

Studies in Intestinal Healing:

III. Observations on Everting Intestinal Anastomoses

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IN *An Inquiry into the Process of Nature Repairing Injuries of the Intestines*,⁹ Benjamin Travers in 1812, wrote, quite soundly, "The union of a divided bowel requires the contact of the cut extremities in their entire circumference . . . The species of suture employed is of secondary importance if it secures this contact." He pointed out that healing was dependent upon peritoneal adhesions and that contiguous mucous surfaces might agglutinate but that "The opposed villous surfaces, so far as my observation goes, neither adhere nor become consolidated by granulation, so that the interstice marking the division internally is probably never obliterated." Today credit for the recognition of the importance of an inverting suture of the bowel with serosa-to-serosa apposition is generally assigned to Lembert,⁴ although he indicated that Dupuytren had proposed this. Perhaps of particular interest is the fact that although it is generally stated that Lembert's suture did not penetrate into the lumen, his own initial account indicates that it was a matter of indifference whether the suture penetrated through into the lumen or between the muscular coat and the mucosa. "L'aiguille pénètre dans la cavité de l'intestin ou bien sa pointe glisse entre les

tuniques musculouse et muqueuse suivant que l'intestin est plus ou moins épais." The submucosa was not mentioned. The cardinal importance of the submucosa as the single tough layer in the intestine was pointed out by Halsted² who also emphasized the importance of avoiding penetration into the lumen to protect the suture tract from contamination.

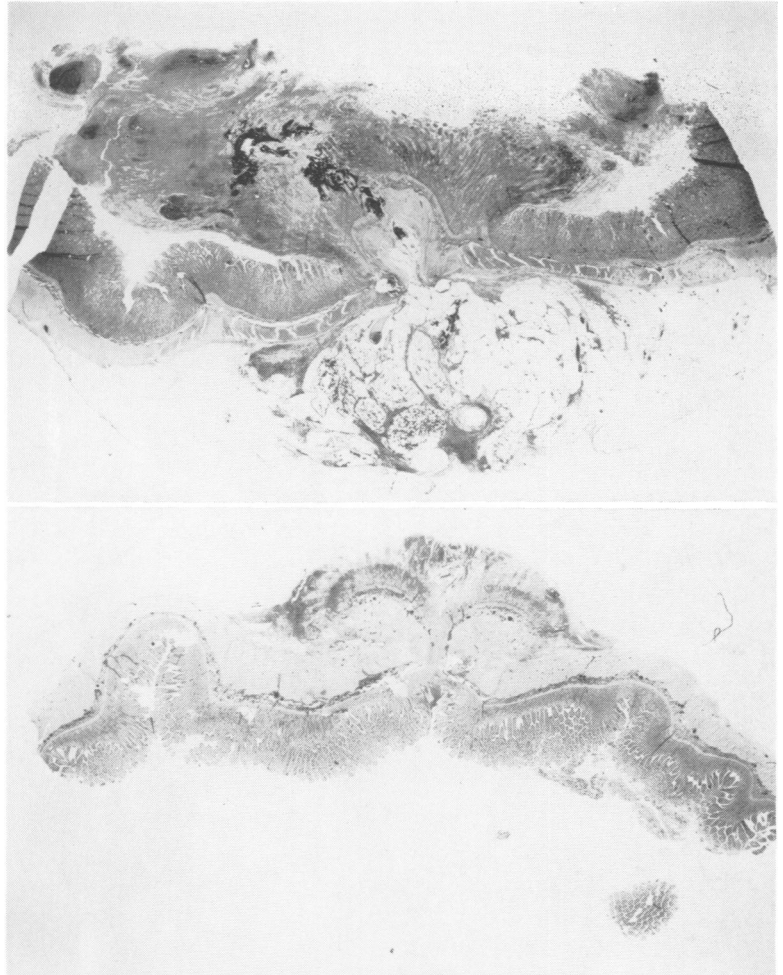
In the course of evaluation of the application of mechanical stapling devices to intestinal closure, we observed that healing was regularly achieved by the simple through-and-through closure of the cut end of the stomach, duodenum and large or small bowel with two staggered rows of wire staples. Healing occurred without abscess formation, localized peritonitis or excessive inflammation to suggest even a temporary leak.⁶ It was apparent that mucosa-to-mucosa, staple closure of bowel secured a sufficiently tight seal to allow primary healing and to prevent leakage or significant bacterial contamination of the peritoneal cavity. It seemed possible, therefore, that this method of closure might be applied to end-to-end, mucosa-to-mucosa, everting-anastomoses. The principal attraction of an everting anastomosis is the fact that there is little risk of narrowing the bowel at the point of anastomosis, whereas in an inverting anastomosis, it is a matter of technic as to whether one decreases the size of the lumen much or little.

A series of end-to-end everting anasto-

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FIG. 1. Anastomoses at 6 hours. (Top) Inverting. There is a large mass of inverted tissue with a large clot of hemorrhagic coagulum projecting into the lumen. On one side the suture hole can be seen and although it is properly placed through the submucosa, there is not very strong apposition of the tissues at this level. The serosal fat in this section being taken through the mesentery, is moderately infiltrated and the surface is smooth. (Bottom) Everting anastomosis. There is a smoothly covered serosal wedge of hemorrhagic coagulum already covered by a smooth layer of what may be mesothelial cells. The suture holes can be seen on both sides and there is obviously very firm apposition of the two sides. India ink is seen on both sides, but this is the result of an improper injection into a vessel feeding both sides. The mucosal surface is remarkably smooth, there is no intraluminal protrusion, the mucosa appears at this power, to be united and the everted mucosa appears to be undergoing necrosis and resorption.



moses in the intestines of dogs was performed with the Russian vascular stapling machine. Although this instrument was devised for the more delicate tissues of blood vessels, these anastomoses were uniformly successful, counter to accepted doctrine. It appeared that this was due to the formation of adhesions around the suture line, although we had not encountered adhesions so dense or so thick as to constitute an effective seal. To test this hypothesis, a number of end-to-end everting intestinal anastomoses were lightly wrapped with polyethylene fabric or thin rubber sheathing, the oblong of fabric tacked to itself through the mesentery above and below the anastomosis. When anastomoses invariably broke

down and animals died of abscess or peritonitis, the thesis of the dependence of an everting anastomosis upon adhesions seemed to be proved. As an afterthought, a number of end-to-end inverting silk anastomoses of standard type were similarly covered and three of nine animals died with abscesses and peritonitis.⁷

The most reasonable explanation of this phenomenon was that even with the ordinary inverting anastomosis performed as an open anastomosis in a bowel not prepared with antibiotics, there was enough contamination of the peritoneal surfaces in the area of anastomosis to cause infection, which if isolated from the protective defenses of the peritoneum by the interposed

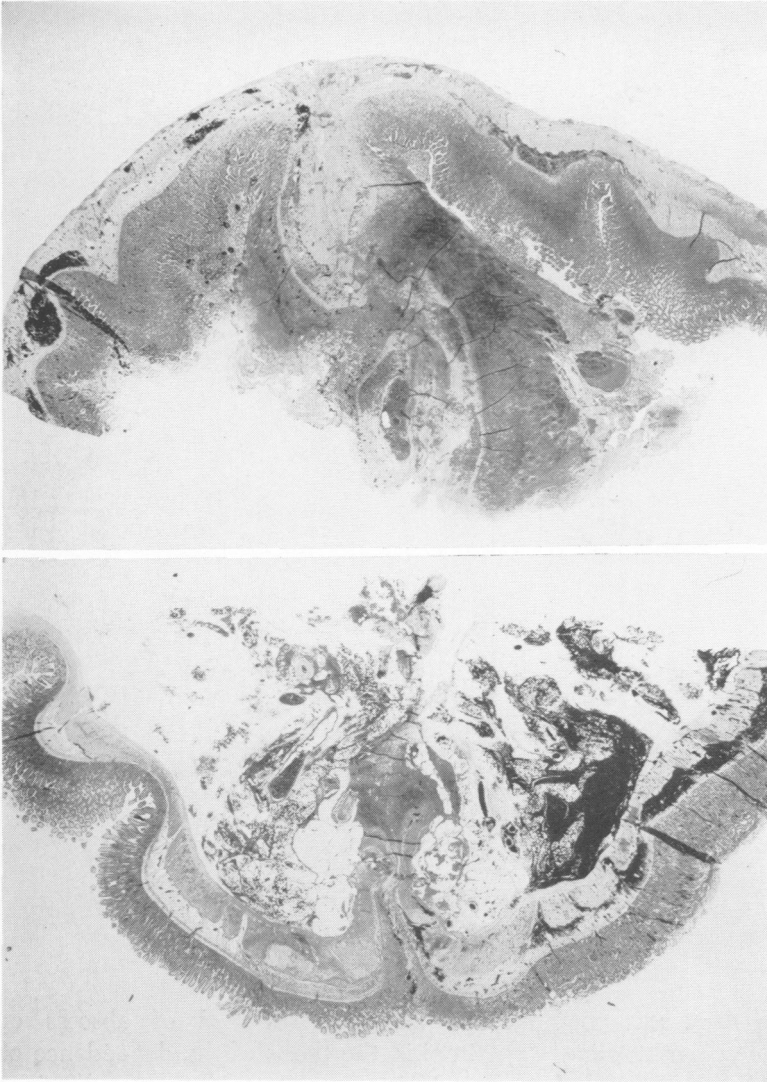


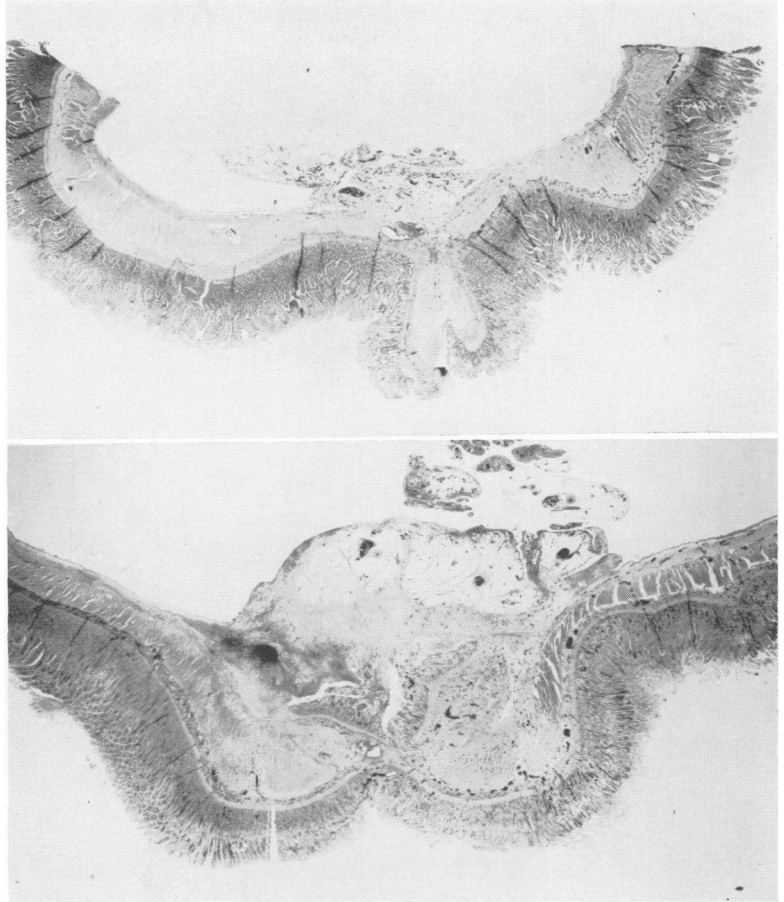
FIG. 2. Anastomoses at 12 hours. (Top) Inverting. The intraluminal protrusion of swollen hemorrhagic mucosa covered by hemorrhagic coagulum is more prominent than at 6 hours. The inverted flange seems firmly agglutinated at its base by the suture. (Bottom) Everting anastomosis. The mucosal surface continues smooth and unbroken, there may be a little crossover of India ink and the everted mucosa is not recognizable. There is remarkably little inflammation any where along the line of union or in the everted coagulum.

foreign material would result in infection around the suture line, rapidly proceeding to areas of necrosis, leaks and fatal peritonitis.

We now undertook a systematic study of everting and inverting anastomoses. In the first series five intestinal suture methods were employed, in groups of 24 dogs. In each group, 12 animals were prepared with oral antibiotics prior to operation and 12 were not, and half of each set of 12 had the anastomosis wrapped with a layer of fine silastic gauze and half did not. The

anastomotic methods were: Group I—Everting anastomosis, one layer of interrupted silk mattress sutures placed through and through, parallel to the cut edge. Group II—Everting anastomosis with the Russian ASTS 20 vascular stapling machine designed for suturing vessels 9–20 mm. in diameter, with a ring of one row of stainless steel staples parallel to the cut edge. Group III—An inverting anastomosis, open, with a single layer of interrupted Halsted sutures of silk. Group IV—An inverting anastomosis, open in two layers, inner of

FIG. 3. Anastomoses at 7 days. (Top) Inverting. Intraluminal hemorrhagic plug has been resorbed. Submucosal layers of the two sides seem to have fused at the level at which sutures had been placed, but intraluminal flange persists and its surface is still granulating and uncovered by mucosa. (Bottom) Everting. Mucosal surface healed and continuous, and one can see free crossover of the India ink. The serosal surface is quite smooth and most of the everted mucosa has been resorbed although in this section one can see retained mucosa and a cleft between the mucosa from the two sides. It is happenstance whether the section is taken quite close to the sutures, in which case one will see a firm mucosal union or between sutures when one may see an open cleft going up into the everted flange. There is not now, nor has there ever been in the everting anastomosis, any inflammation on the mucosal side although there is still at 7 days, more cellular reaction on the serosal side than is present in the inverting anastomosis.



continuous catgut and outer of interrupted silk. Group V—A closed inverting silk anastomosis with one layer of silk sutures. The details of these experiments are reported elsewhere.⁸ The wrapping with silastic gauze was as uniformly deleterious to inverting as to everting anastomoses and unaffected by previous preparation of the animals with antibiotics. The few survivors with a wrapped anastomosis had been prepared with antibiotics, but in most of these the silastic gauze had become displaced and was not actually covering the anastomosis. The chief benefit of antibiotics appeared to be a distinctly lessened degree of intra-abdominal adhesions. Of the theoretical possibilities accounting for the disruption of suture lines in the presence of

loose wrapping of the anastomosis with silastic gauze, three seemed most likely: 1) Contamination at the time of operation and 2) Continued seepage of bacteria through the suture line in both inverting and everting anastomoses for minutes or hours after the operation. In either case, the bacteria were protected from the peritoneal defenses by the foreign material. 3) Interference with or prevention of a peritoneal sealing-off and healing, with delayed leakage.

The matter of the sealing-off of the mucosa-to-mucosa everting anastomoses and the manner in which healing is produced were of particular interest since quite obviously, and as Travers observed, an uninjured mucosa cannot heal to uninjured

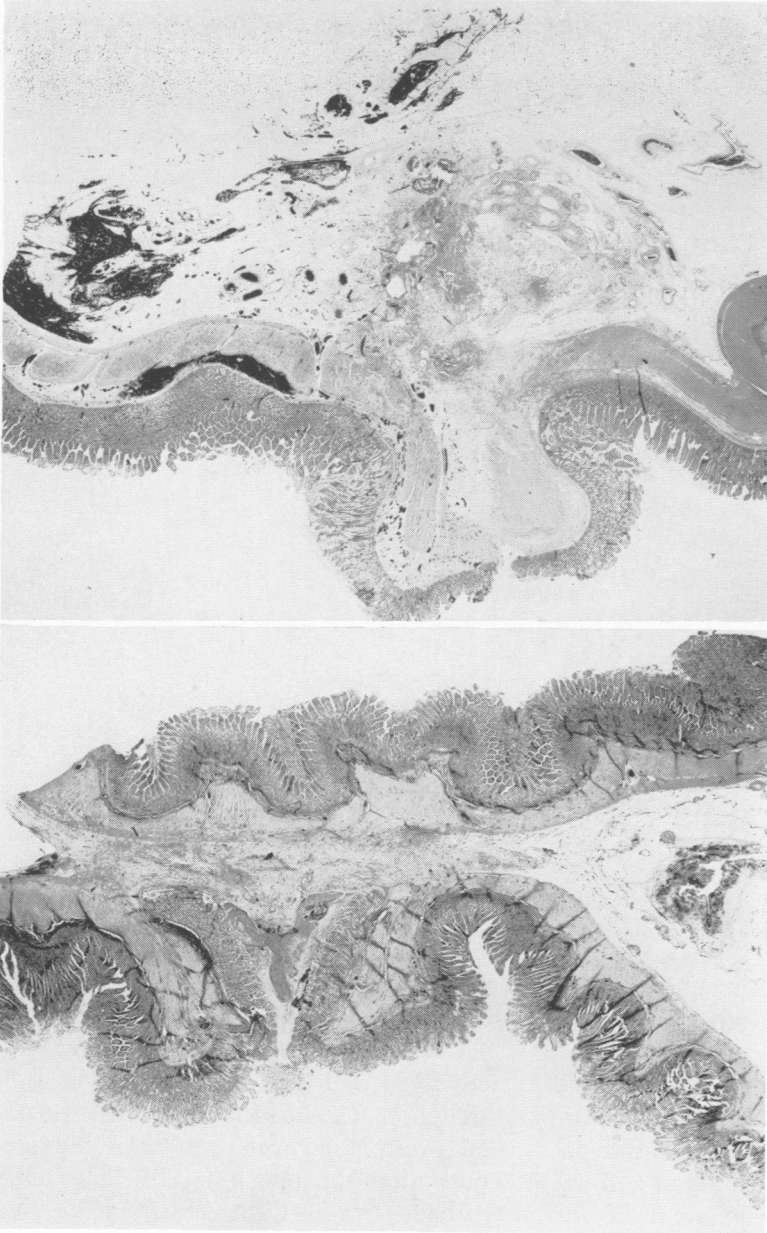


FIG. 4. (Top) Inverting anastomosis, two weeks. There is a minimal crossover of the India ink, still a substantial intraluminal protrusion, still incomplete mucosal coverage of the inverted flange and in this animal, considerable inflammation of the mesenteric fat. (Bottom) Inverting anastomosis, three weeks. This section was taken to show the adherence of another loop of bowel and having been taken between sutures, shows the cleft still within the everted flange, although there is only a moderate inflammatory response about it.

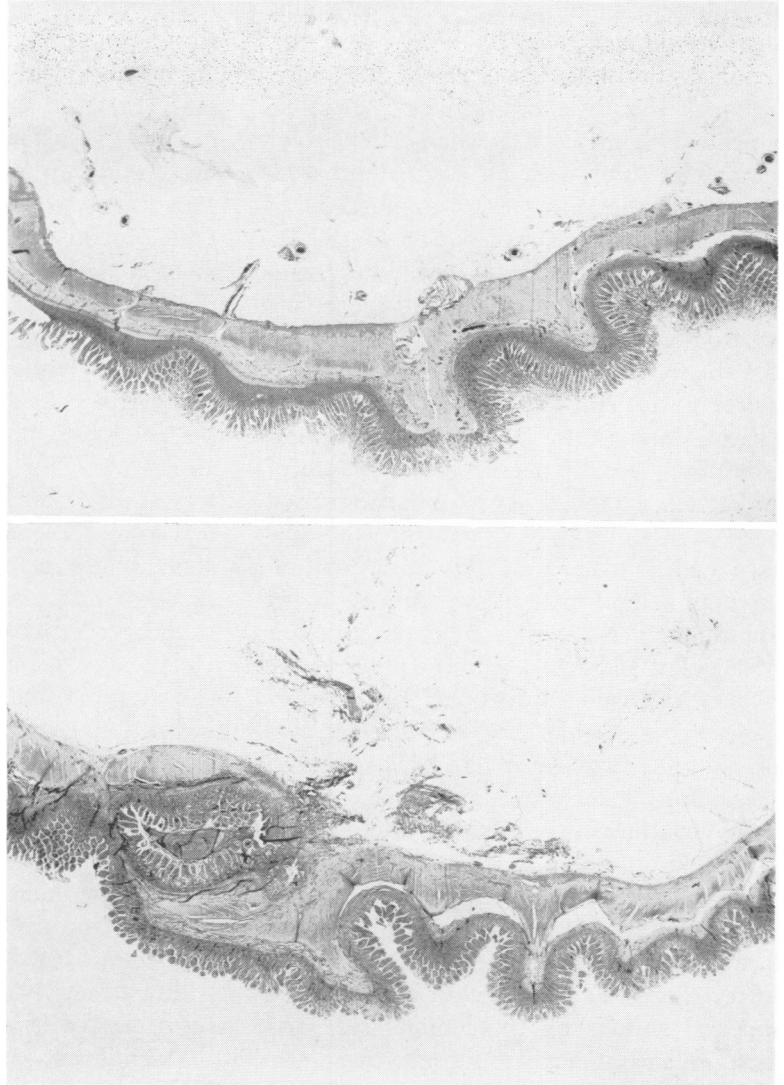
mucosa and experiments were performed to attempt to elucidate the manner of healing.

In 60 dogs operated upon in pairs without antibiotic preparation, everting and inverting anastomoses were performed with sutures of 4.0 silk. In both cases, Halsted mattress sutures were used, the everting anastomoses being produced by through-

and-through sutures with the bar of the mattress suture parallel to the cut end. No attempt was made to trim or to oversew the flange of everted full-thickness bowel.

At intervals of from 6 hours to 6 weeks, animals were anesthetized and the mesenteric vessels occluded so that the bowel on one side of the anastomosis could be separately injected arterially with an India ink

FIG. 5. Anastomoses at 12 weeks. (Top) The inverting anastomosis is completely healed and stabilized. The mucosa has grown over the intraluminal protrusion which is not now very impressive and there is no remaining residual inflammation. (Bottom) Everting. The mucosal surface is smooth and the serosal surface shows very little evidence of inflammation although there is some around what appears in this section like encysted mucosa. Sections taken a little more to one side would show a much broader band of tissue between the healed mucosa and the apparent buried cyst whereas sections taken a little further on the other side would show an open mucosal cleft.



suspension. Any pigment which appeared on the other side of the anastomosis would be due to vascular anastomosis occurring across the suture line. The animal was killed and appropriate histologic studies performed.

The findings were surprising. In the 6-hour studies, there was closer apposition of the bowel wall in the evverting than in the inverting anastomoses, and an astonishing degree of hemorrhage and edema of the inverted mucosa and submucosa in the inverting anastomoses. By 12 hours little

mucosa was recognizable in the everted flange, whereas on the inverted flange, there was hemorrhagic, necrotic, edematous mucosa. There was more intense polymorphonuclear response in the inverted flange than in the everted flange. In both types of anastomosis the cleft in the flange, everted or inverted, was filled by a wedge-shaped plug of hemorrhagic coagulum. In the evverting anastomosis, this was already laminated and smoothed out on the serosal side by 12 hours by which time, the mucosal surface on the exerting anastomosis

was already smooth and neat. By 72 hours, the everting anastomoses showed complete union of the mucosa on the luminal side, although there was still some recognizable mucosa either in the anastomotic cleft or superficial to it with an area of granulation tissue separating the two. In general, there was an earlier crossover of the injected India ink in the everting anastomoses, which began to occur in the everting anastomoses as early as 48 hours although the differences may not have been significant. At the end of a week, the everting anastomoses showed a smooth mucosal continuity, usually a crossover injection of India ink, a modest external inflammation and an organizing scar covering the surface with occasional islands of discontinuous epithelium externally. The inverting anastomoses showed infrequent crossover of injected India ink, a fibrin plug on the mucosal side which was still largely pyogenic and a sizable intraluminal projection of the inverted flange. It took about 2 weeks for the inverting anastomoses to develop continuous mucosa on the luminal side.

It was disconcerting from the standpoint of histologic appearance to find at 3 and 6 weeks when the inverting anastomoses were essentially healed with a continuous mucosal surface on the luminal side and little inflammation, that the everting anastomoses showed an apparent discontinuity of the mucosa with a zone of polymorphonuclear inflammation in the cleft, sometimes with and sometimes without islands of epithelium buried in the zone of fusion.

The relative characteristics of inverting and everting anastomoses observed in these studies were as follows. In the immediate postoperative period there was substantially more inflammation, edema and hemorrhage in the inverting anastomoses and considerable infringement upon the lumen by the edematous and hemorrhagic inverted flange which for some days appeared to be the site of a much heavier

inflammatory response than the everted flange. The mucosal surface of the everted anastomosis surprisingly was almost normal. However, some weeks later, when the inverting anastomosis had already stabilized and assumed its permanent condition, it was seen that the apparent mucosal union in the early stages of the everting anastomosis was illusory and that a cleft persisted in which an active inflammatory response remained.

Our observations of the early histologic appearance of the two types of anastomoses reinforced those of Getzen, Roe and Holloway.¹ Our observations at later intervals did not show as much difference in favor of everting anastomoses from the standpoint of completion of healing and absence of inflammation. Nevertheless, these experiments and those of Getzen, Roe and Holloway,¹ Hamilton³ and of Mellish⁵ clearly refute the idea that serosa-to-serosa apposition is necessary for the successful performance of intestinal anastomoses. It was obvious and clearly demonstrated in our work and in that of others^{1, 3} that inverting anastomoses produce some obstruction to the lumen. To avoid obstruction, one must accept the increase in adhesion formation caused by everting anastomoses. Although survival of animals without abscess, peritonitis or obstruction would seem the significant criterion, Getzen, Roe and Holloway reported that the tensile strength of the inverted anastomosis is only two-thirds as great as that of the everted anastomosis up to 21 days. Hamilton tested the leaking pressure of various types of anastomoses distended with air and found that inverting anastomoses was airtight at higher pressures than everting anastomoses. Mellish⁵ found no difference in airtightness in inverting and everting anastomoses in rats.

It is important to point out that the suture employed by Getzen, Roe and Holloway begins as an everting suture, but probably shortly after the suture has begun to

cut through, results in an end-to-end anastomosis without much of a flange. A mattress suture parallel to the cut edge results in a true and persistent eversion providing a more radical test of the principle of eversion.

The everting anastomosis even in the extreme form employed by us probably heals because fibroblasts penetrate through the suture holes into the tissue compressed by the sutures. Leakage, abscess and peritonitis seem to be as unimportant as in traditional inverting anastomosis. Luminal obstruction is essentially avoided, but adherence to other viscera and the abdominal wall is common.

The technic of everting anastomosis is simpler than that of the inverting anastomosis. If there is difference in tensile strength between everting and inverting anastomoses in favor of the former, it is probably due to the fact that in the everting anastomosis there can be no uncertainty about including the submucosa in the suture. The immediate excess of inflammation in the inverting anastomosis is significant only in the contribution this makes to obstruction because of swelling of the inverted flange. The apparent prolongation of inflammatory response in everting anastomoses may not appear to be clinically significant, on the other hand it does produce undesirable delay in healing. To us, the chief disadvantage in the everting anastomosis is the invariable increase in adhesions.

From the standpoint of our interest in the development of mechanical suturing apparatus, it is obvious that everting anastomoses are more feasible with a one-step suturing device than are inverting anastomoses. Consideration is now being given to devising a stapling apparatus which will compress the portion of the everted flange peripheral to the stapled suture line to the point of obliteration. It is hoped this will eliminate adhesions and lead to rapid healing free from inflammation.

Summary

Everting anastomoses with a single row of mattress sutures parallel to the everted edge of small bowel or with a single row of metal staples heal as well as inverting anastomoses.

With either inverting or everting anastomoses there is an almost universal disruption of the suture line if the region of the anastomosis is lightly wrapped with a sheet of pervious or impervious foreign material.

The immediate histologic appearance of everting anastomoses is superior to that of inverting anastomoses in terms of absence of intrusion upon the lumen, minimal inflammation, and closer apposition of the anastomosed surfaces.

Vascular injections suggest that arterial anastomoses occur across the suture line sooner in everting than in inverting anastomoses.

Peritoneal adhesion formation is greater with everting than with inverting anastomoses.

Despite earlier preponderance of inflammation in the inverting anastomoses, studies after several weeks show essentially stable and completed healing in inverting anastomoses at a time when there is still an inflammatory response in everting anastomoses and incomplete mucosal healing.

The technical simplicity and mechanical superiority of everting anastomoses justify continued work toward the technical solution of the problem of external adhesions and delayed mucosal union.

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DISCUSSION

DR. WILLIAM H. MORETZ (Augusta, Ga.): Dr. Bricker, Members and Guests: I wish to inject a note of caution about clinical application of the everting intestinal anastomosis.

In our laboratory Drs. Jennings, Vaughan and Rhode are making a similar study, which, although not yet completed, indicates a significant increase in the tendency of the everting intestinal anastomosis to leak. After excising the omentum in 19 dogs, single everting anastomoses using the horizontal mattress suture, which Dr. Ravitch described, were made in the small intestine. In ten dogs the mucosa was excised between the everting edges of bowel, and in nine the mucosa was left in place. Two of the nine dogs with mucosa intact died of peritonitis. None of the ten dogs with the mucosa excised died.

In 20 dogs the omentum was left in. Ten of these had single everting anastomoses with the mucosa excised, and all lived. Ten had single or multiple anastomoses with the mucosa left in, and five of these ten dogs died.

In addition, the survivors with the mucosa separating the everting edges had far more adherence of surrounding structures to the anastomoses than did those with the mucosa excised.

These observations, admittedly limited and as yet without complete matching controls, suggest that the intervention of mucosa between tissues is detrimental to healing, and may lead to more leakage from intestinal anastomoses. We advise caution in accepting the everting intestinal anastomosis for clinical use. I have enjoyed the paper very much.

DR. CLARENCE DENNIS (Brooklyn, N. Y.): Dr. Bricker, Members and Guests: It's refreshing to learn of this new look at everting anastomoses which Dr. Ravitch and his associates have just reported.

Several years ago my associates, Dr. Charles Fries and Dr. Sigmund Wesolowski, impressed with earlier reports such as that of Dr. Yoshio Sako 20 years ago concerning everting anastomoses, included everting anastomoses as one of the six different types of end-to-end jejunal anastomoses performed in suckling Cheshire pigs to permit evaluation of growth as the pig grew to the adult weight of 200 pounds, a tenfold increase in weight.

At slaughter, anastomoses were measured internally and externally by x-ray photography with

a standard degree of distention by fixed pressure. Similar observations had been made immediately upon the conclusion of the anastomosis. Sections were also made at slaughter.

In only one type of anastomosis, made in divided layers, did the anastomosis grow as the pig grew. (Slide) Others, including the very oblique closed anastomosis with rotation of one end with respect to the other which I proposed 30 years ago, compensated for lack of prolongation of the suture line by adoption of a more transverse orientation of that suture line, such that the lumen at slaughter was no smaller than the bowel just above or just below.

All other anastomotic patterns resulted in relative, if not absolute, stenosis.

(Slide) While the everting anastomosis, which was constructed in 40 pigs, was simple to make and did not leak or give rise to much more extensive adhesions than those seen in the others, it was the only anastomosis observed to decrease in absolute diameter while the rest of the animal grew, and inadequacy of some lumina as the pigs got bigger resulted in death from obstruction.

In conclusion, the everting anastomosis appears advantageous in the solution of the acute problem in the very young patient with a minute intestine, but it is precisely in these infant subjects that the later constriction of the suture line may be expected to cause obstruction as the subject grows. It is hoped that Dr. Ravitch's observation may lead to a technique which will provide a long enough initial line of anastomosis to answer the needs of the patient throughout a normal life span.

DR. J. ENGLEBERT DUNPHY (San Francisco): It's always difficult to have our firmly established concepts challenged, and I think most of us have grown up with the concept that the inverting, Halsted type of anastomosis was essential to proper healing.

It is important to point out that Halsted emphasized an adequate blood supply and a sub-mucosal suture. He specifically warned against inversion—at least excessive inversion—and this was his reason for emphasizing the single-layer suture.

One problem that we face in trying to decide this particular variable is that healing in the colon is remarkably rapid. In contrast to skin or fascia, the bursting strength—and I emphasize bursting strength (blowing air into the lumen of the intestine) of the suture line reaches that of normal bowel within 10 to 12 days, and actually it be-