

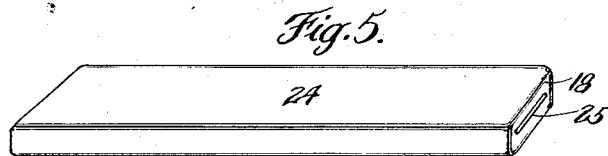
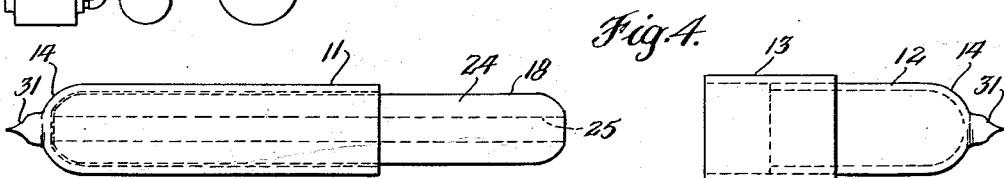
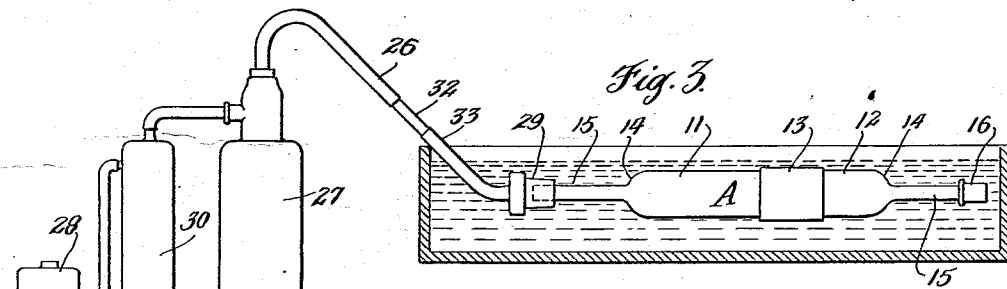
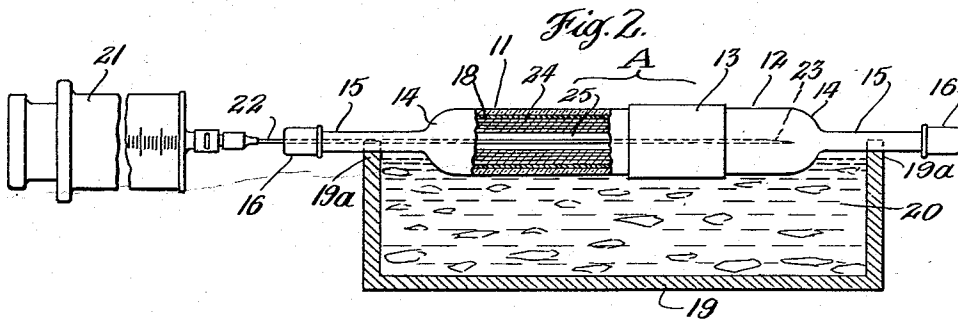
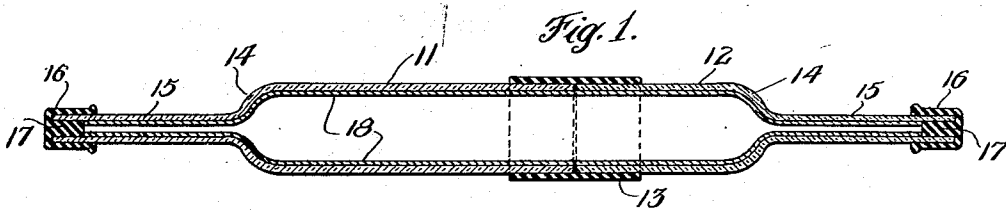
July 6, 1954

J. O. BOWER

2,682,872

ABSORBABLE WOUND PAD

Filed June 29, 1950



INVENTOR

JOHN O. BOWER

BY *Symonds & Sechman*  
ATTORNEYS

## UNITED STATES PATENT OFFICE

2,682,872

## ABSORBABLE WOUND PAD

John O. Bower, Wyncote, Pa.

Application June 29, 1950, Serial No. 171,166

21 Claims. (Cl. 128-156)

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This invention relates to surgical instrumentalities having hemostatic and healing properties. For lack of a better term, the products of the present invention will be referred to as "wound pads." The invention involves not only a new product, but also a new process for producing that product.

It is the primary object of this invention to provide a sterile pad, the function of which is chiefly two-fold: to check bleeding, that is, to inhibit further escape of blood from capillaries, veins and arteries; and to promote healing in the tissues involved. In addition to its hemostatic and healing properties, the wound pad of this invention embodies two other important features not present in products now available for such purposes; namely, it provides materials for the replacement of lost hemoglobin, and inhibits the spread of microorganisms in infected tissues. These are virtues inherent in the product itself, and the latter of them can be further enhanced by incorporating such antibiotics as penicillin and streptomycin. These antibiotics are fully compatible with the material of the wound pad, and may be combined with it to form a product which is uniquely effective in combatting infection.

The wound pad of this invention is used when the blood escapes from a vessel in which it normally circulates. This may occur because of erosion of tissue, as with bleeding ulcers. It usually occurs, however, because of trauma, either accidentally suffered, or as incidental to surgical procedure wherein blood vessels are divided. Where circumstances permit, severed veins and arteries are usually clamped by means of a hemostat (metal pinchers) and are tied off with absorbable or nonabsorbable sutures. Oozing from capillaries may be controlled by suture stitches. However, when numerous capillaries are divided, or when the ends of a bleeding vessel retract, resort is had to other expedients to stop blood leakage. Surgeons commonly use pieces or pads of gauze, relying on pressure of the gauze against the thin walls of the involved blood vessels to control loss of blood. This packing has to be removed eventually.

Hemostatic materials also have been used. Among the most common has been iron in solution (Monsel's solution) and, more recently, "Oxycell" (soluble cellulose) and "Gelfoam" (an expanded gelatine product). Since all such materials are composed of substances foreign to the tissues of man, injured tissues react against them when they are placed in the body. Indeed some materials rather commonly used for such

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purposes contain substances which are actively deleterious to living cells, and all such materials heretofore in use retard normal tissue repair to at least some extent simply because they are foreign bodies. Living cells cannot utilize them to repair cell damage or promote cell growth, and the body must eventually get rid of them.

The wound pad of the present invention is made primarily from blood, preferably human blood, which has been preliminarily treated to reduce it to the state of a solution. Blood has been referred to as "the liquid tissue." Wound pads made from it by the process hereinafter disclosed are not rejected, as foreign bodies, by living tissue, but are accepted and utilized in the healing process.

I deem the stroma, or cell wall structure of the blood corpuscles, to be a valuable constituent of the composition. However, the individuality of blood types seems to be associated in some way not fully understood with the structure of the blood corpuscle. Whole corpuscles, or even powder made by pulverizing desiccated blood corpuscles, may induce adverse reactions, such as burning, stinging pain, when applied to wounds in vivo. I attribute such effects to a lack of compatibility of blood types, as between the patient and the medicament. I have discovered that such reactions may be avoided if the corpuscular structure, or stroma, is reduced to sub-microscopic dimensions, so that it enters into solution in the liquid portion of the blood.

A preferred method for accomplishing this is described and claimed in my copending application Serial No. 519,686, filed January 25, 1944, now Patent No. 2,527,210, granted October 24, 1950. According to that application, human blood is withdrawn from donor by the "closed" method, and is centrifuged under sterile conditions to separate the plasma. The red cell residue which remains (and which will also include more or less plasma, depending on the degree of centrifugal separation) is then subjected to a freezing treatment so drastic as to completely disintegrate the stroma or structural matter of the blood corpuscle, so that, upon thawing, the solid matter enters into solution in the liquid. This solution is probably colloidal or sub-colloidal in nature. Suffice it to say that if the stroma is still in particle form, the particles are nonetheless beyond the resolving power of ordinary laboratory microscopes, although it may be that ultra-microscopes could differentiate them.

The freezing must be initiated at a temperature so low as to result in the practically instan-

taneous freezing of at least the superficial portion of the mass, and must be continued for a substantial interval to produce the desired result. Using a 30 cc. test tube as the receptacle, and a constant melting point mixture of carbon dioxide and refined kerosene or other hydrocarbon as a standard of reference, I have found that the desired result will be produced in from 2 to 3 minutes. The temperature of such a refrigerant will be in the neighborhood of  $-70^{\circ}\text{C}$ . Using the same size test tube and liquid air, at approximately  $-180^{\circ}\text{C}$ ., the desired result will be produced in from approximately 30 seconds to 1 minute. If larger batches are treated, the time of freezing must be extended.

I prefer to use receptacles containing about 300 cc., and to employ Methyl Cellosolve (monomethyl ether of ethylene glycol) and Dry Ice as the refrigerant, freezing being maintained for 18-24 hours, at well below  $-70^{\circ}\text{C}$ . The frozen material is then permitted to thaw. It is then in the state of a solution—that is, it is a clear homogeneous liquid, free of precipitates or sediment or suspended solid matter, even under microscopic examination. This solution may be referred to as a hemoglobin solution, or as an hemoglobin-electrolyte-stroma solution (abbreviated as H. E. S.).

The solution produced in accordance with the foregoing technique (which, as previously noted, is disclosed and claimed in my copending application above referred to) is the material of which the wound pad of the present invention is composed. The wound pad itself, in finished form, consists essentially of a porous, relatively frangible, readily absorbable cake of this solution, in a thoroughly desiccated state, enclosed within a glossy envelope or membrane, also formed from the solution, by methods hereafter described. Toughness, resilience, and an increased resistance to moisture are imparted to this membrane as later pointed out.

One method for producing the wound pad of the present invention from a solution of blood such as just above described is diagrammatically illustrated in the accompanying drawings, and more fully explained hereinafter.

Figure 1 is a longitudinal section through a two-part ampoule, used in producing the wound pad of this invention.

Figure 2 is a longitudinal section through a refrigerating bath, showing the ampoule of Fig. 1 partly in elevation and partly broken away.

Figure 3 is a diagrammatic illustration, showing the relative arrangement of the parts during the desiccating step of the process.

Figure 4 illustrates in elevation the finished ampoule, with its two parts separated to expose a portion of the wound pad, the remainder of the pad being still within one part of the ampoule.

Figure 5 is a perspective view of a wound pad at the time of use, showing the normally cylindrical shape flattened to adapt it to the contour of the wound.

Figure 1 shows, in assembled relation, the various parts used to form the vessel in which the wound pad of this invention is to be produced. These parts are, primarily, two tubular members, 11 and 12, which are united by means of a sealing collar 13, preferably of rather tightly-stretched rubber. Considering the member 11, it will be seen that it is of fairly large diameter at the end which abuts the corresponding end of the other tubular member 12, and that this large-

diameter portion is of substantial length. If, for example, a wound pad of about 12 cm. long and 1.75 cm. in diameter is to be produced, the large-diameter portion of the tube 11 will be 2 cm. inside diameter and about 8 cm. in length. At that distance from the open end, the tube 11 is narrowed, forming the annular shoulder 14, and the narrow tubular neck 15, which has a length of about 4 cm. The short end, 11, will have a large-diameter portion only about 4 cm. long, but will in all other respects be a counterpart of the member 11. Conventional skirt caps 16 are applied to close the ends of the narrow necks. These caps are preferably of the type which has a soft center plug 17, through which a hypodermic needle may be inserted, and which are self-sealing when the needle is withdrawn.

Figure 1, as mentioned above, shows the parts in assembled relation. In carrying out my process, the first steps are preferably performed before the parts have been assembled in this way. Considering now these preliminary process steps:

The first step of the process is to coat the inner surfaces of the members 11 and 12 with a fairly substantial film of the hemoglobin-electrolyte-stroma solution previously described. This may be done in any convenient manner, as by immersion, spraying, or spreading. I prefer the latter, using a medicine dropper to place the desired amount of solution in the tube and then rotating or manipulating it to assure even distribution of the film over the entire inner surface of at least the large-diameter portion. If dipping is used, it is desirable, immediately after removing the tube from the liquid, to wipe the liquid off the outer surface.

The second step of the process is to subject the film or layer of H. E. S. solution, immediately after it is spread, to the action of alcohol. This I prefer to do by immersing the tube in a beaker of alcohol for several minutes, removing it, and permitting it to dry in air. Alternatively, the alcohol also may be applied by spraying or otherwise. If, for any reason, the treatment with alcohol is delayed, so that the surface of the coating of H. E. S. solution has begun to dry, contact with alcohol must be prolonged. If so much time elapses before the alcohol is applied that the stratum of H. E. S. solution has completely dried out, the alcohol treatment should be continued for a matter of hours rather than minutes. Under such circumstances, overnight immersion in alcohol is recommended.

It should be mentioned that the thickness of the stratum of solution is important. To check this factor, it is desirable to hold the tube to the light after the stratum has been inundated with alcohol, and visually examine the texture and color of the film. The color and refraction of the film or coating under transmitted light is a ready and quite reliable index to the thickness, quality, and state of the film. If a thin coat is wanted, the film should be almost transparent and light pink in color; if a very heavy coat is needed, the film should be dark red and almost opaque.

The thickness of the film may be varied by using a more concentrated hemoglobin-electrolyte-stroma solution, by manipulating the tube so as to facilitate run-off or to retard or prevent run-off, etc. If heavier films than can be provided in these ways are needed, the process may be repeated one or more times, that is, the cylinder may be dipped into the blood solution (or sprayed, or otherwise coated), may be subjected to alcoholic action, and be dried and

visually inspected as many times as may be needed. With very little practice it is possible to produce and evaluate accurately, precisely the quality of film desired.

The action of the alcohol on the blood coating is quite significant. On examination with the unaided eye, the surface appears glossy, as though varnished. Under microscopic examination it seems that the coating has become minutely crystalline in character. Whether or not the residuum of solution adhering to the inner surface of the glass tube is actually crystalline, the fact is that the material is very much more coherent. The deposit which remains seems to have been transformed into a membranous lining for the cylinder, rather than a residual deposit.

After the membranous lining has been built up and "cured" as just described, the outer surface of each of the tubular members 11 and 12 is coated with castor oil or some other semi-drying or non-drying oil, for a short distance back from the end of the large-diameter part. The rubber collar 13 is then stretched over one of the large-diameter ends; the other large-diameter end is brought into endwise abutment, and the rubber collar is slid back across the junction. The oil facilitates positioning the collar, and also serves to ensure that the joint sealed by the collar will be air-tight. Caps 16 are then applied, and the vessel is now ready for the next step in the process. This is the condition illustrated in Figure 1, the membranous lining being indicated at 18.

An alternative procedure for carrying out these preliminary steps is to bring the tube ends together and apply the collar 13 before spreading the H. E. S. solution over the inner surface. If this is done, the solution is injected, as by use of a long-needle syringe, through neck 15 into the large-diameter space, and is spread by manipulation. This is not as desirable, however, because air-drying of the film after inundation with alcohol seems to be quite important, and it takes undesirably long to circulate a sufficient volume of air through the narrow necks 15.

The next step in the process is the formation of a hollow cylinder of H. E. S. solution within the ampoule A. The apparatus used in carrying out this step is illustrated in Figure 2. It consists of a vessel 19 having upper wall surfaces 19a, filled almost to the brim with refrigerant 20. This refrigerant may be a mixture of Dry Ice and refined kerosene, or any other intensely cold liquid such as Methyl Cellosolve (melting point  $-98.1^{\circ}\text{C}.$ ).

A large size hypodermic syringe 21 is used to inject the H. E. S. solution through the cap 16 and neck 15 into the large-diameter portion of the ampoule. I prefer to use an instrument having a barrel about 3 cm. in diameter and about 12 cm. long, provided with an extra-long needle 22, of 18 or 20 gage for preference. The 7" (18 cm.) size is long enough for most purposes.

The syringe is charged with H. E. S. solution and the needle is inserted through one of the caps 16 (traversing the self-sealing plug 17) until the mouth 23 of the needle enters the wide-diameter section beyond shoulder 14. Pressure is then applied to the plunger of the syringe, while the needle is being advanced progressively into the wide-diameter section. When the region of the opposite shoulder is reached, the direction of the needle is reversed. Meanwhile, the ampoule A is continually rotated, spit-wise,

so that the solution deposited on the inside of the membranous layer 18 is spread evenly over the surface and is progressively frozen in a thin layer. The needle tip 23 is traversed several times, back and forth through the wide-diameter section, care being taken to maintain substantially constant pressure on the plunger so as to ensure a uniform rate of discharge of the solution. Rotation of the ampoule is maintained all the while, so that a body 24 of frozen solution is gradually built up, from the periphery towards the center of the ampoule. Each fresh increment of solution freezes to the layer of solution previously injected and frozen.

When the body of frozen material reaches such a thickness, radially, as to leave a central, axially-extending core space 25 of about 0.5 cm. in diameter, the needle is withdrawn and the ampoule is connected to a desiccation unit, as shown diagrammatically in Figure 3. In the present example, when the volume of the ampoule is about 40 cc., the amount of liquid injected is from 30-35 cc.

In an effort to expedite building up of the body of frozen material, I have simply filled the ampoule about four-fifths full of H. E. S. solution before placing it in the refrigerant; have then immersed it in the refrigerant and rotated it quite rapidly during freezing. Useful results can be secured in this way, if rotation is maintained at a speed sufficient to drive all of the liquid to the periphery by centrifugal force and keep it pad ultimately produced is likely to be distinctly more frangible than when the solution is frozen sequentially in layers during relatively much slower rotation.

In any case, when the desired body of frozen material has been provided, the cap 16 is removed from one end of the cylinder and the vacuum line from a conventional lyophilizing unit is substituted. Mechanism of this sort is now well known in this art, and it is therefore only diagrammatically illustrated in Figure 3. It comprises a test tube for biological liquid to be desiccated (or several such tubes connected to a common manifold), a vacuum line 26 to a primary condenser 27, through which vapor is withdrawn from the material being treated, and a vacuum pump 28. In the present case the ampoule A is substituted for the usual test tube, and the vacuum connection is made by removing one of the caps 16 and substituting a ported nipple, as illustrated at 29 in Figure 3. In the primary condenser 27, the larger part of the moisture content of the material in the ampoule A is collected in the form of vapor and precipitated in the form of ice. One or more secondary condensers 30 may be used if desired.

For reasons not yet clear to me, when the material being desiccated is a blood solution incorporating the disintegrated residue of blood corpuscles, such as the hemoglobin-electrolyte-stroma solution referred to heretofore, it seems to be much more important to maintain the temperature at a low value, and to maintain the degree of vacuum applied at a high value than when lyophilizing plasma. Otherwise, the material in the cylinder 11-12 tends to reliquefy, and flow to the bottom of the cylinder, so that a channel is no longer available in the body of material through which vapor may be withdrawn. If its level reaches that of the exhaust port, the liquid may completely plug this passage and re-freeze there.

As a general indication, I may say that best re-

suits have been secured when the vacuum gage showed from 10 to 15 microns, throughout the process of desiccation, and the thermometer showed temperatures around  $-70^{\circ}\text{C}$ . or, better still,  $-90^{\circ}\text{C}$ . at least until a major portion of the free moisture had been sublimated.

If the frozen mass does re-liquefy, the ampoule must be removed and its contents must be re-frozen, spinning the ampoule quite rapidly to displace the liquid and re-establish the axial cavity while freezing takes place. As suggested above, the pad ultimately produced when this is done is more frangible than when the solution is sequentially frozen.

I surmise that the problem is consequent upon the presence of all of the electrolytes normally present in the blood, since under my process nothing is removed of the useful blood constituents, except, permissively, that quantum of plasma which is deemed unnecessary, and which is separated by centrifugal action before the blood residue is initially frozen. Certainly the freezing point of the hemoglobin-electrolyte-stroma solution which I use is much lower than the freezing point of plasma.

Preferably, the lyophilizing treatment is carried on until practically all free moisture has been removed. Using a small size commercial lyophilizing unit, having a 24-position manifold, I continue desiccation for from 18 to 24 hours. This, according to the manufacturer's manual, should ensure that not more than 1% of the moisture content initially present will remain.

I have discovered that the membranous lining which was first produced within the ampoule tends to adhere to the blood solution injected and frozen in situ as previously described, and tends to separate from the glass wall of the cylinder when the material in the cylinder shrinks in volume as the water is removed. Indeed, some degree of separation is initiated by the alcohol treatment, and one indication that that treatment has progressed sufficiently is the appearance of indications that the film or coating is no longer firmly adherent. As the volume of the mass being desiccated is reduced, the membrane thus becomes a jacket or shell for the contents of the ampoule. Ultimately, there will be an annular cake of desiccated blood residue within the cylinder, encased within the cured H. E. S. membrane. It is therefore possible to remove the entire charge as a cohesive, handleable unit. It may then be pressed into the desired shape, placed in a hermetically-sealed container, and stored until used.

In practice, I much prefer to avoid the extra handling involved in removing the desiccated wound pad, shaping it, and re-packaging it, for reasons both of economy and sterility. Instead, after desiccation has been finished, I prefer to seal the ends of the ampoule in which the wound pad was formed, so that this same ampoule becomes the package in which the wound pad is stored and sold. This may be done by removing the ported nipple 29 to which the vacuum line had been connected, and replacing the rubber cap 16.

A better procedure, in my opinion, is to flame-seal both ends of the wide-diameter section while it is still under vacuum. A short section of flexible tube 32 is inserted in the vacuum line for this purpose. When desiccation is complete, this flexible tube is clamped shut, and is removed from the vacuum line while still attached to the ampoule by the short tube 33 and the ported nipple

29. Then the necks 15 are flame-sealed adjacent the shoulders 14, producing a pig-tail closure, most clearly seen in Figure 4, where the reference character 31 identifies it.

At the time of use, the surgeon breaks the seal (as in Figure 4) by freeing the collar 13 from the long end 11 of the ampoule. The short end 12 of the ampoule is then withdrawn, leaving the short end of the wound pad 24 projecting from the region of the break. This is usually done in the surgical pavilion at the time of an operation. When the short end of the ampoule has been completely removed, the surgeon, wearing sterile gloves, grasps the wound pad by the short end, and slides the entire pad bodily out of its container. The wound pad may then be applied to the injury. If it seems desirable first to modify its shape or general dimensions, so as to fit the contour of an incision, it is only necessary to press it manually into the shape desired. The membranous envelope is sufficiently strong to avoid crumbling or breaking of the desiccated material within it.

It should be pointed out that the membranous envelope just referred to, and described in detail in an earlier section of this specification, performs several quite important functions. In the first place, it facilitates separation of the wound pad from the cylinder wall during desiccation. In its absence, the solution adheres to the cylinder wall irregularly—so that as the annular cake shrinks during desiccation, it adheres in some places and pulls away in others, fracturing into relatively large chunks in so doing. In the second place, the membrane serves as a jacket for the pad, lending tensile strength and also helping to confine any desiccated material which may be present in free particle form after the pad has been removed from the cylinder. It would be difficult to press the wound pad into special shapes without crumbling it or breaking it, if the membrane were not present. Also, I believe that, under vacuum, separation of the membrane from the cylinder wall facilitates desiccation, by permitting withdrawal of vapor from the periphery as well as from the center of the pad.

But over and beyond these important functions, the membrane serves a very significant purpose in the use of the pad during healing. This is a most interesting aspect of the present invention. Subjecting the solution applied to the cylinder wall to the action of alcohol imparts to the membrane a certain degree of resistance to dissolution. Upon the addition of water, the desiccated residue of an H. E. S. solution is dissolved, in the absence of this membrane, in a matter of seconds, or at the most, minutes. Wherever there is an injury in living tissue, the adjacent areas will be suffused with blood, which is predominantly aqueous. If it were not for the water-resistive characteristics of the membranous envelope, the substance of the wound pad might be hydrated too quickly.

It is possible to increase or diminish the degree of resistance to absorption simply by regulating, first, the thickness of the membranous envelope referred to, and second, the length of time for which it is exposed to the action of alcohol. Thus it is possible to coat the inside of the cylinder rather lightly, immersing it in alcohol for a relatively brief interval, and thus produce a jacket for the wound pad which will dissolve, comparatively speaking, in a very short time. This is desirable, particularly where a superficial injury is to be dressed, because the material with-

in the membranous envelope possesses even stronger hemostatic properties than the envelope itself. When stanching the flow of blood is of primary importance, a relatively readily-soluble envelope is obviously to be preferred. Where somewhat deeper injuries are being treated, it is not only desirable to arrest the flow of blood; it is also quite highly desirable to preserve the structure of the wound pad itself, because the material of which it is composed can and will be utilized by the body in the formation of new tissue. It is as though one had supplied a food for living cells which they seem to be capable of absorbing directly. Where the wound pad is used in this way, it is desirable that the membranous envelope should retain its resistance to the solubilizing effect of bodily fluids for a longer interval, so that the substance of the wound pad will not be quickly hydrated and carried away from the wound, but will be gradually absorbed, right at the site of the injury.

Where the incision is a deep one, as in abdominal surgery, absorption should proceed still more slowly, so that the substance of the wound pad may be kept in place, to exert a maximum of its beneficial healing action over the longest possible interval of time.

It is my belief that hospitals and surgeons will find it desirable to keep on hand at least three grades of wound pads made according to this process, one grade being absorbable quite shortly after application; another persisting long enough for tissue to recuperate sufficiently to permit ambulation of many post-operative patients, and the third having a "life expectancy" of many days or possibly even weeks.

The foregoing comments illustrate a preferred embodiment of my invention. Variation of procedure may be employed, within limits, without departing from the spirit. This is especially true of the manipulative steps, which are presently performed mainly by hand, but which seem to be readily adaptable to mechanical operation. I contemplate several modifications along this line, such as the use of power-rotated quick-acting chucks, to seize and spin the ampoules; of automatic traverse mechanism to control the injection of H. E. S. solution during freezing; and of metering injectors to secure controlled discharge of a predetermined quantum of fluid. Unitary ampoules could be used with such equipment, especially if an air injector were employed to facilitate drying after the alcohol treatment, in which case a fracture line would be inscribed in place of the collar 13.

Physiological alterations are also possible. One such adaptation which I have used is to incorporate glucose in the hemoglobin-electrolyte-stroma solution employed to form the membranous envelope. I find that additions in the neighborhood of 8% of glucose may be used to advantage, where the presence of glucose is indicated.

The "alcohol" which I prefer to use is medicinal alcohol, preferably ethyl alcohol. This may be obtained at various concentrations, as is well known. It is desirable to utilize relatively concentrated forms—say 75%  $C_2H_5OH$ , and upwards, although it is by no means necessary to use absolute alcohol. If solutions of lower concentration than 75% alcohol are used, some of the H. E. S. film may diffuse into the liquid when the cylinder is dipped therein, and, if glucose is present, some of it will do likewise. Moreover, the toughening or "curing" action is influenced by the degree of concentration of pure alcohol pres-

ent. The more dilute the alcohol solution, the longer it takes to "cure" the membrane.

Although ethyl alcohol is preferred, isopropyl alcohol, one of its homologues, may also be used. It toughens the film and imparts resistance to absorption, but tentative conclusions are that clinical effectiveness may be somewhat reduced when it has been employed. Mixtures predominantly of ethyl alcohol and containing relatively minor amounts of iso-propyl alcohol yield results which compare favorably with those secured with ethyl alcohol alone.

It is also possible to incorporate certain drugs, medicines, or biologicals in the hemoglobin-electrolyte-stroma solution before desiccation, or to place them in the hollow core of the wound pad after desiccation. Such additions, however, should be selected with care, so as to ensure compatibility, both as to chemical composition and as to biological effect, with the hemoglobin-electrolyte-stroma constituent. My Patent No. 2,477,171 describes and claims the combination of an hemoglobin-electrolyte-stroma solution with penicillin. Such a solution may be utilized in forming the wound pad of the present invention, with very satisfactory results, where the employment of an antibiotic is indicated. Streptomycin is similar in effect. Delayed action medication is possible, by placing a desired medicament, in dry form, or, in small quantities, in liquid form, or even in capsules, in the hollow core of the wound pad. Preferably, this is done at the time of use, and the ends of the wound pad are squeezed together thereafter, so that much of the wound pad will have to be absorbed before the capsule is dissolved or the medicament is released.

In summary, it will be seen that a new surgical instrumentality of considerable utility has been created. Since it contains all of the constituents of blood and no reaction products hostile to blood, it is as much at home in living tissue as if it had been whole blood administered by transfusion. Yet it is, I think, more useful than transfused blood, for it can be utilized without limitation as to the blood type or R.H. factor of either the patient or of the original donor. Furthermore, the stroma, being in a state of submicroscopic disintegration, is apparently in a form which makes it directly available to living cells, without assimilative action being needed elsewhere in the body. It is more useful than plasma, for it contains not only the life-giving hemoglobin but also the tissue-building stroma, not to mention the blood electrolytes. Furthermore, it is not carried more or less at random to the site of the injury (as with intravenous injections), but is applied precisely at the point of need, where much of it is directly used, and from which some of it is diffused, with beneficial effect upon surrounding tissue. To these advantages must be added the effectiveness of the wound pad in curtailing loss of body fluids—its hemostatic action—its capacity to absorb fluids which are released, and its capacity to be absorbed gradually, so that it may quite safely be embedded in living tissue and permitted to remain there. The potential uses of this wound pad as a medium for applying other therapeutics are also wide indeed.

Alteration in resistance to absorption may be capable of precise control. At present, however, factual data is insufficient to present the full range of possibilities. Using an ampoule of the size and shape herein described, if 3 cc. of H. E. S. solution is employed to form the lining film or

coating, and exposure to alcohol is continued for 10 minutes, the film will be light pink in color and will be quite translucent. The wound pad will resist absorption for almost two days if applied to a superficial injury. If the amount of solution used to form the film is doubled (application in two stages is recommended under such circumstances) and exposure to alcohol is also doubled, the film is deeper in color and transmits noticeably less light. A wound pad encased in such a membrane will not be completely absorbed at the end of five days when applied to a superficial injury, but will be absorbed within that time if implanted in the abdominal cavity. Using 9 cc. of blood solution, in three applications of 3 cc. each, with 10 minutes of exposure to alcohol after each application, a film will be produced which is deep red in color and only slightly translucent. A wound pad having a membranous covering of this character, implanted in the abdominal cavity, may resist complete absorption for ten days or more.

Numerous departures from the comparative illustrations given just above have been made, and all tend to confirm the view that careful control of the amount of solution used and time of alcohol treatment can be relied upon to produce a predetermined absorption time with considerable accuracy. As a general rule, exposure to alcohol should be continued for a longer time where a thick film is applied in a single stage than where a film of the same thickness is applied in two stages. Thus, in the third example given above, if 9 cc. were applied in a single stage, the alcohol treatment would have to be continued for almost an hour, instead of thirty minutes.

I claim:

1. A surgical wound pad comprising a porous body of desiccated organic material absorbable in tissue fluids, having adhered to at least a major portion of its outer surface a relatively non-porous coat comprising the same organic material but in a state less readily absorbable in tissue fluids than said body.

2. A surgical wound pad as defined in claim 1, having a centrally disposed cavity therein.

3. A surgical wound pad as defined in claim 2, wherein the porous body is composed entirely of constituents of animal blood.

4. A surgical wound pad as defined in claim 1 having its porous body composed of constituents, including at least hemoglobin, of animal blood.

5. A surgical wound pad as defined in claim 1, in which the non-porous coat comprises the product which results from exposing to alcohol a solution of red blood constituents.

6. A surgical wound pad having an inner body and membranous material adhered to at least the major outer surface areas of said body, characterized in that it is composed primarily of the desiccated residues of the corpuscular portion of animal blood, both in its inner and in its outer portions.

7. A surgical wound pad as defined in claim 6 characterized in that it is completely absorbable in tissue fluids.

8. A surgical wound pad as defined in claim 7, in which the inner body is porous and hydroscopic and the membranous material is relatively non-porous, and relatively resistant to hydration.

9. A surgical wound pad as defined in claim 7, in which the membranous material comprises the product which results from applying alcohol

to a film of blood solution and evaporating said alcohol in the presence of air.

10. A process for producing a surgical wound pad, which process comprises the steps of distributing a solution containing the corpuscular constituents of blood over the inner surface of a sterile vessel to form a film, applying alcohol to the film so formed, evaporating the alcohol in air, and forming a body of dry therapeutic material within said film.

11. A process according to claim 10, in which the body of therapeutic material comprises the corpuscular constituents of animal blood.

12. A process according to claim 11, in which the corpuscular constituents of animal blood are introduced within the confines of the film in a fluid state and are subsequently desiccated.

13. A process for producing a surgical wound pad, which process comprises the steps of distributing a solution containing the corpuscular constituents of blood over the inner surface of a tubular glass vessel to form a tubular film, treating the film so formed with alcohol and evaporating the alcohol to transform the film into a tubular membrane, infilling the membrane with a tubular annulus of frozen material comprising the corpuscular constituents of animal blood by spraying such constituents in fluid form radially outwardly from the tubular axis while applying refrigeration at temperatures of the order of  $-70^{\circ}\text{C}.$ ; and then desiccating the material so frozen by sublimation under vacuum in the frozen state.

14. A process according to claim 13 which includes the step of flame-sealing the glass vessel while still under vacuum.

15. In the process of desiccating animal fluid in the frozen state by vacuum, the steps which consist in chilling the space within a tubular vessel by application of a refrigerant to the outer surface of said vessel, introducing the animal fluid axially of said vessel, and spraying it generally radially outwardly towards the inner periphery of said vessel whereby to distribute said fluid as an annular film within said vessel, the process being characterized in that the rate of spraying and the temperature of the refrigerant are so correlated as to produce extremely rapid freezing of said film, and being further characterized in that introduction of fluid is continued, forming annular films which freeze to the annular film previously formed, until a substantial body of frozen material having an axially disposed channel therethrough has been provided.

16. The process of claim 15 in which the tubular vessel is partially immersed in the refrigerant and is subjected to rotation about its major axis during spraying and freezing of said fluid.

17. The process of claim 15, in which the film is formed by axial traverse of nozzle means.

18. The process of claim 16 in which the film is formed by axial traverse of nozzle means.

19. The process for producing a wound pad having hemostatic properties, which process comprises the steps of: introducing a preparation containing red blood cells in the state of a solution into a vessel producing a film of such solution by distributing it over the inner surface of said vessel; applying alcohol to the film, and evaporating the alcohol in the presence of air, whereby to transform the film into a cured membrane; introducing a quantity of the solution first mentioned within the membrane; distributing said solution in a layer within said membrane and freezing said layer immediately after its

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formation; repeating said introduction, distribution, and freezing steps until a substantial body of frozen material has been built up, but leaving an axially extending vapor channel through said body of frozen material; and thereafter desiccating the frozen material by the sublimation of its water content in vacuo.

20. The process of claim 19, in which desiccation is carried out at temperatures at least as cold as  $-70^{\circ}\text{C}$ .

21. Apparatus for producing a wound pad comprising a tubular vessel provided with tubular trunnions at either end, a refrigerant chamber having means for supporting said trunnions with the vessel in a horizontal position, pump means for injecting an animal fluid under pressure into said vessel, and a hollow retractable conduit member extending from said pump means into said vessel through one of said tubular trun-

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nions, and having spray nozzle means at least adjacent its delivery end.

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