BLIND-END CIRCULAR SUTURE OF THE INTESTINE, CLOSED ENDS ABUTTED AND THE DOUBLE DIAPHRAGM PUNCTURED WITH A KNIFE INTRODUCED PER RECTUM

By William Stewart Halsted, M.D.
of Baltimore, Md.

The last word on the subject of intestinal suture may some day be written, but surely not until much experimental work has been done with an exactness not hitherto contemplated in investigations of this nature. Authors of text-books and of papers lend their indorsement to some particular variety of suture without offering plausible argument for their preference other than a certain measure of success which has attended its employment in their hands; and faulty methods succeed so well that interest in the relative merits of the details of the various procedures has not been sufficiently aroused to demand greater precision in the experimentation and the critical analysis.

Who knows, for example, how much of the intestinal wall should be turned in; whether two rows of stitching are better than one; whether the suture should be continuous or interrupted; whether the Lembert or mattress stitch is preferable; if the knots should be on the mucous or on the peritoneal surface; why some stitch-loops (knots outside) fall into the lumen and others remain on the peritoneal surface; who has considered the factors facilitating or delaying the release of the inturn; and who, indeed, has endeavored to estimate the weight of the burden thrown upon the experimentee to counteract the operator's shortcomings?

Assuredly there is no subject in surgery which has received experimentally a tithe of the labor devoted to intestinal suture. Lives there, indeed, a surgeon who has not made experiments in suturing the intestine—if not on animals, then on man?[1] Such performance on the human subject without rehearsal on animals is a ruthless play with human life, advancing knowledge scarce a tittle.

Last winter, at one of the monthly meetings of the Johns Hopkins Hospital Medical Society, Doctor Holman and the writer reported[2] the results

[1] In our laboratory operative courses for students of the Johns Hopkins Medical School the leading topic from the time of the introduction of these exercises in 1895 up to the present year has been intestinal suture. I embrace this opportunity to express my indebtedness to Harvey Cushing, for thirteen years my brilliant assistant, for his zeal in elaborating these courses and placing them on such a substantial basis that they are now regarded as one of the dominant features of the surgical curriculum for the third-year medical students at the Johns Hopkins University, and are being adopted by other medical schools of this country.

[2] W. S. Halsted and Emile Holman: An End-to-end Anastomosis of the Large Intestine by Abutting Closed Ends and Puncturing the Double Diaphragm with an Instrument Passed Per Rectum. Johns Hopkins Hosp. Bull., 1921, vol. xxxii, p. 98.

of a few experiments having for their object the development of an end-to-end suture more nearly aseptic than had hitherto been devised. The bulkhead suture [3] had taught me that without danger of resulting obstruction, the inturn of intestinal wall (the flange) may be much greater than is generally supposed, so great indeed as quite to fill the lumen of the gut; and the highly instructive and too little known experiments of my former assistant, Dr. Willis D. Gatch,[4] convincingly support this assertion.

In the course of the speculations, which eventually led to the development of the bulkhead suture, I had entertained and discarded the idea of trusting to the absorption of a catgut purse-string to reëstablish the intestinal lumen occluded by the double diaphragm of abutted closed ends, and wrote of it as follows (*l. c.*, p. 217): "But a double diaphragm remains to impede for a long time the advance of intestinal contents even if the ligature employed in the tying off of the gut could be relied upon to melt away with the desired promptness." Evidently I did not realize at the time how great the inturn might safely be. Later we ascertained that the amount inverted by the bulkhead method proved to be even greater than in the blind-end suture which it is the purpose of this communication to describe, and produced no obstruction nevertheless.

At the outset of the recent experiments outlined in our report to the Johns Hopkins Hospital Medical Society last winter, I had it in mind to seek a method which at least might be applicable to such cases destined for excision of the large intestine as had previously been provided with a colostomy. Doctor Holman and I found that dogs tolerated quite well what we believed to be a complete obstruction of the descending colon for four days or more, the time apparently required, as a rule, for the disintegration of the catgut (No. o doubled) purse-string ligatures with which the abutted blind ends had been closed.[5]

Soon after making our report it occurred to me to test the feasibility of dividing the purse-string ligatures, or at least of puncturing the double diaphragm by a protected cautery wire, or knife, or knives passed from below —per rectum. The cautery was soon abandoned, being considered dangerous and too complicated. The knives—at first one, later three, and finally four—housed in a short cylinder of wood or metal were tested. I believed in the beginning that the cylinder should approximately fill the bowel in order to centre the knife and thus insure the cutting of the purse-strings, but soon

---

[3] W. S. Halsted: A Bulkhead Suture of the Intestine. Jour. Exp. Med., 1912, vol. xv, p. 216.

Ernest G. Grey: Studies on the Aseptic End-to-end Anastomosis of the Intestine. Johns Hopkins Hosp. Bull., 1918, vol. xxix, p. 267.

[4] Willis D. Gatch: Aseptic Intestinal Anastomosis. An Experimental Study. Journ. A. M. A., 1912, vol. lix, p. 185.

[5] Unsterilized or "raw" catgut seemed to dissolve more quickly than the sterilized, but it was not so strong, and Nos. 1 and o would frequently break on the tying of the purse-string.

found that these cylinders might actually prevent the centring of the knives unless the stitches were precisely equidistant from the centre.

One knife proved to be better than three or four because (1) less force was required to cut the ligatures or perforate the diaphragms, and (2) one of the three or four knives (blades parallel and both edges of each knife sharpened) might engage the mucosa of the intestinal wall at the margin of or just below the inturn.

The Method.—The vessels supplying the portion to be excised are occluded by fine transfixion ligatures carried by milliners' needles, and are divided as shown in Fig. 1. Strong Kocher clamps are applied, one at the distal, the other at the proximal end of the piece deprived of its circulation. Along the proximal edge of the mark made by the proximal clamp, and along the distal edge of the mark of the distal clamp, a finely basted purse-string stitch of silk [6] is run with a milliner's needle; these ligatures are drawn home and only a half knot taken in each; the knots are completed at the moment the intestine has been divided with the electric cautery wire. Prior to the burning, stout threads are tied about the isolated segment at a suitable distance from the basting stitches (Fig. 2). The purse-strings can be drawn tighter after the tension caused by the encircling threads has been relieved by the severance of the gut. After the burning, the little overhangs, which may at the discretion of the operator be further sterilized chemically or by the electric wire, are trimmed with scissors as close as feasible to the purse-strings. It is hardly possible to cut these threads in the trimming process, and hence, without fear, one snips the little teat of everted bowel wall completely away (Fig. 5).

For the suturing, a single row of mattress stitches suffices. The first five of these (stay stitches), drawn home and tied, facilitate the introduction of the others and serve as guides to their proper placement. The order in which the stitches have usually been taken is shown in Figs. 6, 7 and 8. The two at the mesenteric border are placed a little closer to each other (Fig. 7, insert) than the remainder, and are the first to be tied.

The suturing having been completed, the dog is drawn down until his buttocks overlap the edge of the operating table. An assistant then introduces per rectum the instrument with which the purse-strings are to be cut. Figs. 10, 11, 12 and 13 depict the manœuvres so well that explanatory notes are hardly necessary. The purpose of the short piece of rubber tubing is to protect the sphincter from the sharp edges of the knife and to facilitate its introduction into the rectum. This tube is left in the position shown in Fig. 10 until the knife has been withdrawn.

The knife point, protected by a little piece of cork on the tip, is

[6] Silk was used for the purse-strings to exclude the possibility of misinterpretation of the results. Were the purse-string ligatures of catgut one could not be sure that the restoration of the bowel's patency was due to the cutting of these ligatures and not to their dissolution.

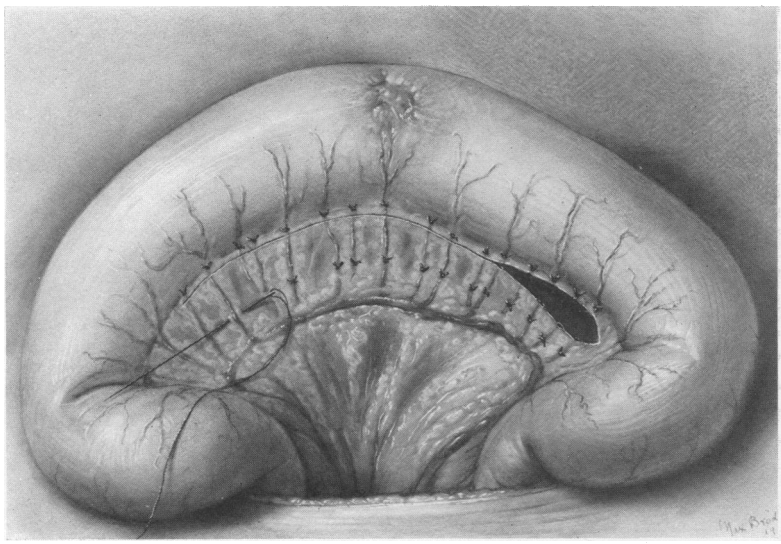

FIG. 1.—Ligation of the blood-vessels by transfixion.

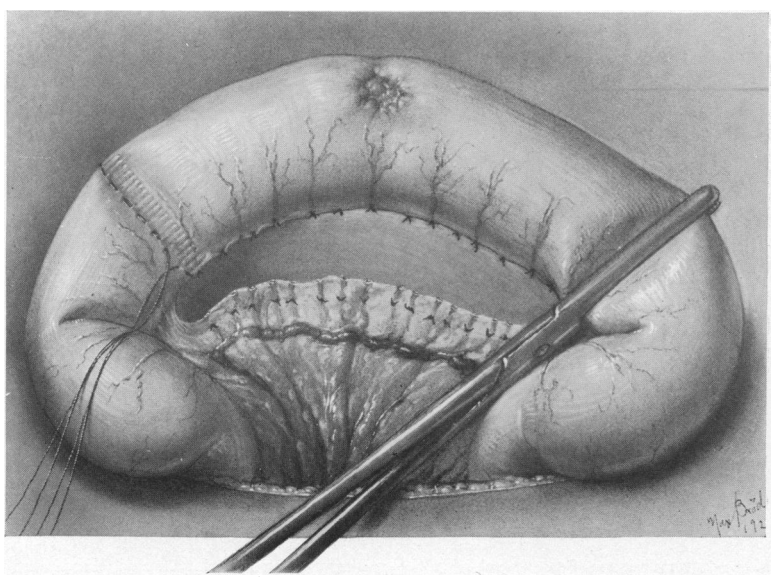

FIG. 2.—The marks made by the crush of the clamp serve merely to guide the placing of the finely basted purse-strings.

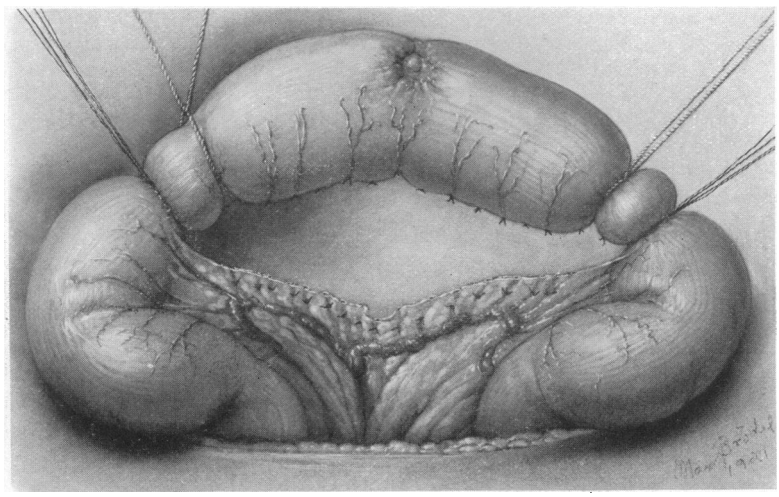

FIG. 3.—Purse-strings tied with half knots; stout ligatures on the piece to be resected.

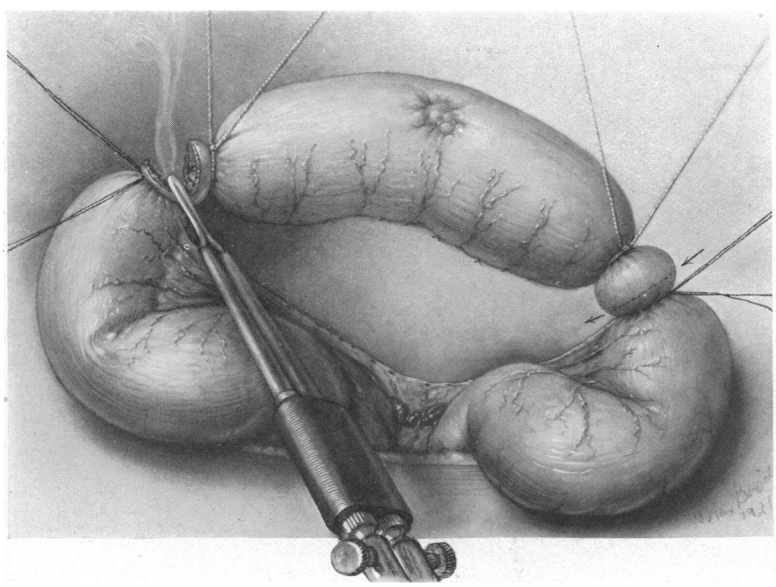

FIG. 4.—After division of the bowel with the cautery the purse-strings are tightened and their knots completed.

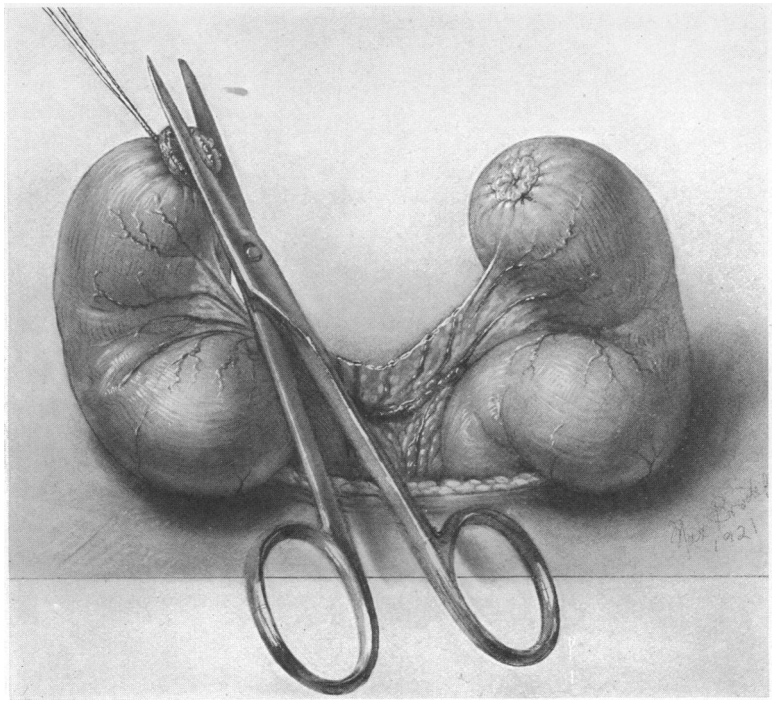

FIG. 5.—The overhang may be trimmed as close as possible without fear of cutting the purse-strings.

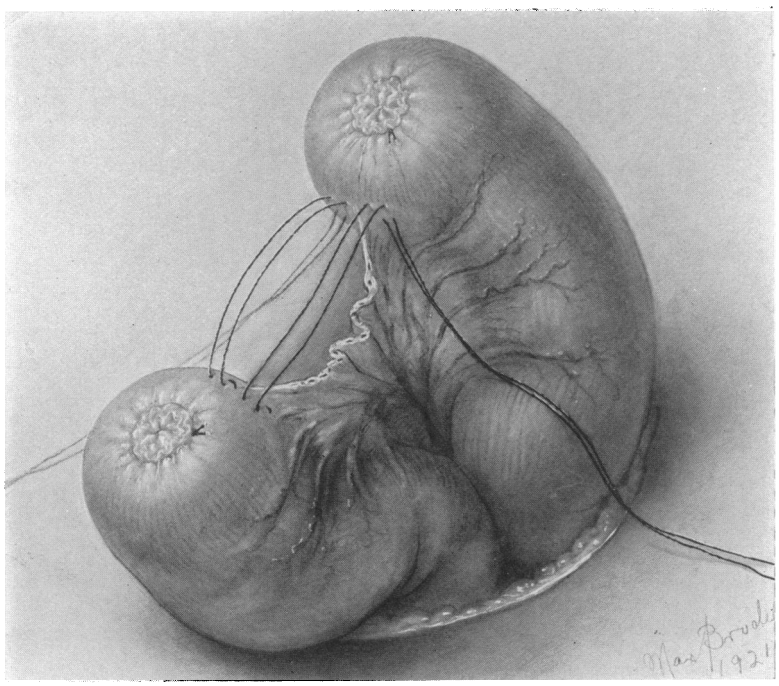

FIG. 6.—The first of the mattress stitches, one on each side of the mesenteric border.

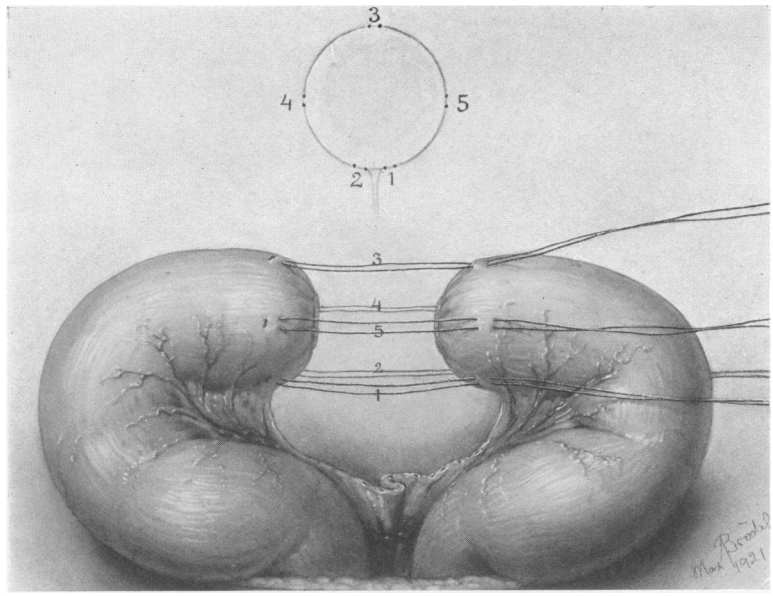

FIG. 7.—The five stay stitches; the numerals indicate the order in which they are taken.

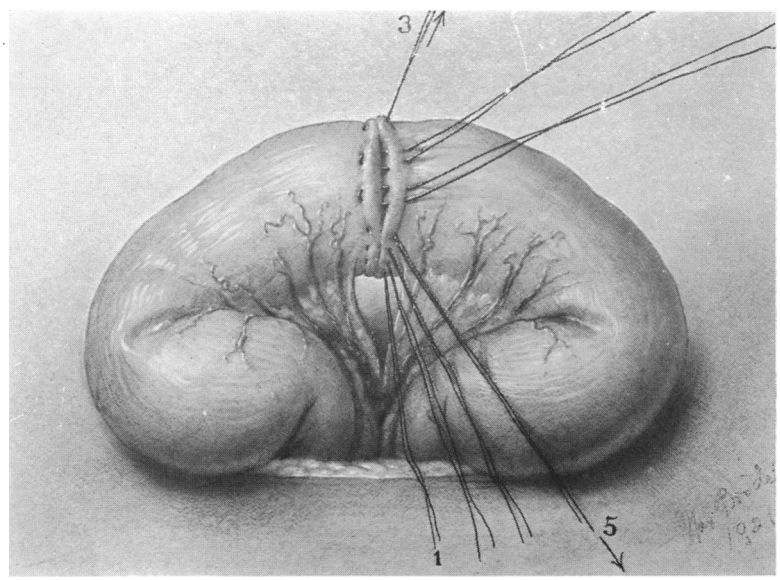

FIG. 8.—Traction on the stay stitches facilitates the taking of the intervening ones.

propelled to the required distance by the assistant who manipulates the flexible metal tail (gas tubing) of the instrument. With no more, or rather less, pressure than is required for the introduction of a stomach tube, the knife will glide along the dog's bowel to the ileocæcal valve. When the knife reaches a point in the pelvis easily accessible to the operator's hand it may be guided by him through the remainder of its course to the double diaphragm; but it rarely needs such guidance. The slightest obstacle to the progress of the knife is detected by the assistant in charge of its trailer or tail. The cork having been removed (Fig. 12), it is slid down the bowel and out of the way (Fig. 13). In making the thrust the operator grasps the metal tubing quite close to the shank of the blade and aims for the centre of the diaphragm, hoping thus to cut both of the purse-strings (Fig. 13). Whether these happen to be divided or not would seem, judging by the results, to be immaterial, nevertheless one should make two or three thrusts at slightly different spots, but all as near the centre as possible, in the endeavor to cut these ligatures. The more experienced the operator the better he can sense the greater resistance to the point of the knife offered by the tissues so tightly compressed by the purse-strings. As a precautionary measure a tapered bougie is passed through the diaphragm before closure of the abdominal wound (Fig. 14).

Forty-seven dogs have been operated upon by this method without a fatality and without symptoms indicative of an abnormal convalescence. The bowel resected was in every instance the colon. The operations were performed by my former and present assistants and myself, some of them by recent graduates of our school without operative surgical experience. The initial experiments were made with an extemporized instrument—a knife housed in wood and mounted on a brass rod. From the outset, however, it was our intention to have a flexible trailer in case the results with our crude apparatus seemed promising. Notwithstanding the defects of the unwieldy home-made instruments used in the earlier experiments and the lack of experience of several of the operators, not a single death occurred.

Hardly a year had passed since 1886 when with the assistance of Dr. Franklin P. Mall I made many experiments in intestinal suture,[1] without further experimental investigation of this subject on the part of my assistants and myself. Not one of us (Gatch, Grey, Holman, Halsted) had a series of more than twenty-three dogs without a death. The present series, therefore, of forty-seven consecutive successes being the longest for our laboratory and, so far as I know, hitherto unequalled elsewhere, it would seem worth while to offer it to the profession for trial and criticism.

It will readily be conceded for this method that the amount of soiling

[1] W. S. Halsted: Circular Suture of the Intestine—an Experimental Study. Amer. Jour. Med. Sci., Phila., 1887, n. s. No. 188, p. 436.
F. P. Mall: Healing of Intestinal Sutures. Johns Hopkins Hospital Reports, Baltimore, 1896, vol. i, p. 76.

could hardly be less; it is little more than occurs in a simple, properly performed appendectomy.

For the first time therefore in the history of intestinal suture two of the factors, the soiling and the amount of inturn, have been reduced almost to a constant, and hence we are now better prepared to test on animals the relative merits of the various stitches in common use.

In operations on the human intestine the surgeon's only criterion has been the mortality; for one cannot explore the abdomen of his patient every few hours after operation in order to determine the amount of reaction (infection and adhesions) about the line of suture, the fate of the stitches, the depth of the inturn, the delay in its unfolding, etc.

Unembarrassed by soiling, or eversion of the mucous membrane, or the presence of a single clamp or other instrument, or by the fear that the mesenteric border may be imperfectly inverted, or that the amount turned in may be too great or too little, or that some point of a running stitch may have been too loose or too tight, the operator proceeds in orderly and uniform manner from the beginning to the end of the performance.

In addition to the two constant factors mentioned above—the amount of soiling and the amount turned in—it is possible, at least in experiments upon the dog, to have another constant factor, *viz.*, the depth to which the stitches penetrate. One may learn in a few minutes to sense the submucosa with the point of the needle and to include a part of it in the stitch without entering the lumen of the gut. With a little practice one learns not only to pick up a thread of the submucosa but to press the needle along in the plane of this coat. The resistance in the latter case may be so great as to remind one of that experienced in the taking of subcuticular stitches. Members of our upper surgical staff can all testify to the accuracy of this statement. And who will not assent to the view that it is desirable to take the submucous stitch when this is feasible? Experience has taught us that stitches which do not enter the mucous coat become ultimately subperitoneal loops, and long before the diaphragm or flange has unfolded. Uninfected, they are cast outwards, and not discharged into the bowel's lumen; whereas, the perforating stitches seem usually to ulcerate their way into the gut. We sometimes find one or more of these perforating stitches hanging in or near the line of suture even when the unfolding process is about complete—when little trace of the diaphragm remains. In the track of all of these stitches which are discharged into the bowel there has necessarily been an infected sinus from the moment of their placement until their release. Dr. Florence Sabin,[8] in her elaborate and unique study of the healing of Doctor Holman's end-to-end anastomoses of the intestine, rarely found that a stitch had perforated; when this had occurred in ever so slight degree there was inflammatory reaction, sometimes a small abscess, about the silk thread.

[8] Florence R. Sabin: Healing of End-to-end Intestinal Anastomoses with Especial Reference to the Regeneration of Blood-vessels. Johns Hopkins Hosp. Bull., 1920, vol. xxxi, p. 289.

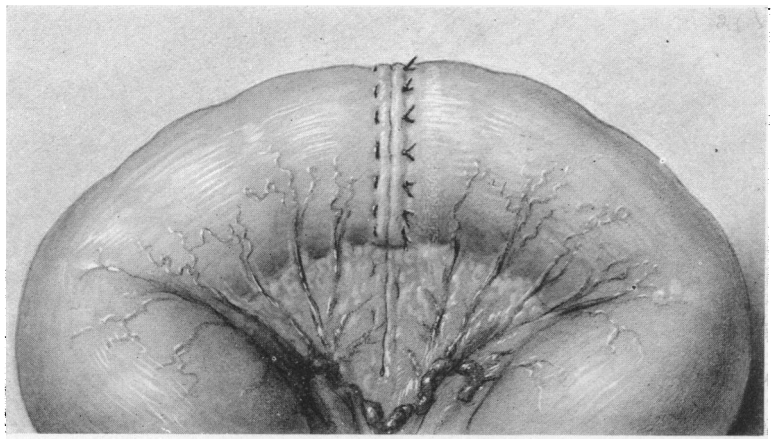

FIG. 9.—Suture completed.

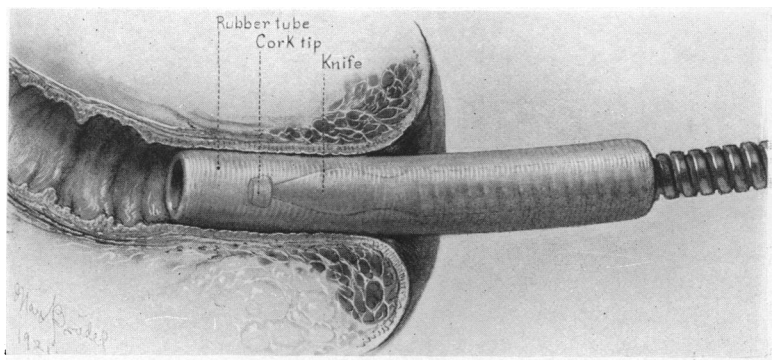

FIG. 10.—The knife in transit through the rubber tube which protects the sphincter.

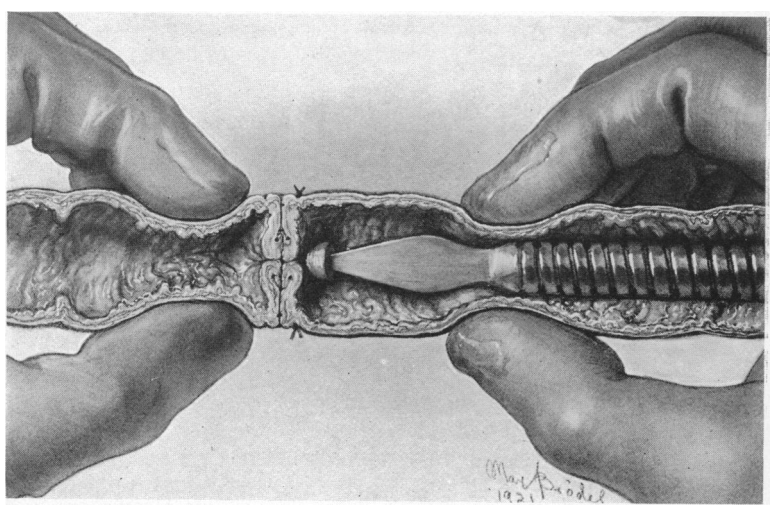

FIG. 11.—The knife has been pushed up to the diaphragm by the outside assistant.

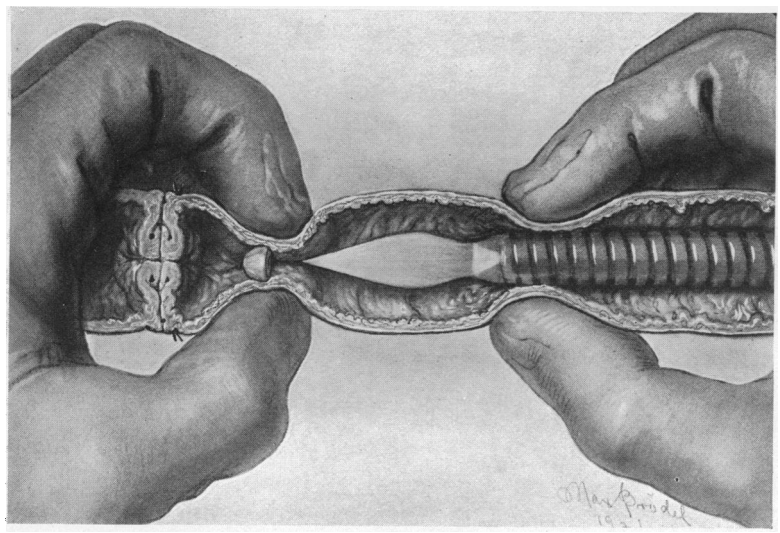

FIG. 12.—Removal of the cork.

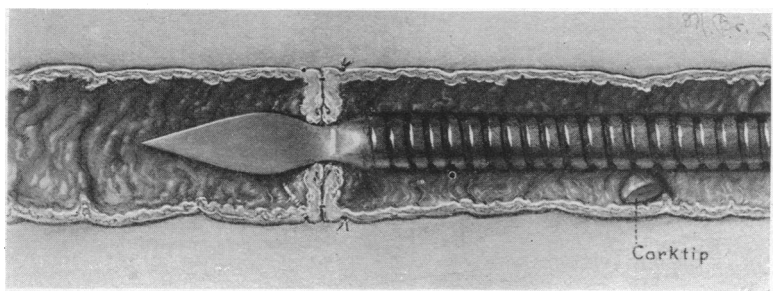

FIG. 13.—The cork pressed downwards and the purse-strings divided.

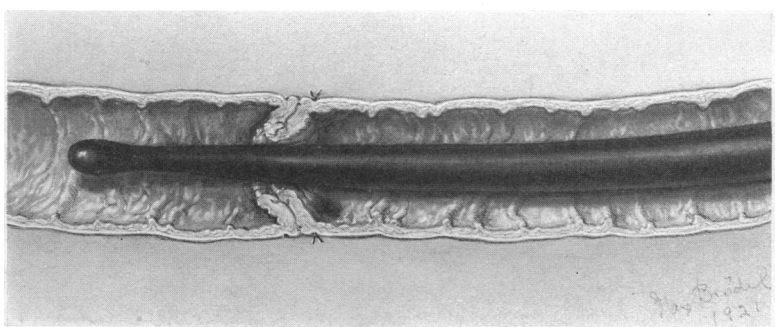

FIG. 14.—Bougie passed for control.

Sutures falling into the lumen of the bowel, being quickly transported, are lost; only such are discoverable as happen still to be attached to the intestinal wall when the animal is sacrificed. Those discarded on the peritoneal surface may remain for several years and be distinctly seen shimmering under an endothelial film. The more perfect the operation the fewer the adhesions, and frequently one finds every one of the loops outside if the mattress stitches have been happily made. Undoubtedly in the hands of novices most of the stitches penetrate the mucosa; nevertheless many of these perforating mattress stitches cut their way outwards; when they have pulled through the mucosa, the fistulous tract becomes sealed from within and the suture's passage towards the peritoneum may thereafter be a clean one.

The slogan "knots inside" naturally makes an appeal, for it seems universally to be taken for granted that the threads necessarily work their way into the lumen. Year after year for thirty-five years I have had opportunities to convince myself of the fact that in the cases which heal most ideally the stitches come to the peritoneal surface. The omental adhesions to the line of suture in such cases are very light (occasionally they are absent) and in a few weeks, in a few days even, may be absorbed and have left no trace.

Consulting the original paper of Lembert,[9] I was interested to find that his stitches were cast off into the bowel. He states this definitely and makes no mention of having ever seen at autopsy a loop of thread shimmering under the peritoneum. This fact of itself suffices to prove that his stitches, contrary to the universal belief, were perforating ones. But we do not require this particular proof, for he distinctly states that he intentionally entered the lumen of the intestine with his needle, except when the wall was thick; and in this event the needle *glided*[10] between the coats. Now it is questionable, I think, that even in the thick-walled cases he slid the needle between the coats without entering the intestinal lumen. He apparently knew nothing of the existence of the submucosa, and his needle, if it "glided," must have passed on one side or the other of this coat—either between the muscular and submucous coats, or between the latter and the mucosa; it could not *glide* along *in* the tough submucous coat. If the stitches had included only the peritoneal and muscular coats they would have split the longitudinal fibres, have constricted or crushed the circular ones and at best have had an insecure hold; and if they had perforated the submucosa they undoubtedly entered the intestine's lumen. Thus, in all probability, Lembert's stitches quite invariably entered the lumen, whatever the thickness of the bowel's wall; and, in any event, Lembert intentionally perforated the wall unless it was thick. Hence the Lembert stitch has been universally misunderstood, and the erroneous

[9] A. Lembert: Mémoire sur l'entéroraphie, avec la description d'un procédé nouveau pour pratiquer cette opération chirurgicale. Répertoire gén. d'anat. et de physiologie pathologiques, etc. Paris, 1826, vol. ii, p. 100.

[10] A. Lembert, *l. c.*, p. 105: "L'aiguille pénètre à 2 lignes environ du bord saignant droit, dans la cavité de l'intestin, ou bien sa pointe glisse entre les tuniques musculeuse et muqueuse, suivant que l'intestin est plus ou moins épais."

description of some early author has been passed on from one writer to another until the present time. Picture the amount of soiling there must have been in Lembert's experiments. In placing his stitches he introduced a finger into the bowel, using it as a guide, as a darning ball.[11] Furthermore, the stitches perforated the intestinal wall and were discharged into the lumen. Nevertheless the five dogs upon whom he operated all recovered.

In the entire literature of intestinal suture there are, perhaps, no more impressive examples of nature's ability to protect against man's faulty operative methods than those furnished by Merrem's[12] resections of the pylorus (1809 and 1810).

Merrem excised the pylorus in three dogs—two in 1809 and one in 1810. In the first dog, attempts at invagination being unsuccessful, the raw edges of the stomach and duodenum were apposed and held by only three stitches. Death occurred on the twenty-third day from "inanition"; there was no peritonitis, and the suture-line was so well healed that no trace of it remained.

In the second and third dogs the stomach was invaginated into the duodenum—serosa apposed to mucosa. The second dog recovered; the third died. In all of the experiments the threads of the gastro-enterorrhaphy were brought out of the abdominal wound and fastened to the surface with adhesive plaster. The severed pyloric artery could not be tied on account of its depth; the hemorrhage was checked with sponge and spirits.

Let those of us who are inclined to be content with our present methods of end-to-end anastomosis bear in mind these experiments of Merrem and of many other early research workers and observe on animals the early stages of repair of our own intestinal sutures, to the end that we may understand the part that nature plays to protect the patient from the crudity of our handiwork.

Notwithstanding much experimentation, we have been unable to improve upon the method developed thirty-five years ago,[13] unless perhaps the procedure submitted in this communication shall prove to be an advance. We have at least learned in recent years that it is safe, and probably advisable, to make a deeper inturn, and have devised a cleaner procedure. It remains to be determined whether in the blind-end method the continuous suture

[11] Lembert, *l. c.*, p. 106: "Le chirurgien, . . . porte l'index de la main gauche dans la cavité de l'intestin, de manière à soutenir les bords saignans avec la pulpe de ce doigt."

[12] Merrem's paper (Animadversiones quædam chirurgicæ experimentis in animalibus factis illustratæ. Giessæ, 1810) is listed in the Index Catalogue of the Surgeon General's Library, but could not be located. Therefore I wrote to Professor Payr, who, unable to find it in Leipzig, kindly sent me Carl Langenbeck's abstract (Abschrift eines Referates von C. J. M. Langenbeck, Professor der Anatomie und Chirurgie, Direktor des chirurgischen Spitals in Göttingen, aus Bibliothek für die Chirurgie, 4. Band, 1. Stück. Göttingen. Rudolph Deuerlich, 1811). I appealed also to Prof. Felix Landois, of Berlin, who found Merrem's paper and sent me quotations from it which he had graciously translated into German.

[13] W. S. Halsted: Circular Suture of the Intestine—an Experimental Study. Amer. Jour. Med. Sci., Philadelphia, 1887, n. s., vol. xciv, p. 436.

will yield results as good as those we have obtained by the mattress stitches. Better they can hardly be.

For lateral anastomosis the mattress stitches possess the advantage that they can all be taken before the bowel is opened, that one row of them suffices, and that infection of one stitch is unlikely to be conveyed to the others.

As stated earlier in the paper, it is not known how deep the inturn should be. It may safely be assumed, however, that the deeper the inturn the better, provided obstruction is not produced by it. Granting this, how many rows of suture should be made? Fortunately the apposed serous surfaces of the diaphragm tend to remain firmly in contact. That the process of unfolding begins promptly we know from the rapid cutting outwards of the properly placed sutures as well as from early observations on the mucous side; and from this continuous effort to unfold we infer the force maintaining the peritoneal surfaces in contact from the line of suture to the raw edges. Every stitch, whether essential or superfluous, interferes more or less with the circulation, hence the necessity for eliminating any that may be unnecessary. In circular suture of the intestines of a variety other than the blind-end we have advocated (1887, *loc. cit.*) a few presection stitches, taken chiefly with the purpose of preventing the outward rolling of the bowel wall and thus facilitating the introduction of the mattress row.

If we bear in mind that every perforating stitch is a source of danger, however slight, as well as a menace to the circulation, our efforts will be directed towards the suppression of unnecessary stitches and the cultivation of the sense which makes possible the appreciation with the needle's point of the resistance offered by the submucosa. That in resection of the human colon one row of mattress stitches is better than two, I am not as yet prepared to affirm, but in the dog it has given results in the blind-end suture so perfect that I should regard a second row as a factor of danger rather than security.

The more perfect the execution of any method of end-to-end anastomosis, the less reaction about the line of suture and the greater the rapidity of the unfolding of the inturn, of the complete restoration of the lumen of the bowel. In one of our specimens, for example, little remained of the diaphragm on the tenth day; in another there was no trace of it on the seventeenth day. On the other hand, the inturn in one case was about as deep on the 109th day as at the beginning. An exceptionally bad result in this case (an early one) was predicted because the force required to puncture the diaphragms with the three broad knives was so great that the stitches (perforating ones) tore little streaks in the bowel walls. The operation was cleverly performed by an eminent European surgeon who had not practised the submucous stitch. The animal's recovery and normal convalescence were surprising; at no time in the 109 days after operation were there symptoms of obstruction. It will readily be understood that great reaction, causing matting of the omentum and intestines about the line of suture, may lead to the formation of fibrous tissue in the infiltrated intestinal wall so dense and so extensive as to delay for a long time, and possibly permanently

prevent the complete unfolding of the inturn. The surgeon should bear in mind this fact, unemphasized perhaps hitherto, and the experimentor in testing the relative merits of the various procedures for lateral as well as end-to-end anastomosis should note the rapidity of the unfolding and accept the tardy disappearance of the flange as evidence of a faulty technic either of method or execution or both.

The opportunity has not as yet presented at the Johns Hopkins Hospital to perform the blind-end suture on the human subject. We shall probably test it first on cases in which a lateral anastomosis is not feasible. The knife passes readily to the ileocæcal valve in the dog, and in one instance Doctor Holman, after resecting the cæcum, abutted the closed ends of ileum and ascending colon and cut the diaphragms with the knife; the dog recovered normally. When the splenic flexure is hooked high (Payr's Doppelflinte) it might be difficult without mobilizing to traverse it with the knife. But for resections of the descending colon, of the sigmoid flexure, of the rectum when the sphincter is to be preserved, and possibly of the gastric end of the œsophagus, the method deserves, I believe, a trial.

I am greatly indebted to Dr. F. L. Reichert and to Dr. Emile Holman for assistance in every phase of the work. Dr. Mont Reid also has most kindly aided me in many ways. A detailed report of the experiments will be made later by Doctor Reichert and Doctor Holman.