasis. As was expected from our earlier experience there has been no acute inflammatory reaction to the material itself. There have been, however, phagocytic reactions, of varying degree. Where no great amount of hemosiderin is present, the phagocytes show large basophilic droplets in the cytoplasm. Almost no granulation tissue is present around the foreign body, and there are only rare infiltrating cells other than phagocytes. A characteristic zone is found, of typical large phagocytes showing intense basophilism, almost diagnostic for the material. Less detailed studies have been made with other materials, and while phagocytes are found in some instances, none has had this particular appearance. These variations and the histologic findings are illustrated in photomicrographs (Figs. 5-10).

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TABLE IV
OXIDIZED GAUZE SPONGE IN OMENTUM
(Square 10 x 10 cm. Folded)
(Eastman OR-1352-B and Parke, Davis 098630)

S.P.No.	Time	Surrounding Omentum	Character of Material	Microscopic Findings
21591 Cat	6 hours	Not inflamed. Not adherent.	Easily cut with knife.	Rare polys. No fibrin.
21630 Cat	22 hours	Not inflamed. Not adherent.	Slightly gelatinous.	No polys. Slight edema. No fibrin.
21576 Cat	24 hours	Slightly injected. Not adherent.	Slightly gelatinous. Culture sterile.	Scattered polys. No fibrin.
21579 Cat	30 hours	Not inflamed. Not adherent.	Light tan, soft, fibrillar. Cul- ture sterile.	No reaction.
21568 Cat	3 days	Thickened, cystic cavity.	Mostly clear fluid. Little brown jelly. Culture sterile.	Polys. Fibroblasts.
21572 Cat	3 days	Thickened; cystic cavity.	Cloudy fluid. Culture sterile.	Fibrin. Polys. Fibroblasts.
21858 Dog Dog	3 days	Fibrinopurulent peritonitis. (Previous appendicec- tomy).	Light tan, gelatinous, fibril- lar.	Pus.
21590 Cat	4 days	Thickened; cystic cavity.	Clear fluid. Culture sterile.	Fibrin. Polys. Fibroblasts.
21600 Cat	5 days	Thickened; cystic cavity.	Cloudy fluid. Culture sterile.	Fibrin. Polys. Fibroblasts.
21886 Dog	7 days	Thin-walled, cystic cavity.	Clear fluid slightly blood- tinged. Few fibers.	Lining of phagocytes. No polys. Fibroblasts.
21887 Dog	10 days	Thick-walled cyst. Little inflammation.	Thick, white fluid. Culture coagulase-pos. Staphylo- coccus.	Polys. Phagocytes. No fibroblasts.
21899 Dog	14 days	Thickened; cystic cavity.	Brown, cloudy fluid. Culture <i>Esch. coli</i> .	Few polys. Phagocytes. Lit- tle fibroplasia.
21905 Dog	18 days	Thick-walled, cystic cavity.	Thick, white fluid. Not cul- tured.	Rare polys. Lining of phago- cytes.
22125 Cat	21 days	Transparent cyst, 2 cm.	Clear fluid.	Few fibers, phagocytes. No polys.
22155 Dog	23 days	Dark red, soft mass, 1.2 cm.	Soft solid on section.	Fragments of gauze. Phago- cytes.
22056 Cat	28 days	Thickening 4 mm.	Entirely absorbed.	Characteristic phagocytes.
22057 Dog	28 days	Thickening 3 mm.	Entirely absorbed.	Characteristic phagocytes.
22181 Dog	28 days	Transparent cyst, 2.5 cm.	Thin, brown fluid and jelly.	Lining composed of phago- cytes.
22248 Dog	29 days	Red-brown zone of thicken- ing 1 cm.	Center friable.	Considerable gauze. Phago- cytes.
N.B. 22257 Dog	This sponge 29 days	had been soaked in blood. Slight thickening, 0.8 cm.	Entirely absorbed.	No gauze. Characteristic phagocytes.
N.B. 22220 Dog	This sponge 30 days	had been soaked in blood. Tiny zone of thickening marked by suture.	Entirely absorbed.	No gauze. Few phagocytes.
22146 Dog	31 days	Slight omental thickening marked by suture.	Entirely absorbed.	No gauze. Characteristic phagocytes.
22191 Dog	33 days	Thickening, 0.5mm. marked by suture.	Entirely absorbed.	No gauze. Characteristic phagocytes.
22065 Dog	35 days	Marking sutures found.	Entirely absorbed.	Phagocytes. No polys.
22066 Cat	35 days	Marking sutures found.	Entirely absorbed.	Phagocytes. No polys.
22154 Dog	35 days	Light brown zone of thick- ening, 1 cm.	Entirely absorbed.	No gauze. Thick zone of phagocytes.
22256 Dog	35 days	Smooth-walled cavity	Brown mass, 5 x 5 x 7 mm.	Fragments of gauze in fluid with some blood.
22157 Dog	36 days	Brown thickened zone 3 x 1 cm.	Entirely absorbed.	No gauze. Phagocytes.
22214 Dog	37 days	Transparent cyst, 2.5 cm.	Clear fluid.	Few fibers, fluid. Character- istic phagocytes.
22356 Dog	40 days	Brown thickening.	Entirely absorbed.	Phagocytes. Scar.

CLINICAL INVESTIGATION

Clinical trial of the material was delayed until the formaldehyde sterilized material which was available had been checked for sterility and tested for irritating qualities in the tissues. It has been used for hemostasis in 17 cases. In four of these packing of some sort was imperative and, in two of the

TABLE V
HEMOSTASIS IN CLINICAL CASES WITH SOLUBLE GAUZE AND COTTON

Case	Hist. No.	Date	Surgeon	Source of Bleeding	Closure	Result
1	633513	4/13/44	Stookey	Internal carotid.	Closed.	Sinus lower angle 6th day. Closed 30 days. No infection.
2	741353	4/18/44	Whipple	Gallbladder bed.	Drained.	Tube out 9th day. Healed 14th day.
3	741879	4/22/44	Humphreys	Liver surface, through diaphragm.	Intercostal drainage 48 hours.	Healed 7th day.
4	627664	5/1/44	St. John	Incisional biopsy liver.	Closed.	Healed <i>per primam</i> .
5	639170	5/4/44	Humphreys	Intercostal vein. Sympathectomy.	Closed.	Hematoma, followed by pleurisy with effusion.
6	706699	5/6/44	Scudder	Metatarsal. Amputation toe.	Open. Infected.	Hemostasis satisfactory. Removed 3rd day. No bleeding.
7	742421	5/11/44	Humphreys	Cervical lymph node. Biopsy: Ca.	Closed.	Hemostasis satisfactory. Healed <i>per primam</i> .
8	744514	5/12/44	Humphreys	Sternum. Biopsy: Leukemia.	Closed.	Hemostasis satisfactory. Healed <i>per primam</i> .
9	738341	5/13/44	Harvey	1. Plantar abscess. Drainage.	Open. Infected.	Hemostasis satisfactory. Removed 24 hours. No bleeding.
		6/4/44	Harvey	2. Plantar abscess. Revision of drainage.	Open. Infected.	Hemostasis satisfactory. Removed 3 days. No bleeding.
10	733473	5/13/44	Auchincloss	Gallbladder bed.	Drained.	Hemostasis satisfactory. Slight bleeding 9th day. Cause? Biliary fistula 2nd to 17th day.
11	743824	5/22/44	Whipple	Spleen collaterals. Splenectomy.	Closed.	Healed <i>per primam</i> .
12	Beth David 44/1849	5/24/44	Bancroft	Scar tissue leg. Releasing incision 20 cm. long down to muscle.	Open. (Leg ulcers)	Hemostasis satisfactory. Removed 3rd day. No bleeding. Wound ready to graft 16th day.
13	737472	5/25/44	Hanford	Liver. Punch biopsy.	Closed.	Hemostasis satisfactory. Healed <i>per primam</i> .
14	747716	5/26/44	Whipple	Gallbladder bed.	Closed.	Hemostasis satisfactory. Healed <i>per primam</i> .
15	747707	5/27/44	Blakemore	Periaortic. Occlusion aortic aneurysm, abdominal.	Closed.	Hemostasis satisfactory. Healed <i>per primam</i> . Some ecchymosis.
16	747805	6/3/44	Blakemore	Periaortic. Wiring aortic aneurysm, abdominal.	Closed.	Died, cardiac failure 24 hours. No autopsy.
17	738386	6/3/44	Mount	Sagittal sinus. Opening sagittal suture.	Closed.	Hemostasis satisfactory. Wound healed 4th day.

four, wounds were closed which otherwise would have had to be left open and from which the packing would subsequently have had to be withdrawn. In three biopsy wounds—two liver and one sternal marrow—it took the place of muscle, which would otherwise have been used, and was considered fully as satisfactory, if not more so. In three oozing gallbladder beds it was a convenience but probably not a necessity. The other cases constitute scattered clinical trials. The complete list is to be found in Table V.



FIG. 5.—S. P. No. 22146: Photomicrograph 31 days after operation, showing broad zone of typical phagocytes immediately adjacent to kidney parenchyma, with almost no granulation tissue. (Low power.)

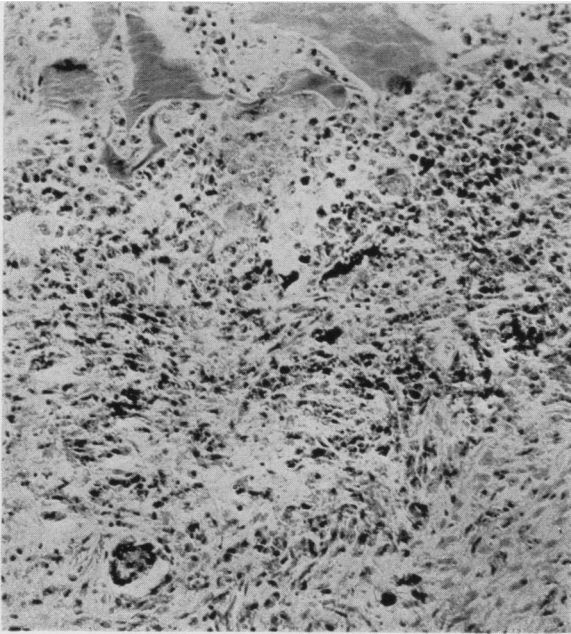


FIG. 6.—S. P. No. 22220: Photomicrograph showing remnants of oxidized gauze, above, persisting in kidney wound 30 days after packing. In this case few phagocytes are seen, and multinucleated foreign body giant cells are present, with considerable cicatricial tissue.

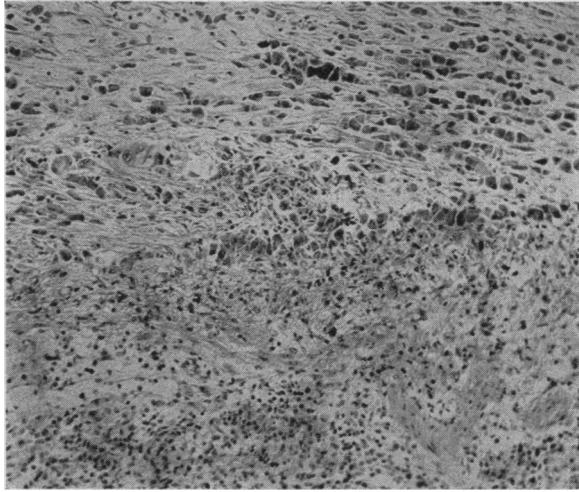


FIG. 7.—S. P. No. 22220: Photomicrograph showing site of "sandwich" packing on surface defect of spleen 30 days after operation. The spleen shows almost no scarring. There are typical phagocytes in scar tissue, above, binding the omentum to the spleen. The gauze has been entirely absorbed.

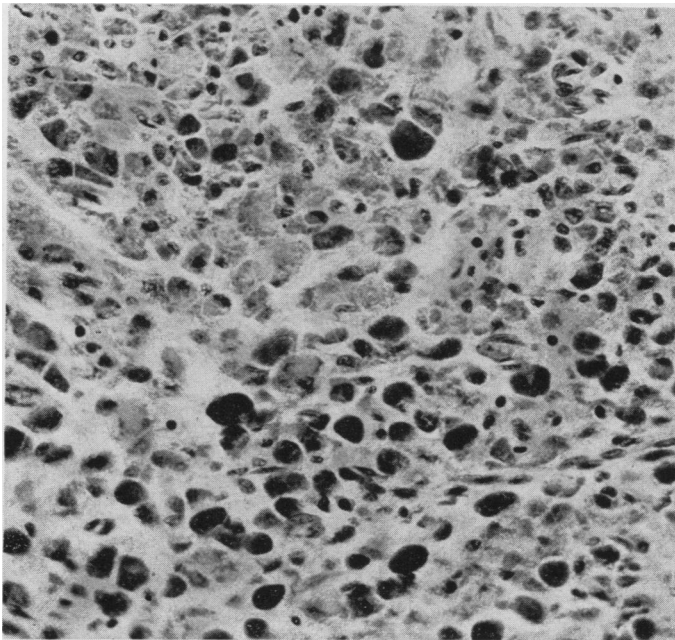


FIG. 8.—S. P. No. 22220: Photomicrograph showing typical phagocytes in the very small zone of thickening in the omentum 30 days after oxidized gauze sponge implant. No cyst was formed. The gauze was completely absorbed.

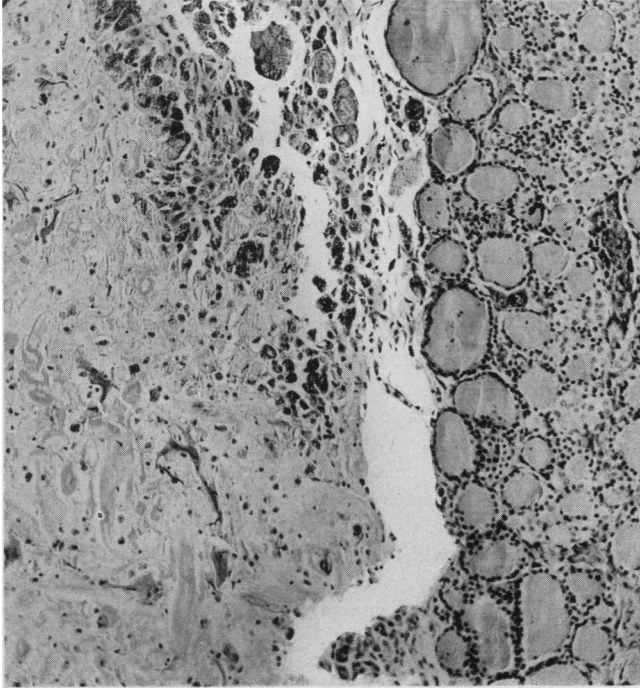


FIG. 10.—S. P. No. 22312: Photomicrograph showing oxidized gauze in thyroid, 14 days after operation. In some parts—left, the gauze lies except for artefact, against thyroid parenchyma with almost no reaction. On the right there is a zone of phagocytes between the packing and the thyroid.

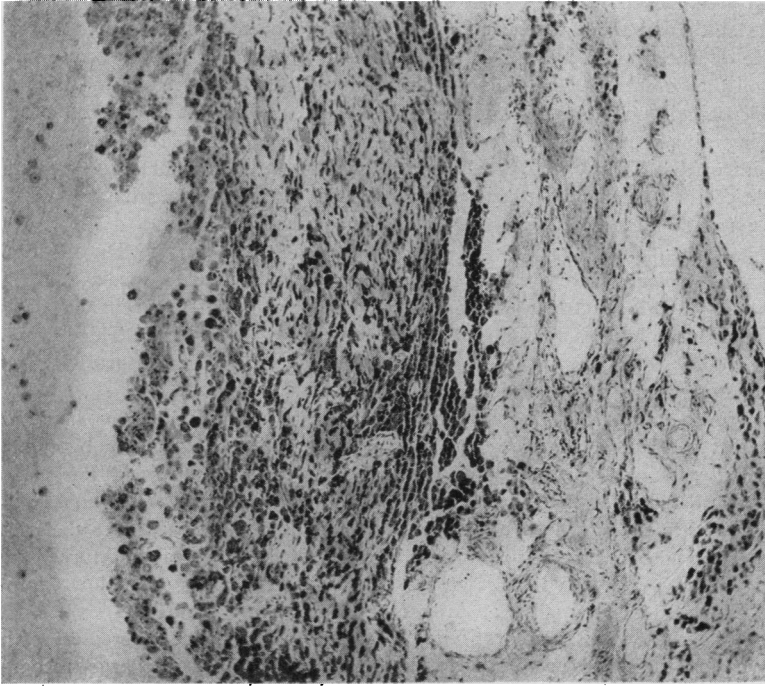


FIG. 9.—S. P. No. 22214: Photomicrograph showing wall of omental cyst 2.5 cm. in diameter 37 days after oxidized gauze sponge implant. The surface of the omentum is shown as the lower border. There is some fibrosis, but the wall is thin. The lining appears above as several layers of phagocytes without granulation tissue. The fluid content shows few cells.

It will be seen in the table of clinical cases that there is one case in which hemostasis was obviously not secured and which was complicated by an hematoma and pleurisy with effusion. This case, together with the four cases in which packing of some sort was imperative, two closed and two open, are analysed in detail.

ANALYSIS OF CLINICAL CASES

Case 1.—History No. 633513: M. D., female, white, age 38. Dr. Byron Stookey. Four previous attempts by other surgeons to relieve pain by division of the sensory root of the right trigeminus. Persistence of symptoms.

Operation.—April 10, 1944: Fifth craniotomy. Scar tissue was encountered which, when slightly manipulated after root section had been completed, gave way, and sudden bleeding occurred, thought to come from the internal carotid. This was controlled by vaselined gauze packing. The wound was drained at the lower angle.

Course.—There was no febrile reaction following this procedure.

Operation.—April 13, 1944: Wound opened. Packing removed. There was fresh bleeding of the same type as at the original procedure three days earlier. This was controlled by packing with formaldehyde sterilized oxidized gauze, Parke, Davis 6-hour oxidation No. 098630. Three strips were used, 8 x 6 cm. each, folded in four. The first strip was impregnated with 1 cc. of sodium penicillin 5,000 units. Bleeding was completely controlled by the first two pieces of packing. The third piece was used as reinforcement, but perhaps added unnecessarily to the bulk—something probably to be avoided. The wound was closed.

Course: Patient ran no fever. There was swelling at the lower extremity of the wound, the site of the original drainage, first observed at the first dressing on the fourth postoperative day, when all sutures but one were removed. There was no redness in the swollen area, which was in the anesthetic zone following root section.

On the sixth day there was spontaneous discharge of thin, brown fluid from the lower angle of the wound, with particles of black, oxidized gauze. Culture of the discharge on the seventh day yielded organisms of the *B. subtilis* group and coagulase-negative micrococci—no pathogens. The sinus continued to drain small amounts of sticky fluid showing almost no cells on smear. On May 1, 1944, 17 days after secondary packing with oxidized gauze, the patient had a small, unhealed, granulating area in the lower angle of the wound with practically no residual swelling or discharge. On May 15, 1944, a month after operation, the wound was entirely healed.

Case 3.—History No. 741879: N. Y., male, Japanese, age 55. Dr. George H. Humphreys. Atypical history. Roentgenograms showed possible mediastinal mass.

Operation.—April 22, 1944: Right lower lobe lobectomy for carcinoma of lung. There were many adhesions to the chest wall and to the diaphragm. The lower lobe was largely occupied by a tumor which, on quick frozen-section, appeared to be a carcinoma. Lobectomy was, therefore, carried out.

In this procedure part of the diaphragm was resected, and the liver immediately beneath was torn. There was bleeding which could not be controlled by ligature, and which required packing. Five pieces of oxidized gauze, 8 x 6 cm. each, Parke, Davis No. 098630 sterilized by formaldehyde, were folded to form a compress about 4 x 2 cm. This was applied to the surface of the liver, and the diaphragm closed over the packing with three interrupted black silk sutures. The oxidized gauze rapidly turned black, and hemostasis was considered satisfactory. Sulfadiazine powder was blown into the cavity and the wound closed, with an intercostal catheter for drainage.

Course.—The patient had a gratifyingly smooth course. The intercostal catheter was removed on the third postoperative day, with no unusual discharge recognized. All stitches were removed on the sixth postoperative day, and the wound appeared healed.

The patient was afebrile from the sixth postoperative day. On May 1, 1944, the ninth postoperative day, roentgenograms showed some fluid at the right base, less, if anything, than one would expect under the circumstances.

Case 5.—History No. 639170: A. P., male, white, age 36. Dr. George H. Humphreys. A case of essential hypertension admitted for a left dorsolumbar sympathectomy, to be done in two stages.

Operation.—May 4, 1944: Through a paravertebral hockey-stick incision, cutting the diaphragm and dissecting the pleura forward off the mediastinum, the sympathetic chain was exposed along the lower dorsal vertebrae. Bleeding was encountered from the intercostal vein in the ninth interspace, which could not be controlled by clamping because of poor exposure. Bleeding was controlled by one 4 x 8 cm. oxidized gauze sponge, Parke, Davis No. 098630, folded into a square approximately 1.5 cm. square, which was pressed into the intercostal space and held in place digitally until the gauze had become black and bleeding had been controlled. For a period of about 15 minutes thereafter no obvious bleeding occurred from the site. The gauze remained stuck without suture. Wound closed without drainage.

Course.—At the first dressing, seven days after operation, the wound appeared well healed. All sutures were removed on the eighth day. The patient was never entirely afebrile, but was apparently doing well until the fourteenth day, when he began to run a spiking temperature, to complain of pain in the posterior part of the wound, and to cough. Roentgenograms of the chest on this day showed pleural effusion, and swelling was also noted in the posterior portion of the wound. Aspiration, extrapleural in the eighth interspace, yielded 40 cc. of thick bloody fluid. On the nineteenth day a second aspiration in the tenth interspace, extrapleural, yielded 300 cc. of ropy, slightly purulent old blood, with a faint fishy odor.

Thoracenteses on the twenty-seventh, thirty-second, and thirty-fourth postoperative days yielded 1,350, 1,350, and 250 cc., respectively, of clear, slightly blood-tinged pleural fluid. The patient was given sulfadiazine. On the thirty-fourth day the extrapleural collection was tapped again, and 150 cc. of thick, grumous, brownish-red fluid was obtained. All cultures were negative, but on the thirty-fourth day the extrapleural pus showed an *hemolytic Staphylococcus aureus* on culture.

COMMENT.—This case is given in detail because it is a failure in hemostasis. Doctor Humphreys is now of the opinion that with bleeding of this magnitude the gauze should have been held in place by suture, and that the hematoma cannot be attributed to a failure of the material but to an error in the way in which it was used. The interpretation of this complication is not altogether clear, the febrile reaction having been somewhat greater than one would expect with a simple hematoma, even though large and a sterile pleural effusion. Very possibly the sulfadiazine therapy was responsible for the failure of growth of organisms, and the infection, in view of the repeated aspirations and the initial absence of organisms or pus, should probably not lead to suspicion that the gauze was contaminated.

Case 9.—History No. 738341: N. C., female, white, age 64. Dr. H. D. Harvey. A case of infection of the foot of three months duration in a woman with arteriosclerosis and mild diabetes. In an effort to save at least part of the foot repeated attempts were made to secure adequate drainage. This included removal of the first three toes, and wide opening down to the plantar fascia. The infection was not completely controlled and although there was considerable healing, a sinus led to sloughing plantar fascia and flexor tendons.

Operation.—May 13, 1944: Revision of drainage. The sinus tract was laid open

down to the deep slough. The granulation tissue was edematous and there was profuse bleeding from many small vessels. Oxidized gauze, Parke, Davis No. 098630, was packed into the wound. Bleeding continued, but stopped when pressure was applied. A pressure dressing, therefore, was used.

Course.—May 14, 1944: First day postoperative. The gauze was gelatinous and came away readily. There was no further bleeding. The slough continued to separate, but in the course of three weeks the sinus had again closed prematurely and drainage was inadequate.

Operation.—June 5, 1944: Revision of drainage. The sinus was opened. There was dense scar tissue around it from which bleeding was brisk. One vessel of considerable size was encountered and transfixation and ligation were not feasible. Packing was, therefore, imperative. Oxidized gauze, Parke, Davis No. 098630, was used, and the wound was filled to the surface with gauze which was allowed to overlap the skin edges slightly to prevent sticking of the dressing.

Course.—June 6, 1944: First day postoper. The gauze was black and the surface dry. There was no marked redness around the wound. The patient said she had had pain during the night. The outer dressing was practically dry. The packing was not disturbed.

June 7, 1944: Second day postoperative. Dressing. The gauze was still dry on the surface and could be removed almost in one piece. A few fragments remained in the wound. These could be picked up with forceps, and although somewhat gelatinous, still had fibrillar structure. No bleeding followed removal of the gauze. The wound edges had been kept apart satisfactorily for the 48 hours. There was no retained exudate in the wound, although there was slough, as expected, in the depths.

Case 13.—Beth David Hosp. No. 44/1849: A. C., male, white, age 55. Dr. Frederic W. Bancroft.

History.—In November, 1942, the patient had a bilateral herniorrhaphy. After discharge from the hospital he developed pain in the right knee and the whole leg became swollen, presumably a phlebitis. After the pain subsided, the leg remained swollen and ulceration began June, 1943.

Past History.—Neisserian infection, 1939. Otherwise irrelevant.

Physical Examination.—Right leg markedly swollen below the knee with a wide zone of brown discoloration and superficial ulceration, two ulcers as large as 5 cm. each. Urine analysis showed no sugar. Blood sugar 100 mg. per cent, W. B. C. 11,800, polys. 64 per cent.

The patient was treated by rest, elevation, and dressings for ten days preoperatively.

Operation.—May 24, 1944: Ligation of saphenous bulb. Release of scar tissue. An incision about 20 cm. was made on the medial aspect of the calf and deepened through dense scar tissue through the deep fascia and the sheath of the muscles. The scar tissue was exceedingly thick, and there was no marked gaping until the deep fascia was cut. The wound then gaped widely, and obvious bleeders were controlled by catgut ligation. There was ooze from all the surfaces of the scar tissue and, accordingly, four pieces of oxidized gauze, Parke Davis D-2340-C, were laid on the wound surface. As a test of the material two cotton pledgets, Parke, Davis D-2339-C, were placed in the lower angle of the wound. It was Doctor Bancroft's impression that the material was hemostatic.

Vaselined gauze packing was then placed in the wound and a light pressure dressing applied. Neither the packing nor the pressure was so much as Doctor Bancroft has used in the previous dozen or so cases of this operation of his own devising.

Course.—May 25, 1944: First day postoper. Doctor Bancroft reported by telephone that the patient's bandages were dry in contrast to the usual postoperative oozing of previous cases.

May 27, 1944: Third day postoperative. First dressing. There was, according to Doctor Bancroft, less blood on the dressing than usual. The gauze was soft, somewhat slimy on the under surface, and could be scooped out of the wound. Nowhere was it stuck, and no bleeding occurred except where the vaselined gauze was stuck on the wound edges. It would have been better to cover the wound edges with the oxidized gauze. Doctor Bancroft felt that the hemostasis had been unusual, and the dressing satisfactory. The wound looked somewhat brown. Vaselined gauze dressing.

May 30, 1944: Sixth day postoperative. Wound still brownish. Little exudate.

May 31, 1944: Seventh day postoperative. Wound still brownish. Little exudate. Acriflavine wet dressing. Dressed thereafter q.2.d. with acriflavine. Wound ready for grafting June 9, 1944, 16 days postoperative.

COMMENT.—In previous cases of leg ulcer and deep scarring, which Doctor Bancroft has treated by one or more releasing incisions, he has found the wound suitable for grafting some time between the tenth and twenty-first postoperative day. This case, ready for grafting on the sixteenth postoperative day, is in line with the others. In his opinion, use of the oxidized gauze facilitated hemostasis and did not hinder repair.

SUMMARY

This report is submitted at this time in the hope that further clinical trial of the material will be made in other hospitals, so that, if it proves useful, its availability to the armed forces may be expedited. It appears to have sufficient hemostatic properties when used dry so that combination with thrombin is probably unnecessary, possibly undesirable. It is hoped that the investigators who are familiar with the control of hemorrhage with thrombin and cellulose as a carrier (Putnam, Ingraham and Bailey, Cronkite, Deaver, and Lozner), will try the cellulose without the thrombin, as the reverse has already been tried. Possibilities of impregnation of the material with antibacterial substances naturally suggest themselves. This field needs further study, but our own preliminary work with penicillin suggests an incompatibility. Work is still in progress on the development of nonirritating membranes, and absorbable suture, or at least ligature, material. It is too early to evaluate these results.

At the risk of being pedantic, we close with a warning. This material, even though soluble and *relatively* nonirritating *is a foreign body* in the tissues and remains as such often for several days. It should be used, at least in wounds which are closed without drainage, in as small quantity as possible. It is not a substitute for meticulous surgery, and surgical principles must not be violated in its use.

We are indebted to Miss Daisy Mapes, R.N., for her assistance in all of the animal experimental work, her close scrutiny of the material, and the results of its application.

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