

A BULKHEAD SUTURE OF THE INTESTINE.*

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It would, I think, be conceded that end-to-end anastomosis of the intestine should be the method of choice if it were as safe as the lateral anastomosis. Occasionally the circular suture is the only feasible one.

Soiling, unquestionably, contributes to the mortality attending the circular suture, particularly of the large bowel, but how important this factor is cannot be definitely determined until it shall have been completely eliminated.

The problem of making an end-to-end anastomosis in a manner more nearly ideal, namely, in truly aseptic fashion, has for many years confronted surgeons, but only during the past two years, and since having had in mind some investigations involving the making, simultaneously, of a number of resections of the gut have I given the matter serious consideration. In experimentation of this kind, the failure of one suture means disaster to all, and the loss perhaps of half a day's work.

That the solving of this problem is also worth while from the humanitarian point of view is indubitable. In the winter of 1909-10, assisted by Dr. Willis D. Gatch, I made a number of experiments on dogs in the hope that we might contribute something toward the solution of this problem which became the more fascinating as the difficulties presented by it increased. Repeatedly certain steps in a procedure which seemed on paper and at night to be solved could be found when tested at the operating table in the morning to be as far from solution as ever.

As to the simple excision of a loop of bowel, this can be carried out as cleanly and as aseptically as the resection of the appendix. If it sufficed merely to sew together the abutted ends of the gut,

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each end having been treated after the manner of an appendix stump, the problem would seem to be solved. The wall of the bowel having been reduced to its submucous coat by crushing or otherwise, firmly ligated, and cut through with the Paquelin cautery, the division of the gut is accomplished aseptically. The two free ends can now be abutted and sewed together without manifest flaw in the technique. But a double diaphragm remains to impede for a long time the advance of intestinal contents even if the ligatures employed in the tying-off of the gut could be relied upon to melt away with the desired promptness. In other words, the amount turned in of the intestinal wall is too great. Diaphragms like these, which in some of our experiments were reduced to the submucosa, may be charred by the cautery in such a way that they will ultimately slough, but the process of separation of tissue so dense is too slow. One experiment was carried out on this plan. The animal recovered with the aid of a prolonged fast without symptoms of obstruction. But a satisfactory result could not be expected uniformly to attend such procedure.

Only a few experiments had been undertaken when Dr. Gatch made a suggestion which is altogether novel and may prove to be the key to the situation. He proposed that the bowel ends, occluded in the described manner, be invaginated over a contrivance like the Harrington collapsible hammer and redivided by the cautery beyond encircling ligatures which should bind the gut firmly to the instrument. The end-to-end suture would then be made and the hammer ultimately collapsed.

To invaginate and redivide the gut seemed to me to be a particularly happy idea and one which promised much toward the elucidation of the whole problem. It was obvious, however, that a contrivance of the order of the hammer could not be suitable, for the invaginated ends, after having been burned away, would be too far apart for the act of stitching them together. An instrument might, I grant, be devised which would admit of the approximation of the seared ends, but I think it would be better for various reasons to be able to treat each gut-end separately. On a hammer-like instrument one could not, for example, invaginate the gut indefinitely nor, having burned off the ends beyond the ligatures, repeat the process at another point should there be indications for this.

Believing, therefore, that it was desirable to be able to treat each of the ends separately, rings of very thin soft metal were tested. These were made broad enough to carry a groove on their circumference for the reception of the bowel with its confining ligature and were provided with a little radial spur, within, to facilitate the holding of the rings. But for the crushing of the rings, even of lead ones, with their concavo-convex rims, the force required was so great that it occasioned trauma of the bowel.

Furthermore, the tendency on compressing the rings was, of course, to an elliptical form which did not permit the disengagement of the encircling ligatures; and the indenting or sectoroid form of collapse was attained only with still greater damage of the intestine. And even when indentation of the rings was satisfactorily accomplished, they were not easily released from the embrace of the binding threads.

Then we tried soluble rings, and Dr. Gatch provided hard disks of sugar—thick lozenges which he had grooved on the circumference. We experienced, however, great difficulty in engaging these with the ligature. The intestinal peristalsis and slipperiness of the peritoneal surfaces and of the moistened sugar contributed to the difficulty of maintaining the plane surface of the sugar disk at right angles to the long axis of the bowel.

At last it occurred to me to produce the invagination by means of a soluble cylinder or rod which, grooved at regular intervals for the reception of the doubled wall of the intestine, might be burned through together with the invaginated gut. Sticks of candy and extract of licorice, being easily available, were employed, and the result of the first trial with candy was encouraging. The division with the cautery being easily and accurately accomplished, each end of the bowel remained securely plugged with what might be termed a *bulkhead* of sugar. These warm, sticky bulkheads were pressed together and, adhering to each other with considerable firmness, possibly assisted the act of suturing, which happened to terminate precisely at the moment that the sugar had melted sufficiently to liberate the finger-cot-like diaphragms or invaginations of the bowel-wall.

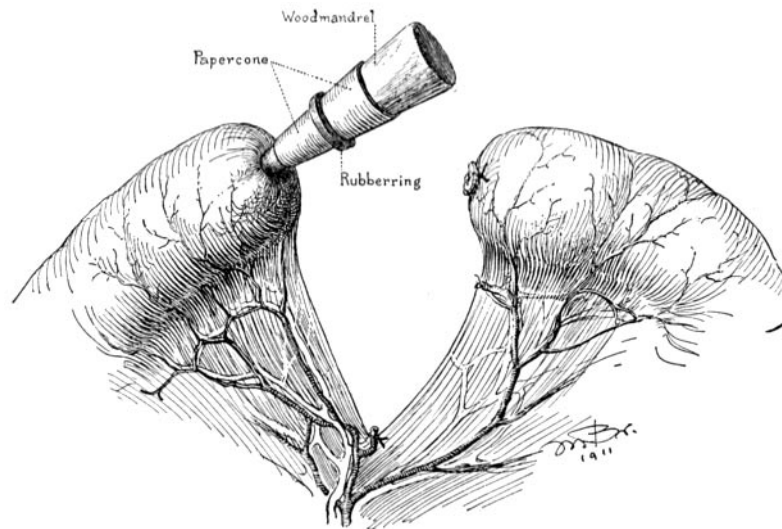
Our satisfaction was of brief duration, for at the next experi-

ment we were not so lucky in engaging the grooves on the sticks, whether of candy or licorice, so I decided to arm the cylinder with a number of flanges which might easily be palpated through the wall of the intestine, being confident that no difficulty would be experienced in binding the gut to the cylinder between two of these flanges.

After having had a brass model constructed to serve as the positive for mould, it seemed to me that it would greatly simplify matters, discarding the mould idea, to make flanges of rubber—these to be slipped on a smooth, soluble cylinder.

So rings of rubber were cut from a catheter of the proper size and sticks of licorice armed with these as flanges.

Thus another difficulty was overcome. But the procedure was still in need of great refinement. A hollow cylinder would, I

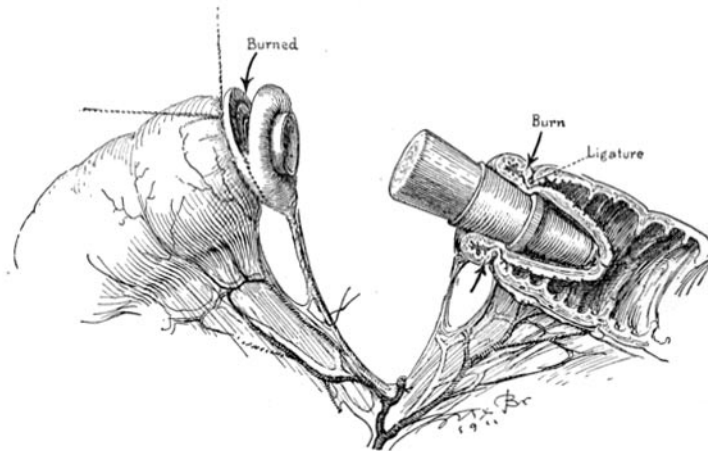


TEXT-FIG. 1. One of the ends of the divided gut is being invaginated by the wooden mandrel which carries the paper cone.

thought, be preferable to the solid ones, for the burning of a solid rod of licorice or sugar was a disagreeable and clumsy performance. Hollow cylinders of hard gelatin coated with shellac were mounted on brass mandrels, over all were drawn the rubber rings, and the gelatin was burned through to the brass mandrels. But the heat of the cautery made the gelatin adhere to the mandrels so that the

latter could not be nicely dislodged; and the capsules when employed without the mandrels lost the required firmness on being cut through with the cautery knife.

Then the licorice was again resorted to. I found that it could be turned in perfect cylinder form and also grooved on a lathe. Close to the edge of each groove on the licorice rod, a rubber flange was placed. The determination of the situation of each groove was made easy by the use of the rubber bands which could be distinctly felt through the intestinal wall even when peristalsis was taking place. As the ligature encircling the invaginated intestinal wall in front of a rubber flange was being tightened, the invaginating rod of licorice



TEXT-FIG. 2. On one side the gut has been partially burned through by the cautery knife.

was slowly withdrawn until the ligature became engaged in the groove intended for it, as it was compelled to do by the rubber flange.

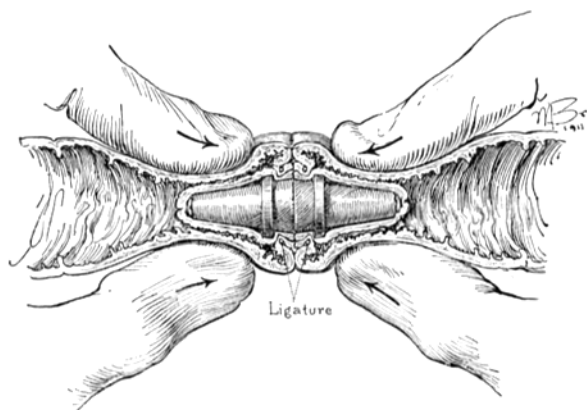
The procedure had reached this stage in its development when, at the meeting of the American Surgical Association in the spring of 1910, I reported the progress which had been made.

Since then the method has been decidedly improved by the substitution of paper cones for the licorice rods.

Cones of any desired size and thickness can be manufactured in a few minutes by twisting and pasting together narrow strips of

paper, one after the other, on a conical form of wood, the latter to be used later as a mandrel. The paper cones are armed, each with a rubber flange or ring cut from a catheter.

The operation is then performed as follows: The peritoneal and muscular coats are divided and stripped back on the submucosa far enough to enable the operator to place two ligatures around

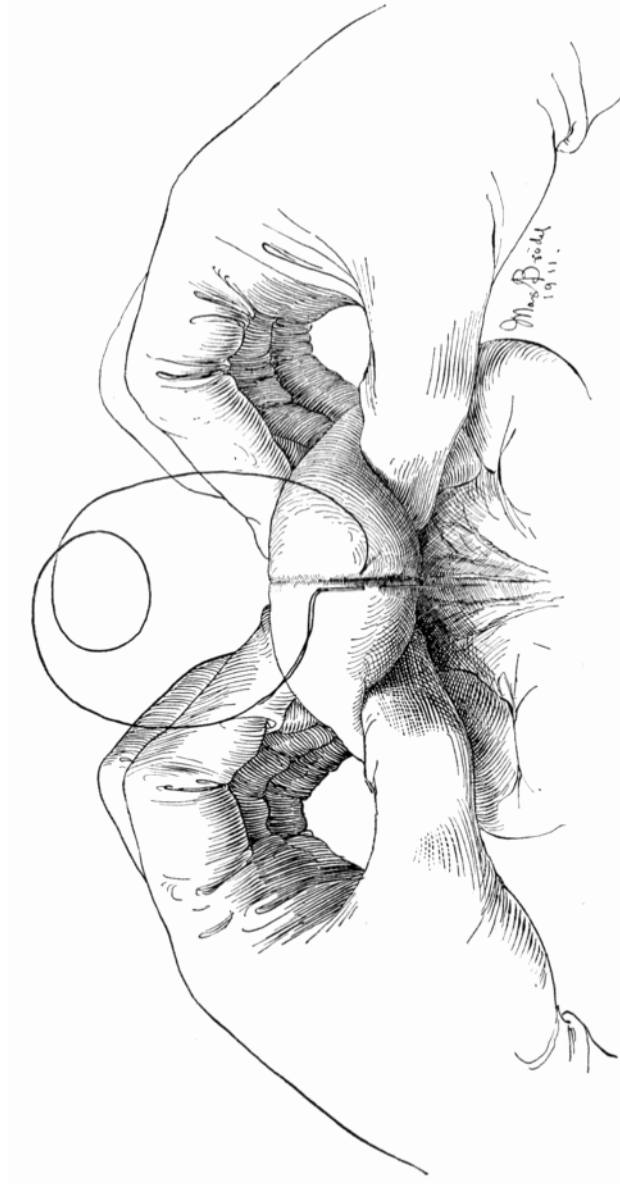


TEXT-FIG. 3. The ends of intestine and the paper cones, having been divided with the cautery knife are apposed, the invagination bulkheads being held firmly in place by the encircling ligatures.

the gut and to divide between these with the hot knife. To prevent the slipping of these ligatures which are of fine silk, and threaded on straight needles, they are made to engage, but not completely pierce, the submucosa at, say, three or four points before being tied.

The paper cone armed with the rubber ring and mounted on the mandrel of wood is carried by the latter into the invagination in the manner shown in text-figure 1. When invagination to the desired extent has been made, a ligature of strong silk is tied with force, binding the gut to the cone distal to the rubber flange. Both ends of the intestine having been treated in this manner, they are burned, close to the ligatures, down to and through the paper cones (text-figure 2). The invaginated portion of bowel constitutes the bulkhead, the paper cones serving merely to sustain the pressure of the confining ligatures.

The surgeon has not, until now, concerned himself with the liga-



TEXT-FIG. 4. The fingers of an assistant are producing a slight additional invagination to eliminate the danger of engaging the invaginated bowel in the suture.

tion of the mesenteric vessels. The blood supply having been undisturbed is, of course, perfect up to the exact site of the ligature. Precisely at this point the mesentery is transfixed close to the bowel with one of the fine milliner's needles carrying a thread for the circumvection ligature which is to occlude the ultimate little mesenteric vessel. The larger vessels supplying the gut distal to this point are now tied off by circumvection ligatures carried by needles of the kind named. The end-to-end anastomosis is then made¹ with the continuous mattress suture, described by Dr. Hayward W. Cushing and myself, reinforced here and there by an interrupted stitch (text-figures 3 and 4).

Particular attention is called to the possibility of a calamity which even those who are not novices might not always avert unless they exercised especial care to avoid it. I refer to the danger of including in the suture the wall of the invaginated bowel. This error will not occur if the intussusciens on each side is slid a little further over its intussusceptum or bulkhead by the fingers of an assistant, as shown in text-figure 4. The stitching being completed, it remains merely to crush the paper cones with the fingers. By this act, the invagination-bulkheads are liberated and the lumen of the bowel is reestablished. I usually push the freed upper cone a foot or two centrally along the intestine so that it may be better softened by the time it has descended to the line of suture.

In certain details the method is still imperfect. For example, the size and thickness, and the degree of conicity and of impermeability to fluids of the paper cones best suited to the purpose have not been carefully determined. But in our hands the operation in its present stage of development proceeds without embarrassments. It is, of course, probable that something better suited to the purpose than paper cones will be found.

Advantages of the Method.—1. It is aseptic, except as contamination may occur from stitches which of necessity or by accident have been carried into the lumen of the intestine.

¹CAUTION. Neither in the act of suturing nor at any time after the final division of the bowel, should one push so hard against the edges of the cones as to dislocate them into the intestinal lumen. Should there be a tendency to this dislocation, it may be obviated by winding a ligature-thread around the cone a few millimeters distal to the rubber flange, room being left between the flange and the thread for the application of the binding ligature.

2. The gut may be invaginated to any extent, and even after the binding ligature has been applied, if it should seem desirable to invaginate further, the process may be continued indefinitely, without redivision of the bowel, after merely cutting the ligatures.

3. Precise control of the blood supply.

4. Relief from the annoyance of clamps of any kind, which is particularly to be desired when the operator is working in places difficult of access.

5. The bowel-ends are reduced to the same size, which is desirable for the end-to-end suture.

6. The absolute certainty with which the mesenteric border is turned in.

7. Greater ease of stitch-taking, particularly of the mesenteric border.

8. Its simplicity.

How often have we heard the merits of new methods of intestinal suture extolled almost in the same words!

The working out of the problem has at least been interesting.

This procedure should be practiced repeatedly on animals before being undertaken on the human subject.

Most of the experiments were conducted without aseptic precautions, and the dogs were killed on the operating table.

Three were operated upon aseptically, and these were kept under observation for several weeks. All made uninterrupted recoveries, and the intra-abdominal findings at autopsy were ideal.

I have not, for several years, had occasion to make an end-to-end suture of the intestine in the human subject, and am not sure that I should venture, without further experimentation on animals, to employ the bulkhead suture. The procedure is not, as yet, sufficiently perfected to be "marketable," and this is one of my reasons for desiring to publish it in the *Journal of Experimental Medicine* rather than in a periodical devoted to surgery.