

# Closure of Duodenal, Gastric and Intestinal Stumps with Wire Staples: Experimental and Clinical Studies

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IN 1924, Aladar Von Petz,<sup>11</sup> of Hungary, described his instrument for temporary closure of gastric and intestinal stumps with staples of "New" (German) silver. He referred to the previous instrument of Hüttl and Fischer, but pointed out that its weight of 3.5 Kg. was a disadvantage. His own instrument was a large Payr's clamp, manually loaded with two rows of moderately large staples made of flat German silver. The staples were activated by a wheel which travelled the length of the clamp as it was manually turned, driving in the staples two by two. For temporarily sealing the cut end of a portion of the gastrointestinal tract, Von Petz thought his own instrument met his conditions that it be "quick, reliable, aseptic, and hemostatic."

Although the instrument is familiar in many institutions, its large size makes it moderately awkward, even for use on the gastric stump, and inapplicable to the duodenum. This, together with a certain awkwardness involved in the turning of the wheel, has prevented general adoption. Von Petz specifically stated that his instrument produced a "B" closure of the staples, but

those we have seen in use appear to have produced completely flattened staples. Apart from the fact that the Von Petz machine employs staples, it has little in common with the instruments whose use is described below. Surgeons other than Von Petz had introduced stapling instruments<sup>4</sup> but none seem to have achieved wide acceptance.

The family of instruments developed by the Scientific Research Institute for Experimental Surgical Apparatus and Instruments in Moscow in general depend upon a two-step action, first the approximation of the tissues to the required degree, and second, the driving home of the staples in the B closure. The Institute opened in 1951, and most of the instruments appear to have been developed by 1954. The first instrument developed for closure of the cut end of the stomach or bowel<sup>1</sup> placed a row of staples across the cut end of the stomach in one step, and then in a second step, inverted the first row, placing another row of staples which did not go through into the mucosa. About 1958 there became available a series of C-clamp instruments which placed staples in various patterns. That, for the bronchus, which we have used extensively,<sup>7,8</sup> placed a single row of staples across the cut end of the bronchus, the staples themselves being in the line of the axis of the bronchus. Others placed two rows of

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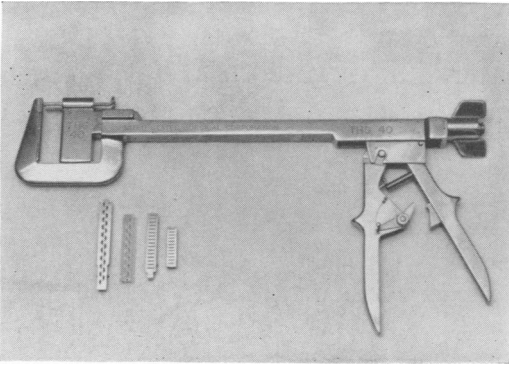


FIG. 1. C-Clamp Stapler, taking a 4.0 cm. cartridge. Shown are a steel 6.0 cm. cartridge, used with larger stapler for closure of gastric stumps, and a disposable plastic 4.0 cm. cartridge used for the duodenal stump for closure of bronchi, pulmonary vessels and pulmonary parenchyma. Both of these insert a double row of staggered staples whose bar is parallel to the line of closure. Below, in two sizes, are the cartridges of the stapler which places one row of staples, whose bar is at right-angles to the line of closure. This was designed specifically for the bronchus. With this instrument, if every other staple is removed, we get a spacing which is ideal for compartmentalization of the vena cava in the prevention of pulmonary embolism. For other uses it has, in general, been replaced by the previous double staggered row closure.

staggered staples, the long axis of the staple being parallel to the line of closure. This instrument was devised for the pulmonary parenchyma and for the pulmonary vascular hilum, and we have used it with satisfaction for this purpose, as have others in this country.<sup>2, 5</sup> It is probable that various surgeons in the Soviet Union have been using this latter instrument for closure of intestinal ends since 1958, although the first publication appears to be that of Gritsman in 1961.<sup>6</sup> P. I. Androsov, one of the surgeons most closely involved with the development of these instruments reported,<sup>3</sup> in 1957, an extensive experience with the instrument which puts in a single row of staples and then inverts that by a second row of staples which do not penetrate the mucosa. We have seen this instrument in operation. It is extremely ingenious in producing a two-layer inverting closure but is large and cumbersome. It would seem that the simple C-clamp, which with one operation

closes the gastric or duodenal stump, might be of particular interest to American surgeons.

### Experimental Studies

In order to provide a severe clinical test we have employed this instrument in dogs on duodenal, colonic, small intestinal and gastric stumps, without reinforcing sutures and without inversion or any other method of protection. The sealing was thus dependent entirely on the primary closure with two rows of staggered staples on the flattened cut end, mucosa to mucosa. The instrument was employed for 58 duodenal stumps, 58 gastric stumps, 24 small bowel ends and 30 large bowel ends,\* always *without inversion or additional closure* after the staples had been applied. Under such circumstances closure of the duodenal stump and of the entire cut end of the transected stomach required only a matter of seconds.

**Operative Results.** Several immediate observations were noteworthy. There was no blood loss and no leakage from the lumen. We had feared that the pressure involved in approximating the jaws of the instrument in the first step of its operation would hopelessly crush and necrose the tissue. This apparently was not so. 1) Minute bleeding points could be seen to form in the end of the cut submucosa after the stomach or bowel had been cut and the clamp removed. As it continued to form, this blood was wiped away and reappeared. 2) Histologic study of the progress of healing showed no significant evidence of necrosis and no massive destruction of tissue, and frequently mucosal epithelium survived in the flattened, stapled ends.

In 58 duodenal stumps closed in this manner there were no fatalities or evidences of leaks. In 58 gastric stumps, either across the entire cut end of the stomach—

\* On the small bowel and colon stumps, 3.5 mm. staples were used rather than the 4.8 mm.

or partially across, as for a Hoffmeister type of reconstruction—there was a single failure. This was in an animal, one of a series done in rapid succession on one afternoon, in which the instrument was applied fresh out of the sterilizer and so hot that it had to be held with a towel. Two days later the entire end of the stomach came away, undoubtedly as a result of the compression with the hot instrument fresh out of the autoclave.

In the 24 small bowel stumps and 30 large bowel stumps similarly closed, without reinforcement and without antibiotic preparation, there was a single instance of an abscess around a colonic stump, found at the time the dog was sacrificed, and no instance of peritonitis or other evidence of leakage.

Vilianski, Zveshneve, Zinoviev and Kotserov<sup>10</sup> in 1964, contributing from Omsk, in the book of the Institute on Clinical Experiences with the Stapling Instruments, stated that in dogs they found stapled closure alone to be sufficient, but like other Russian surgeons, also inverted the stapled closures in clinical practice.

It seemed an obvious extension of the application of this instrument to employ it for forming *Heidenhain pouches*. These can be prepared either by applying the instrument twice on each side of a "V" from the greater curvature, then cutting between the two applications, or much more simply by pulling out on the greater curvature with a Babcock clamp and subtending with the C-clamp the portion of stomach which it is intended to use for the pouch. The clamp is applied twice and the stomach cut between the two applications, requiring no sutures either on the gastric side or on the pouch side. The formation of a Heidenhain pouch in this way requires about 3 minutes. Four dogs were operated with the "V" technic. Three were sacrificed at 21 days, and all showed intact gastric pouches. On the last one, as a further demanding

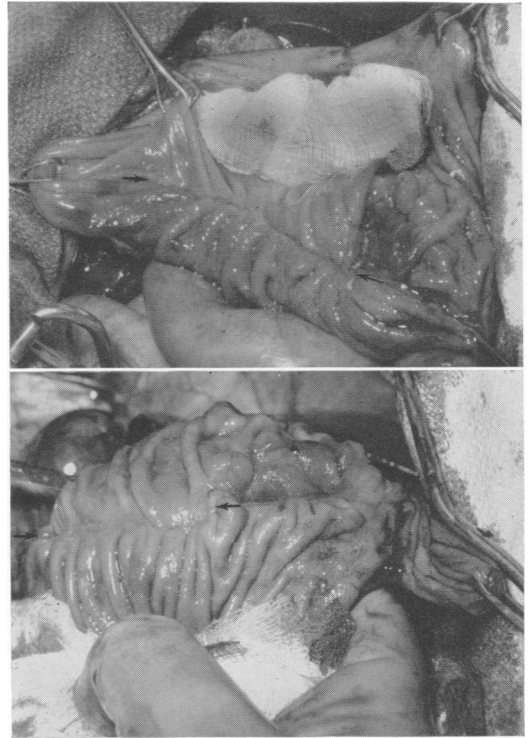


FIG. 2. Billroth II Gastrectomy, Hoffmeister Type, with the use of stapling instruments. (Top) Dog stomach, 33 days. (Bottom) 40 days after operation. In each case the stapled closure of about two thirds of the cut end of the stomach, is a fine mucosa-covered line. At 33 days the hand-sutured anastomosis, by contrast, still shows a good deal of edema and some of the catgut suture material can be seen still undigested.

test, the pouch was left without an external opening; this dog was killed 13 days later, and the pouch was found to have a small opening into the peritoneal cavity on the vertex of the "V." Curiously there were no apparent ill effects from this situation. In seven dogs the simplified technic was employed. One died at Day 6 after disruption of the stoma-skin juncture and consequent peritonitis caused by the dog having bit the tube. The other six were followed between 5 and 7 weeks with the pouches functioning satisfactorily.

Another obvious use of stapling instruments is for formation of greater curvature tubes, as in the Gavrilu procedure, and a longer jawed (9 cm.) C-clamp is being fabricated for such uses.

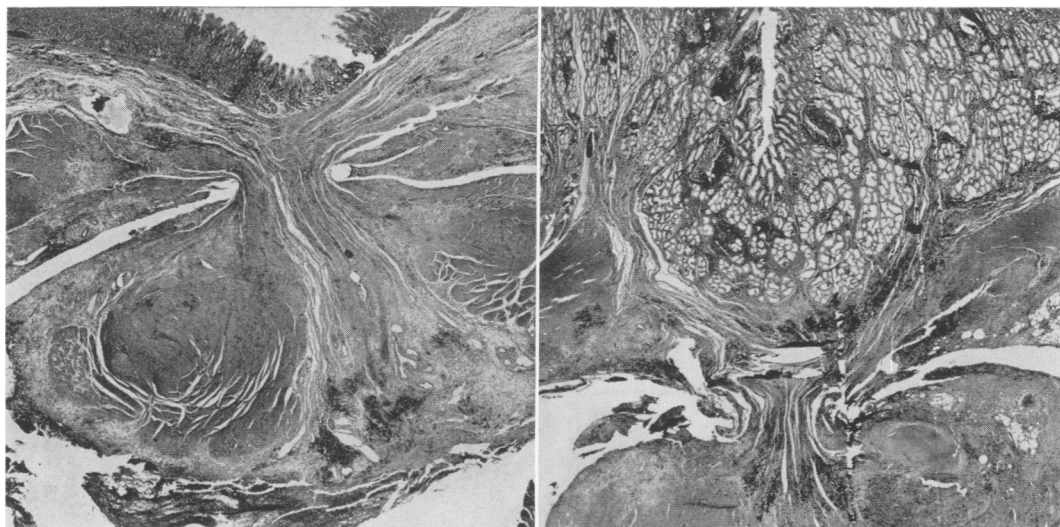


FIG. 3A. Photomicrographs of stomach and duodenum after staple closure. Stomach and Duodenum ( $\times 12$ ) 6 days after stapling. Notice regeneration of mucosa and relative acellularity of the scar connecting the muscle on either side. As in all experiments, the duodenum and the stomach were closed solely by the staples.

We have used both the Soviet instruments and the prototypes of the American modifications \* with equal satisfaction. The American instruments have disposable pre-loaded plastic cartridges facilitating clinical use, saving time and effort involved in loading, and minimizing the problem of cleaning the instruments. The original Russian staples were of tantalum, but both the current Russian and the American instruments now employ stainless steel staples.

*Pathologic Studies.* At autopsy the closures usually have omentum or loops of bowel etc., adherent to the stumps of stomach, duodenum or bowel. There was only the one pericolic abscess already mentioned, and evidence of inflammation has not been remarkably greater than with other types of closure.

Histologic study of the healed ends has shown good healing with strikingly little cellular reaction at any stage. Of particular interest, considering the manner in which healing takes place, in what is essentially a flat, mucosal surface to mucosal surface closure, is that *some epithelium survives* in the

approximated flattened tissue. Sometimes this is in crypts which communicate with the lumen, and at other times, in what appear to be microcysts. In animals sacrificed more than 6 months after operation these cysts are still minute. It seems improbable that they will ever cause any difficulty, but several animals are being kept for long-term study.

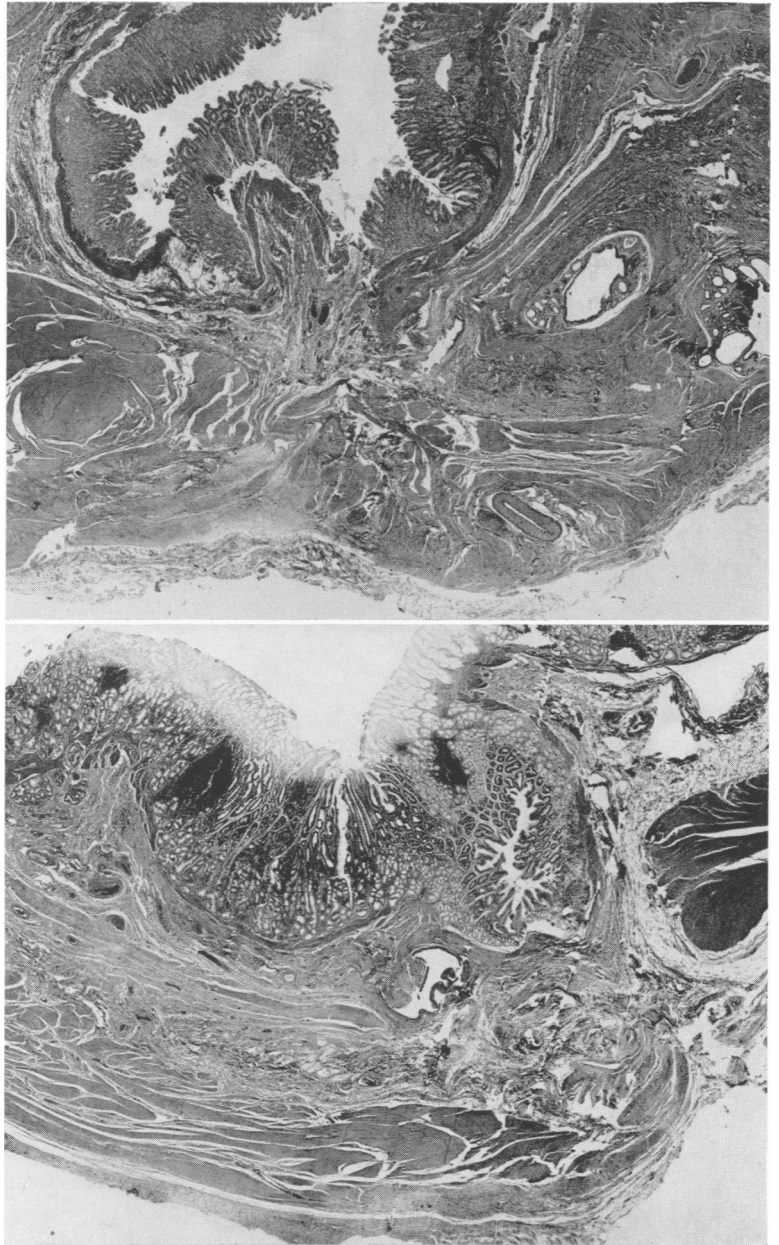
Survival of this epithelium is, at least, evidence that closure of the cut ends of the various portions of the intestinal tracts was not dependent upon complete necrosis of the mucosa, and a secondary fibrotic healing. At all stages the gross appearance within the lumen of the stomach or intestine is one of extraordinarily reactionless healing. Experiments are now in progress to examine the extent to which sealing of the stapled closure may be dependent upon adhesion to neighboring structures.

#### Clinical Experience

The instrument has proved to be as swift, easy and satisfactory to use in the human as in the dog, so that it has become routine for use in the duodenal stump—except

\* U. S. Surgical Corporation, New York.

FIG. 3B. Stomach and duodenum ( $\times 12$ ) at 120 days. Note complete regeneration of mucous membrane, the maturity of the scar, and in both cases the presence of microcysts lined by the appropriate epithelium. In sections from other animals these cysts sometimes are seen to communicate with the lumen, and it may be that in all cases these were not cysts so much as small recesses connecting with the lumen.



where the stump is so densely scarred that it cannot be mobilized for this purpose—and also for closure of a portion of the gastric stump preparatory to a Hoffmeister or Billroth I anastomosis. It is in regular use by the residents at both The Johns Hopkins Hospital and the Baltimore City Hospitals. In some instances we have used it

in small and large bowel, sometimes for temporary occlusion of the segment to be resected and sometimes for closure of the cut end, preparatory to an end to side anastomosis. In one instance it has been applied to the body of the pancreas in a patient having a distal pancreatectomy. One or two additional sutures of silk had to be

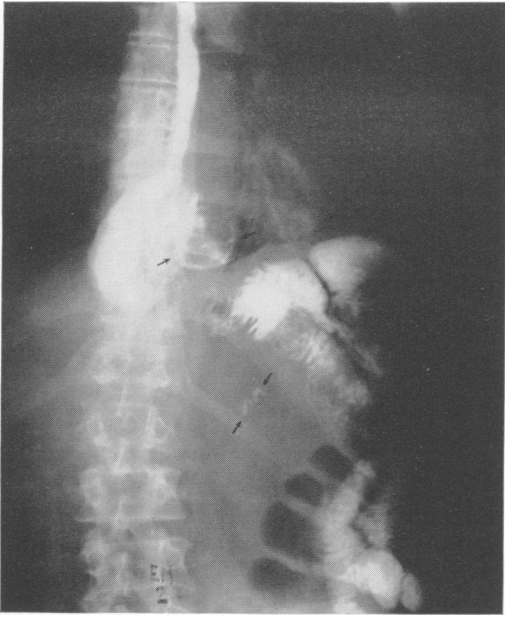


FIG. 4. Total gastrectomy and partial esophagectomy—Roux-Y-Esophagojejunostomy. Barium shows the esophagus hand-sutured to the side of Roux loop, near its end, which has been closed by staples (upper arrows). Lower arrows show staples in the transected pancreas, the distal portion of which was taken with the stomach and spleen. Staples were also used to close the duodenum, but this closure overlies the vertebral column, and the staples are not visible in the reproduction.

placed in the pancreas to control bleeding. The patient did well. In clinical application of these instruments we have chosen to *invert the staple closure* with a row of Lembert sutures of fine silk. The turn-in with a single row of Lembert sutures of silk of the cut end of stomach or duodenum, flattened by the application of the staples, is extraordinarily neat and quick, and particularly on the stomach—as opposed to the substantially less elegant procedure involved in turning in the suture-closed end of the thick-walled stomach.

We employed stapled closure of the duodenum and the closed-over portion of the cut end of the stomach in 34 Billroth II gastrectomies, at The Johns Hopkins Hospital and the Baltimore City Hospitals, and in operations at a few institutions in other States. The same technic has been used for

the closed-over portion of the cut end of the stomach in 11 gastrectomies with the Billroth I reconstruction. The cut end of the stomach has been sealed off with staples in three esophagogastrectomies. In ten resections of small or large bowel the staples have been used to close a blind end. In one total gastrectomy with splenectomy and distal pancreatectomy (Fig. 4) staples were used on the blind end of a Roux loop, on the pancreas, which required two additional sutures for bleeding, and on the duodenal stump.

There have been no problems in clinical use of the instruments but despite satisfactory animal experience, we have, in all human patients, inverted the stapled closure of bowel or stomach with interrupted Lembert sutures of silk. In no instance has there been a leak from any suture line, or any operative difficulty in employment of the instrument. The saving in time is significant, and the neatness and dispatch involved in use of these instruments is attractive.

More recently we completed a series of experiments with an extraordinarily ingenious *anastomosing clamp*<sup>9</sup> which places two rows of very fine staples between stomach and jejunum, or between two loops of bowel, and in the same operation cuts between the staples. Only purse-string sutures around each blade of the instrument being withdrawn from the viscera are required. The blades are graduated and the size of the anastomosis is accurately controlled. This instrument, in conjunction with the stapled closure of the gastric and duodenal ends, provides a remarkable saving in time. In dogs, again, we closed the cut ends of the duodenum and stomach with a single application of two rows of staples without sutures, and have used the anastomotic instrument with only one modified purse-string suture about the stab wounds in stomach and jejunum through which the blades of the instrument were inserted and

withdrawn. In patients, in whom we have used this instrument with great satisfaction, we have both inverted the stapled cut ends of stomach and duodenum, and reinforced the stapled anastomosis with a row of fine silk sutures. The most striking feature of instrumental anastomosis seen in experimental animals has been the neatness and cleanness of the anastomosis when viewed fresh. It has the appearance of a fine razor-thin incision in mucosa, rather than of a suture line closure. When, as in some animals, we stapled and sutured closures or anastomoses in the same animal, the difference in the degree of reaction between the two at all stages has been remarkable. The same anastomosing instrument, as suggested to us by Dr. G. C. Child, III, lends itself to rapid performance of a Finney pyloroplasty.

### Summary

Closure of the cut ends of duodenum, stomach, small or large bowel in dogs, with a single application of two rows of staggered staples parallel to the cut end, results in uniform and satisfactory healing without additional measures.

Survival of epithelium in the compressed tissue is evidence that the compression is not severe enough to cause significant necrosis.

In patients, such stapled closure, accompanied by inversion by a row of 4-0 silk Lembert sutures, has been uniformly satisfactory and seems to present advantages in terms of speed, precision, neatness and absence of bleeding or soiling.

An anastomosing instrument which produces an inverting, serosa-to-serosa anastomosis with one row of fine staples has been

satisfactory experimentally and is now undergoing clinical trial.

There are numerous other applications of the stapling instruments in gastrointestinal operative surgery, one being the very rapid creation of Heidenhain pouches in experimental animals.

### References

1. Babkin, S. E., Astofev, G. V. and Kalinina, T. V.: Contemporary Equipment for Operation on the Intestines. *in* New Surgical Apparatus and Instruments and Experience in their Use. Moscow, Ministry of Health, U.S.S.R., 1957.
2. Betts, R. H. and Takaro, T.: Use of a Lung Stapler in Pulmonary Resection. *Ann. Thor. Surg.*, 1:197, 1965.
3. Bobrov, B. C., Androsov, P. E., Virzhikovskaya, M. F., Kriuchkova, G. C. and Linkova, M. N.: Experimental Prerequisite for the Use in the Clinic Apparatus for Suturing the End of the Stomach. *in* New Surgical Apparatus and Instruments and Experience with their Use. Moscow, Ministry of Health, U.S.S.R., 1957.
4. Friedrich, H.: Ein neuer Magen-Darm-Nähapparat. *Z. Chir.*, 61:504, 1934.
5. Goldman, A.: An Evaluation of Automatic Suture with UKL-60 and UKL-40 Devices by Pulmonary Resection. *Dis. Chest*, 46:29, 1964.
6. Gritsman, Y. Y.: *cited in* Geselevich, A. M.: Experimental and Clinical Results with the Use of Mechanical Suture in the Operative Surgery of Cardiac Defects in Large Blood Vessels. *Cor Vasa*, 5:203, 1963.
7. Ravitch, M. M., Brown, I. W. and Daviglus, G. F.: Experimental and Clinical Use of the Soviet Bronchus Stapling Instrument. *Surgery*, 46:97, 1959.
8. Ravitch, M. M., Steichen, F. M., Fishbein, R. H., Knowles, P. W. and Weil, P.: Clinical Experiences with the Soviet Mechanical Bronchus Stapler (UKB-25). *J. Thor. Cardio. Surg.*, 47:446, 1964.
9. Svinin, E. K.: Gastroenterostomy with the Aid of a Mechanical Stapling Device. *Vestn. Khir. Grek.*, 7:48, 1961.
10. Vilianski, M. P., Zveshneve, E. M., Zinoviev, A. S. and Kotserov, A. E.: Resection of the Stomach for Cancer and Ulcer Disease with the Use of the Suturing Apparatuses of the NIIEChAE. *in* New Surgical Apparatus and Instruments and Experience in their Use. Moscow, Ministry of Health, U.S.S.R., 1964.
11. Von Petz, A.: Zur Technik der Magenresektion. Ein neuer Magen-Darm-Nähapparat. *Z. Chir.*, 51:179, 1924.