A Clinical and Experimental Study OF THREE HUNDRED PERFORATING WOUNDS OF THE ABDOMEN.

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(Report to the Medical Research Committee.)

[WITH SPECIAL PLATE.]

SOME time ago we published a summary of some seventy cases of perforating wounds of the abdominal cavity. We have had an opportunity of increasing our experience of these cases, and the following article is an embodiment of that experience. We have been more especially induced to publish this further summary as increased experience has taught us that we must alter certain opinions expressed in our earlier publication. The paper is introduced by an account of a small amount of experimental work which we have done in attempting to throw light on certain clinical problems which perplexed us. There follows a consideration of various abdominal wounds as they occur locally. The paper concludes with a summary of general remarks.

EXPERIMENTAL SUMMARY.

In the course of carrying out the clinical work, part of which is here summarized, certain problematical points arose, and it was with a view to throwing light on these points that the experimental work was undertaken. We shall summarize the work in the form of question and answer.

1. What are the relative values of end-to-end and lateral anastomosis?

Belgian hares were used in these experiments. End-to-end anastomosis was unsatisfactory, as rabbits operated on in this way all succumbed after an interval of from two to three days. *Post mortem* there was found to be very marked distension of the intestinal canal above the site of suture.

When lateral anastomosis was employed the results were different—no complication developed, and the animals, without exception, made good recoveries. One naturally asked oneself the question, What was the feature in end-to-end anastomosis which rendered its results so unsatisfactory? There was no complete obstruction, for, both at operation and in later investigation, intestinal contents could always be forced through the opening; it was observed, however, that in end-to-end anastomosis the mucous membrane surrounding the line of suture became intensely oedematous; therefore a series of experimental operations were performed in which the mucous membrane was snipped away as closely as possible around the open lumen of the gut. The anastomosis was completed in the usual way, but fewer Lembert sutures than usual were necessary. When the anastomosis was performed in this way the animals invariably recovered.

From these experiments one would draw the following conclusions: Lateral anastomosis is, on the whole, a more reliable proceeding than end-to-end anastomosis; the results of end-to-end anastomosis are rendered more satisfactory when the mucous membrane at the open ends of the gut is clipped away.

2. When distension of the intestine occurs after resection and anastomosis of intestine, is it influenced by the presence of blood in the peritoneal cavity or by peritoneal infection?

A series of experiments was performed in which the gut was anastomosed either by end-to-end (modified method) or by lateral anastomosis. After each anastomosis was completed, a measured quantity of blood was spilt into the peritoneal cavity together with contents of small intestine.

In every case the animal made an uninterrupted recovery, and no parietic distension resulted. It would there-

fore appear that haemorrhage *per se* or combined with intestinal infection is not responsible for subsequent intestinal distension.

3. What are the relative values of the different forms of lateral anastomosis?

There are two possible ways in which lateral anastomosis can be accomplished. The ends of the bowel may be laid side by side and the anastomosis so completed. (See Diagram 1.) Or the two ends of the bowel may be brought so that the two blind ends are in apposition. (See Diagram 2.)

Diagram 1.

The second method of approximation may sometimes be of great value—for example, in cases in which it might be impossible to secure the first mentioned approximation. A series of experiments was carried out to explore the values of these methods.

The various anastomoses were completed and the parts examined at varying later periods. No difference could be detected between the two methods—both did equally well. A further series of experiments was carried out to prove whether there was a tendency in either of these forms of anastomosis for intestinal contents to collect in the blind ends of the gut. For these experiments the animals were fed upon food in which small shot were mixed.

Diagram 2.

It was found that in the first method of anastomosis (Diagram 1) there was a greater tendency for arrest of contents to occur than in the second method.

Both forms of anastomosis give excellent results. As far as the arrest of intestinal contents in the blind ends of the gut is concerned, the second method of anastomosis (Diagram 2) is even preferable to the first method.

Illustrations of these experimental anastomoses are shown in the Plate (Figs. 1 and 2).

4. To what extent is devascularization of the gut possible without damaging the vitality of the gut?

This is a matter of great clinical importance, as in the cases of wounds of the abdomen one is constantly meeting with examples of tearing of the mesentery, and it is frequently debatable whether or not resection should be done.

Devascularization of the Colon.

In a large rabbit 1 inch of colon was devascularized by ligaturing four vessels of supply close to the edge of the gut.

A later examination showed the devascularized colon to be apparently unaltered, but, as though in protection, a portion of omentum had come down from above and surrounded the related bowel.

In a second animal the devascularization was carried a step further, and five vessels were ligatured, implicating 1½ in. of colon. Later examination showed no change in the bowel.

In a third animal a still more extensive devascularization was performed. The colic artery was ligatured just below the origin of the inferior mesenteric artery, and again all four vascular loops passing to the bowel. The involved bowel at once became of a bluish colour; it was returned to the abdominal cavity, and the wound closed. Three days later the colon was examined, and found normal in every respect.

These experiments showed that the colon rapidly establishes a collateral circulation, and that a very considerable devascularization must occur before the vitality of the gut is interfered with.

Devascularization of the Small Intestine.

By ligature of the mesenteric vessels 1 in. of bowel was cut off from its direct blood supply. After some days no change was apparent in the related loop.

In a second experiment 1½ in. of gut was devascularized and returned. Forty-eight hours later the area was examined. The section of bowel the vessels of which had been ligatured was found surrounded by an omental graft.

After removing this graft the underlying small intestine was found to be gangrenous—there was a central perforation about ½ in. in size surrounded by an edge of gangrenous bowel ½ in. wide.

The experiment was repeated in another animal—a rat—the

vitality of the intestine of which is notorious: $1\frac{1}{2}$ in. of the small intestine was devascularized; at the end of forty-eight hours the related bowel showed a complete ring of gangrene at the centre of the related gut.

From these experiments one may draw the deduction that the colon bears devascularization more readily than the small intestine, and that both portions of bowel stand really a very considerable devascularization without their vitality becoming affected. From clinical experience we believe that 3 in. to 4 in. of the small intestine may be devascularized without gangrene ensuing, and from experimental evidence we believe that even a greater degree of colon may be affected without gangrene resulting.

5. Omental grafts. What are their uses and values?

In cats the omentum was completely removed from its attachments and left free in the peritoneal cavity; the animals died within a week to ten days. They gradually wasted away, becoming more and more drowsy and refusing food.

In a second group of experiments the omentum was completely freed from its attachments, but coincidentally the peritoneum over a loop of small intestine was scratched and partially removed. No ill result followed the operation, the animals were scarcely any worse than after a simple laparotomy—the omentum apparently obtained a new blood supply from the loop of bowel to which it became attached.

The Behaviour of Free Omental Grafts on the Normal Intestine.

Small portions of omentum loosely tacked on to the normal bowel wall by a fine suture of fine thread were practically unaltered when examined a few days later. After three days the graft was found to be adherent with fine adhesions to the loop of bowel to which it had been applied—there were no adhesions to the surrounding loops. Six days after application the grafts no longer adhered to the bowel wall to which they were originally attached except at the points at which the sutures had been applied. There was no further attempt at fixation except where the graft was actually secured by sutures. It was noticed that after fixation of the graft the fatty elements in its constitution gradually lessened.

Omental grafts applied to damaged intestine showed that when the damage produced sepsis the graft was of little value; this was demonstrated by the following experiments. The small intestine of a dog was crushed with artery forceps, severely damaging all coats of the bowel wall. A free omental graft was applied to the bowel damaged in this way, while another portion of the intestine similarly damaged was left free in the peritoneal cavity and the abdomen closed. The animal was upset and ate little for three days; after that period it began to improve.

Laparotomy five days after the original experiment showed that the omentum was firmly adherent to both the crushed portions of bowel. The area covered by the free graft on separation of the omentum showed the graft to be infected with patches of necrosis. The area of bowel crushed and left free in the abdominal cavity showed (after removal of the omentum which had become fixed there of its own accord) very little destruction to the crushed segment of gut. Repair in this latter case was much more perfect than in those in which the detached graft had been applied.

If the small intestine was devascularized to such an extent as to cause gangrene, and free grafts applied, the grafts became infected and did not prevent the animals from dying of peritonitis.

The conclusions drawn from these experiments are that free omental grafts are only safely used in cases where no sepsis is present. Grafts remain free in the peritoneal cavity, and do not adhere to the loops of gut; they are useful in covering raw or denuded areas of peritoneum, or in strengthening suture lines. See Plate, Fig. 3.

6. What deductions may be drawn from the experimentally produced wounds of the intestine?

We were led to investigate the point by observing clinically that in extensive wounds of the small intestine there is a remarkably slight escape of intestinal contents. We made the further observation that the less the degree of damage the greater possibility was there of intestinal content escape.

Experiment 1 (Cat).—The small intestine (ileum) was divided half across; omentum was laid over the wound and the viscera returned. Twenty-seven and a half hours later the abdomen was opened; the injured gut lay where it had been placed; the omentum was no longer over the wound, but rather to one side; there was no peritonitis present and there was no escape of intestinal contents.

Experiment 2 (Belgian Hare).—The jejunum was recognized and divided half across. After seven hours there was no sign of peritonitis and no intestinal contents had escaped.

Experiment 3.—The jejunum was brought out and divided half across; into its lumen shot was placed, as shown in sketch

Diagram 3.

(Diagram 3). Five hours later the abdomen was reopened and the loop examined; the contents were found to be as shown in the accompanying sketch (Diagram 4).

Diagram 4.

As in Experiment 2 there was no extravasation. This experiment illustrates the considerable arrest of peristalsis which followed the injury to the gut wall.

7. When the wound runs in the long axis of the gut, has it a greater tendency to leak?

Clinically we would answer this question in the positive, and say that wounds in the long axis of the gut certainly have a greater tendency to leak than those that occur across the long axis of the gut. We investigated the matter experimentally.

Experiments 4 and 5.—Large hares were used for the experiments. A loop of jejunum about 8 in. from the stomach was chosen, and a longitudinal cut $\frac{1}{2}$ in. long was made in the long axis of the bowel; the omentum was laid over the wound, and the abdomen was closed. Ten hours later the animal, on examination, was found to have a marked general peritonitis, with extravasation of small gut contents all over the peritoneal cavity. Fluid from the peritoneum examined showed abundant organisms, mostly large and of the *perfringens* type; there were very few leucocytes present, and these showed no tendency to phagocytosis.

The results of these experiments are very striking when compared with transverse wounds of the small intestine; it would appear that the transverse division of the longitudinal muscular fibres diminishes, for a time at least, the liability to leakage.

We have made the clinical observation that isolated perforated wounds of the small intestine had a greater tendency to leak than more extensive wounds.

We believed that this demanded two explanations: First, that the comparatively slight degree of injury did not result in any lessening of the peristalsis, and secondly, that the non-division of the longitudinal muscular fibres rather tended to increase the risk of extravasation.

This observation was not confirmed by experiment.

Experiments 6 and 7.—A large hare was used in this experiment. The lowest loop of ileum was brought out and three small holes were made into the lumen at different places. Into each of these holes a single piece of shot was introduced. At once the mucous membrane pouted out through the openings. The animal showed no ill result from the experiment and it is now perfectly well.

Experimentally complete division of the small intestine is followed by extensive leakage. This is shown in the following experiment:

Experiment 8 (Belgian Hare).—Laparotomy performed; the ileum was completely divided 6 in. from the ileo-caecal junction; the intestine was returned. Six hours later the abdomen was again opened. There was a great amount of extravasation and a general peritonitis was commencing. It was noticed that the distal end of the gut was firmly contracted and no leakage appeared to have occurred from that end. The upper end was distended and liquid contents persistently leaked from it.

We have repeatedly observed that wounds of the large intestine, in contradistinction to wounds of the small intestine, universally leak. This was experimentally investigated.

Experiment 9.—A large Belgian hare was used in the experiment. The transverse colon was exposed and the gut was wounded transversely; the omentum was laid over the opening and the intestine returned. Six hours later laparotomy showed extravasation of gut contents, but the escape was quite localized. The escape, however, was marked in comparison with a similar experiment performed in small intestine. The perforation was sutured and the gut returned; the animal recovered.

In the course of these experiments we have noticed that the degree of extravasation largely depends upon whether the intestinal tract at the time of operation has a large or small amount of content. The smaller the

amount of content the less likelihood is there of an early extravasation.

This observation is in keeping with the good results obtained in perforating wounds of the intestine in such a campaign as the South African war.

WOUNDS OF STOMACH. *Morbid Anatomy.*

Under this heading there are one or two observations to be made.

Occasionally entrance and exit wounds of the anterior wall of the stomach are found with an extraordinarily small extent of stomach wall separating the wounds; it is difficult to surmise how such mechanically occur.

We have confirmed a former observation that while entrance and exit wounds of the body of the stomach are very similar in size, an exit wound in the thicker musculature of the pylorus is generally considerably larger than the entrance wound.

While the peritonitis which results is, as a rule, of slow development and subacute course, if bile has escaped from the stomach wound the peritonitis is much more intense.

Clinical Features.

In addition to the signs common to wounds of any hollow viscus there are certain distinctive features.

Sickness is usually more pronounced than in wounds of the other abdominal viscera, and in the vomited matter it is rarely that one fails to find the presence of blood. The degree of collapse is less marked than that found in intestinal injuries, but whether or not this is related to the comparatively smaller amount of haemorrhage one cannot say.

It is interesting to note that, while the pulse and respiration rates are both increased, the respiration rate has proportionately increased more rapidly than the pulse rate. The degree and the variety of the clinical features are influenced considerably by the situation of the lesion. Pain would appear to be more intense when the cardiac or pyloric ends of the stomach are involved; it is correspondingly less so when the wound is related to the body of the stomach.

Wounds of the curvatures of the stomach, with the greater destruction which invariably accompanies them, are associated with severe symptoms of collapse. The clinical features are also influenced by the condition of the stomach at the time of injury; if the stomach contains a quantity of food, the wound is followed by more intense clinical features than if the organ had been empty.

Treatment.

We would remark upon the importance of routinely examining the posterior wall of the stomach. A wound of this region is very apt to be overlooked.

Wounds may occur in the cardiac region which are almost impossible of access for suture unless the tear be a very large one. Such wounds may be left with a fair degree of certainty that natural healing will occur with little or no leakage.

Results of Stomach Cases. Total cases, 24.

Bullet wounds	...	...	...	14
Bomb and shell wounds	...	...	...	10
Simple suture	...	...	...	20
Suture and gastro-enterostomy	...	...	...	1
Gastro-enterostomy	...	...	...	1
Resection and gastro-enterostomy	...	...	...	1
Complicated wounds	...	...	...	22
Results:				
Recoveries	...	...	...	10
Died	...	...	...	13
Unoperated on	...	...	...	1

WOUNDS OF SMALL INTESTINE. *Morbid Anatomy.*

When a bullet passes through the pelvis it is not uncommon to find the loop of intestine which was lying in the pelvis at the time of injury riddled with holes over a very limited area. In one case, where the bullet entered the sacrum and passed through the pelvis, there were eight perforations, all of them within one foot of the caecum.

We have observed that wounds of the left flank, damaging the descending colon and apparently out of the small intestine area, may wound coils of the jejunum.

It is remarkable how seldom there is a massive escape of contents from the lumen of the gut. Rarely have we

seen it occur to any marked degree. Apparently there is a complete inhibition of peristalsis for some time subsequent to the injury. Further, the less the degree of damage to the gut and the fewer the number of perforations the more likelihood is there of extensive peritoneal soiling. We believe the converse holds good.

We have had several examples of cases in which intestinal contents have escaped between the layers of the mesentery. They have been cases in which the projectile has not actively perforated the gut, but, by passing near it, has exerted such a force that the gut wall ruptures in that portion which is unsupported by peritoneum—namely, between the layers of the mesentery. This is a serious type of injury, as it invariably necessitates resection of the damaged area.

When the blood vessels in the mesentery are damaged the surgeon is faced with the question whether the viability of the associated gut is or is not interfered with. We have carried out some experimental work, noted above, to assist us in coming to a decision on that point.

Experimentally and clinically it would appear that there must be a considerable destruction of the vascular supply before the vitality of the gut is interfered with. The colon is more liable to subsequent necrosis than the small intestine.

The practical bearing of the point is that cases of mesenteric injury previously dealt with by resection we now treat by simple suture of the mesentery and ligation of the divided vessels. The extensive injuries of their blood vessels must, of course, be dealt with by resection.

In this relation we have observed that, while interference with the mesenteric blood supply may not actually endanger the viability of the gut, that portion of gut is particularly liable to a subsequent distension, which may pass to an actual paralysis.

Clinical Features.

The clinical features are generally those of commencing peritonitis, coupled with the evidences of rapid and progressive haemorrhage.

Under the influence of morphine, and sometimes when the intra-abdominal bleeding is profuse, we have seen the muscular rigidity of the abdominal wall almost disappear.

Treatment.

Later there are described measures we have carried out preliminary to all abdominal operations for this class of case—measures which are intended to antagonize the shock and loss of blood which occurs. As a preliminary to operating for perforating wounds of the small intestine these precautionary measures are of the highest importance, as the amount of shock and the loss of blood in these cases are often exceptionally severe.

To open the abdominal cavity we have almost invariably used a middle-line incision; it is important that there should be no hesitation in making the incision one of considerable length. In localizing the sites of injury we have followed a well-defined routine. After opening the abdomen the caecum is identified, and from it the small intestine is traced upwards, beginning with the lower end of the ileum. As each perforation of the gut is exposed, it is wrapped up in a small moist swab; to one side of the swab a length of tape is stitched. This is slipped through the mesentery and doubled twice round the gut covered by the swab; in this way each perforation is marked, and there is less chance of massive infection from the injured gut. The whole length of the small intestine must be examined before any decision as to treatment is arrived at. There is nothing more disconcerting than to deal with a perforation by resection and to find that a few inches further on there is another perforation which could have been included in the same procedure.

When the degree of damage to the gut has been brought under review, there are three varieties of operative treatment which may be followed. These are: (1) Simple suture of the perforation; (2) resection of the damaged intestine, followed by a lateral or end-to-end anastomosis; (3) resection of the damaged intestine with an accompaniment of a temporary enterostomy.

1. *Simple Suture of the Perforation.*

In a former paper to which we contributed it was held that cases suitable for suture of the perforation were in the minority. It was believed that a wound to be suitable for suture should be small, without damaged edges, and

with an intact mesentery. Further experience has shown us that the range of possible suture is very much more extensive than we had at first imagined—there are very few wounds of the small intestine which do not prove amenable to suture. It may be said that there are three possible contraindications to its use: (1) Extensive damage to the mesentery; (2) a wound which, when sutured, results in marked narrowing of the gut, and the type of wound which most commonly results in this complication is one running obliquely across the long axis of the gut; (3) when the perforation is associated with resulting necrosis of the surrounding bowel—a condition which is more common in the colon than in the small intestine.

The method of suture has the advantage of speed (when the perforations are not too numerous), of simplicity of technique, and of lessened post-operative shock.

There are, of course, distinct disadvantages. The suture may result in considerable narrowing of the lumen of the gut, and where there are a number of similar sutures within a short distance of each other the multiple narrowing becomes a very real objection. The second disadvantage is, that if the perforations are very numerous their closure would take considerably longer than the time which would be entailed in a resection of the damaged gut.

In the suture operations which we have done we have not excised the edges of the wound, and we have used a linen thread for stitching.

We have from time to time made use of omental grafts to reinforce doubtful suture lines. The matter is dealt with more fully in the experimental section of this paper.

2. *Resection of the Damaged Intestine, followed by Lateral or End-to-end Anastomosis.*

As has been said, we originally favoured this method of treatment in preference to multiple and extensive suturing. We believed that the indications for the operation were the multiplicity of the perforations, the extent and degree of the perforations, and the involvement of the related mesentery; we now consider that only the last constitutes a real indication.

Under exceptional conditions, such as have been already stated, the first two indications may be entertained.

The advantages of resection may be summarized as follows: The operation is complete and thorough, the risk of damage following a mesenteric involvement is minimized, there is less likelihood of sloughing of devitalized intestine, and there is less possibility of subsequent stricture.

Several disadvantages may be quoted: The complexity of the technique, the time the operation takes, and the intense degree of shock which almost invariably follows it. The first and the second are no real objections, but the third is a more potent one; it is the one feature which has led us to abandon the resection operation for the multiple suture. The degree of shock is infinitely greater after a resection operation than after an extensive multiple suture operation.

Having weighed the choice of the operation, the question next arises whether the anastomosis is to be lateral or end-to-end. When we began this work, we favoured and used an end-to-end anastomosis, on the ground that it could be accomplished in a shorter period of time than the lateral anastomosis. We discovered that this method was apt to be followed by a certain degree of paresis in the proximal segment, with subsequent distension and eventual obstruction. On several occasions we have had to perform a second short-circuiting operation to overcome the obstruction,

The gut appears to be predisposed to the distension from various causes: the general degree of nerve shock, and more especially of sympathetic nerve shock; the paresis of Auerbach's plexus as a result of the blow; the presence of blood in the peritoneal cavity, and the degree of the peritonitis which is invariably present. As a result of this disadvantage we began to employ a lateral anastomosis, and from it we had undoubtedly greater satisfaction and better results. At this point one must allude to the bearing which experimental work had upon the feature. End-to-end anastomosis of small intestines in animals was inevitably followed by distension of the gut above the suture, with subsequent death of the animal. When lateral anastomosis was performed no complications arose, and recovery was invariably the result. The technique of the end-to-end anastomosis was then modified in so far as the mucous membrane was clipped away around the cut edge of the bowel; a subsequent distension did not occur, and recovery followed the operation.

The influence of blood and peritoneal infection was submitted to experimental investigation. After resection and anastomosis of the gut, both end-to-end (modified method) and lateral, a quantity of blood was placed in the peritoneal cavity and a peritoneal infection was started by allowing a slight escape of intestinal contents; no subsequent distension occurred, a fact pointing to the conclusion that these complications have little bearing on the development of the subsequent distension.

In point of time the lateral anastomosis takes a few moments longer, in so far as it involves closing the open ends of the gut, but it apparently largely overcomes the possibility of distension of the proximal segment. We do not intend to enter into any details of the operation beyond mentioning that when the resected gut involves the extreme lower end of the ileum, we have anastomosed the proximal bowel to the centre of the transverse colon. Short-circuiting, so to speak, by a unilateral short circuit the caecum, ascending colon and hepatic flexure, there are obvious mechanical advantages related to this method.

DESCRIPTION OF SPECIAL PLATE.

FIG. 1.—Experimental (Belgian hare). Small intestine anastomosis. Lateral, with blind ends laid apart from one another. Resection and anastomosis of this type gave very much better results than in the cases where the resection was followed by end-to-end anastomosis. Large anastomotic opening and long blind ends.

FIG. 2.—Experimental (Belgian hare). Small intestine anastomosis. Lateral, with blind ends together. The results of resection of gut and anastomosis of this type were even better than those done with the blind ends apart, as in Fig. 1.

FIG. 3.—Experimental (cat). A free omental graft, one month old; implanted on to normal small intestine. The graft is firmly united to the mesentery of the gut, but is only adherent to the bowel wall at the points of suture.

FIG. 4.—Experimental. Free omental graft applied to the normal small intestine. When examined, a week after its application, the graft was found to be universally adherent to the underlying gut.

FIG. 5.—Bullet wound of anterior stomach wall. The missile completely divided the right gastro-epiploic artery, and the wound extended on to the posterior wall of the viscus for half an inch.

FIG. 6.—Bullet wound of small intestine. The specimen illustrates the extensive damage to the mesentery which is so often sustained.

FIG. 7.—Twelve inches of small bowel (ileum). The gut shows three perforations. A and B are typical bullet wounds with eversion of mucous membrane; C shows a rupture between the leaves of the mesentery. The peritoneum at this point is sodden and gangrenous from escape of intestinal contents into the mesentery. Removal of the overlying damaged peritoneum exposed a similar wound showing everted mucosa.

TABLE I.—Results of Small Intestine Cases.

	Total cases, 96.			
Bullet wounds...	...	...	...	47
Bomb and shell wounds...	...	...	...	49
[Complicated wounds ...]	...	...	...	80]
Operations:	...	...	...	
Suture...	...	...	...	57
Resection...	...	...	...	38
Enterostomy...	...	...	...	1
Results:	...	...	...	
Recoveries...	...	...	...	37
Died...	...	...	...	59
Analysis:	...	...	...	
Suture operations...	...	...	...	57
Recoveries...	...	...	...	29
Resection operations...	...	...	...	38
Recoveries...	...	...	...	8
Bullet wounds...	...	...	...	48
Recoveries...	...	...	...	15
Bomb and shell wounds...	...	...	...	48
Recoveries...	...	...	...	22
High small intestine cases...	...	...	...	44
Recoveries...	...	...	...	17
Low small intestine cases...	...	...	...	54
Recoveries...	...	...	...	21

It is interesting to note that in uncomplicated wounds of the small intestine demanding a simple suture operation there was a recovery-rate of 100 per cent.—

Uncomplicated wounds of small intestine	...	...	...	9
Recoveries...	...	...	...	9

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FIG. 1.

FIG. 2.

FIG. 7.

FIG. 3.

FIG. 5.

FIG. 6.

FIG. 4.

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FIG. 8.

FIG. 9.

FIG. 10.

FIG. 11.

FIG. 12.

FIG. 14.

FIG. 13.

WOUNDS OF DUODENUM.

Wounds of the duodenum have a very high mortality, and the majority of the cases die before surgical assistance can be obtained. This is explained by the proximity of the duodenum to such structures as the aorta, vena cava, and portal vein, wounds of which would necessarily be rapidly fatal.

In the majority of the cases we have seen the second part of the duodenum has been wounded—more exactly at the junction of first and second portions; in one instance the third part of the duodenum was injured. The thin-walled duodenum is very readily torn, and the wound is larger than is usual in small intestine. Haemorrhage is not generally severe; there is an escape of bile into the peritoneal cavity and occasionally of food; there is usually an associated wound of the right kidney. In several instances we have found multiple fat necrosis.

Clinical Features.

The clinical features are similar to those of wounds of small intestine; there is generally intense shock, and sickness is usually present.

Treatment.

Operative treatment consists in suture of the torn bowel; the possibility of performing at the same time a gastro-enterostomy must be considered. Suture of the duodenum may result in contraction and narrowing, and further, duodenal wounds are especially liable to leak after suture; both of these possible disadvantages are avoided by the performance of a gastro-enterostomy.

Suture of the duodenum is facilitated when the intestine is mobilized in the manner suggested by Kocher by incision of the parietal peritoneum on the outer side over the right kidney.

TABLE II.—Summary of Cases of Wounds of Duodenum.

No.	Position of Wound.	Complications.	Treatment.	Result.
1	Junction of first and second parts	Wound of liver	Suture	Died.
2	Junction of first and second parts	Perforation of colon	Suture	Died.
3	Junction of first and second parts	Perforation of colon and liver	Suture (colostomy)	Died.
4	Complete division of second part of duodenum	Perforation of the stomach, ruptured kidney and liver	Suture and gastro-enterostomy	Died.
5	Perforation of third portion of duodenum	Perforation of kidney	Suture	Recovery
6	Perforation of second portion	Perforation of liver and colon	Suture	Died.

WOUNDS OF COLON.

Morbid Anatomy.

Effusion from a wound of the colon has a tendency to become shut off and localized, more especially when the wound occurs in the ascending or the descending colon. In late colon wounds it is common to meet with a collection of faecal and semipurulent matter entirely shut off and opening into the underlying colon.

Effusion from a wound of the colon too often extends into the retrocolic and retroperitoneal tissues. When this occurs the result is frequently fatal; absorption of the extravasated material appears to occur very rapidly, and an extremely virulent septicaemia is established. In a wound of the colon of fifteen hours' duration, we have found *post mortem* the evidence of an intense septicaemia and haemorrhages in splenic tissue, multiple septic throm-

bosis, etc. Naturally it is subsequent to wounds of the fixed portion of the colon that this complication generally develops. The clinical features associated with such a colon septicaemia are discussed under the next heading.

Colon wounds appear to be peculiarly liable to secondary haemorrhage; in several instances we have lost cases at varying dates after operation as a result of this complication. The haemorrhage is the result of septic change in the gut, and it generally appears on the third and fourth days after operation.

Clinical Features.

The clinical features are very similar to those of small intestine injury; they are, primarily at least, not so widespread. Subsequent to the injury three possibilities may develop:

1. The effusion and infection may remain localized.
2. The infection may spread and a general peritonitis result.
3. The infection may extend into the retrocolic and retroperitoneal tissues and the group of symptoms which we have called "colon septicaemia" may develop.

1. In the first instance (if the effusion and infection remain localized the patient's general condition is good) there are signs of a local inflammatory focus and further neglect of the condition will result in abscess formation and the establishment of a faecal fistula.

2. The second possibility is accompanied by all the signs and symptoms of a general peritonitis—the peritonitis is generally an acute and progressive one.

3. In the third instance the features of an intensely rapid septicaemia appear. The signs may appear and develop with startling suddenness. Patients suffering from this condition have generally a grey pallid appearance, and it suggests that there has been an extensive loss of blood, but investigation of the history will show that this has not been the case. There is restlessness and great uneasiness. Signs of delirium appear and become established. The pulse is characteristic: from the normal rate it very rapidly increases, so that in the course of a few hours it may have reached a speed of 150 a minute. The respiration rate increases until it reaches 40 to 50 a minute.

The temperature behaves variously; in the most intense cases it falls to subnormal and remains so, in less acute cases it rapidly rises to a considerable height (104° to 105°), and shortly before death it falls with a crisis. Vomiting is common, frequently in mouthfuls, ultimately resulting in acute dilatation of stomach. Before death the delirium passes into complete loss of consciousness, and the extreme general pallor is replaced by a slightly jaundiced appearance. The abdominal signs are primarily those of localized infection. Later the abdomen becomes markedly distended; there is not the same degree of tenderness or muscular rigidity as one associates with a generalized peritonitis.

Post mortem the signs are those of an acute septicaemia, with marked congestion of the viscera; frequently there are haemorrhages throughout the substance of the spleen. The *Bacillus perfringens* has been isolated from the blood and from the visceral lesions.

Treatment.

We have drawn attention to the liability of wounds of the colon to become localized, and this fact has a bearing on the operative treatment. The bearing is that if the patient comes under treatment at a period longer than twenty-four hours after the receipt of the injury, it is a

DESCRIPTION OF SPECIAL PLATE.

FIG. 8.—The middle third of the transverse colon, showing multiple shell fragment wounds; in addition to the perforation the bowel showed considerable bruising and tearing of the mesentery.

FIG. 9.—Gunshot wound of the gall bladder. The entrance and exit wounds of a rifle bullet are as outlined by an arrow.

FIG. 10.—Small intestine. This portion of gut was not actually pierced by a bullet, but it lay in close proximity to the passing projectile. The areas marked A and B showed an effusion of infected fluid beneath the peritoneum. Examination showed that all the coats of the intestine had given way except the peritoneum.

FIG. 11.—Portion of the descending colon showing three gangrenous patches with extensive ulceration caused by a bullet wound. The missile passed down the outer aspect of the bowel without actually cutting the coats of the gut. At the operation one gangrenous patch was seen, with no extravasation of gut contents.

FIG. 12.—Shell wound of right lobe of liver.

FIG. 13.—Gunshot wound of kidney. Almost complete destruction of the lower pole of the kidney.

FIG. 14.—Bullet wound of colon. Note the comparatively large wound of exit.

wise principle, primarily at least, to enlarge the original wound, on the possibility that the infection is becoming localized. At an earlier period than twenty-four hours it is probably better to open the abdomen through a separate incision.

We have been impressed with the risk run of over-looking injuries to the colon; the risk is greatest when the wound lies in one or other of the flexures of the gut.

The actual operative treatment may be summarized in the following methods: (1) Simple suture; (2) suture with a proximal colotomy; (3) colotomy at the site of injury. The operation of resection may be left out of account; it is rarely advisable to practise it in this type of surgery.

At first we followed the practice of a proximal colotomy in combination with the operation of suture. There are the obvious advantages that it increases the safety of the suture, while it obviates the passage of faecal matter through the damaged gut. At this time we were suspicious regarding the viability of the line of colon suture, and we felt that the colotomy added greater security. Later we recognized that the performance of proximal colotomy was rarely necessary, and we have therefore almost abandoned its use. We now reinforce the suture line by an omental graft. We believe that our results have improved since we have altered our procedure.

When the wound of the colon is very extensive colotomy at the site of injury is the only possible procedure.

We believe that all wounds of the colon should receive very thorough local drainage. In wounds of the ascending and the descending colon we have been impressed with the advisability of draining the retrocolic space by a tube passing into the loin. The establishment of efficient local drainage is the means of lessening the likelihood of development of infection of the retrocolic tissue and the establishment of colon septicaemia.

TABLE III.—Results of Colon Wounds.

Total cases, 85.				
Bullet wounds ...	...	...	...	34
Revolver bullet wounds ...	...	...	...	2
Shell wounds ...	...	...	...	42
Bomb and grenade wounds ...	...	...	...	7
Complicated wounds ...	...	...	...	64
Pure colon wounds ...	...	...	...	21
Treatment:				
Simple suture ...	...	...	...	55
Suture with proximal colotomy ...	...	...	...	25
*Colotomy ...	...	...	...	4
Resection ...	...	...	...	1
Results:				
Recovered ...	...	...	...	37
Died ...	...	...	...	48

* That is to say, colotomy at the site of injury.

WOUNDS OF RECTUM.

Morbid Anatomy.

Wounds of the rectum may be intraperitoneal, extraperitoneal, or a combination. The entrance wound is generally in the buttocks. Of all possible types of wound, that most commonly met with is the wound of the anterior wall of the rectum, low down and immediately above the floor of the pouch of Douglas. The wounds are nearly always complicated by compound fracture of the pelvis or wounds of the small intestine or bladder.

There is liability to severe bleeding from the large pelvic vessels in close relation to the rectum. Unless the wound is large, it is unusual to find intestinal contents escaping to any degree.

Clinical Features.

There are all the features which one associates with injury to the abdominal viscera; in the early stages the symptoms are ill defined and are liable to be overlooked.

Recent haemorrhage is usually found escaping from the rectum. There may be retention of urine, and if urine is voided, pain is complained of in the region of the bladder.

In uncomplicated wounds of the rectum the degree of shock is not severe.

Treatment.

It is necessary in every case to explore the abdomen. It is possible that beyond an infiltration of blood in the pelvic tissues, no wound may be found. In such a case the injury is probably extraperitoneal.

If an intraperitoneal wound is discovered, it is sutured with a primary layer of catgut and a series of linen thread Lembert sutures. The question has then to be considered whether or not a temporary colostomy is necessary. If the wound in the rectum is severe, it is advisable to do a temporary colostomy. The problem of whether an inguinal or a transverse colostomy be performed must be decided by such points as the situation of the surface wounds, and the degree of damage and position of the rectal wound.

Transverse colostomy has the advantages that it is more easily controlled, that the restoration of the continuity of the bowel is more easily accomplished when the need for the artificial opening is past, and that should surgical interference be necessary later in order to repair the damaged rectum, the pelvic colon can be mobilized and brought down to the injured part.

If it is found that the wound of the rectum is extraperitoneal, the entrance wound is opened up and efficient drainage established; in fact, in every case of wound of the rectum it is advisable to open up the entrance wound very thoroughly, as this diminishes the risk of a subsequent pelvic cellulitis. The question of whether a colostomy is necessary in an extraperitoneal wound must be decided by the character and position of the wound.

TABLE IV.—Results of Wounds of Rectum.

Total cases, 10.				
Bullet wounds ...	...	...	...	4
Bomb and shell wounds ...	...	...	...	6
[Complicated wounds ...	...	...	...	9]
Treatment:				
Suture ...	...	...	...	3
Simple drainage ...	...	...	...	2
Drainage and colotomy ...	...	...	...	5
Results:				
Died ...	...	...	...	7
Recovered ...	...	...	...	3

WOUNDS OF THE BLADDER.

Morbid Anatomy.

The missile may reach the bladder laterally, antero-posteriorly, or from above or below; the relationship of the wound to the peritoneum will vary according to the portion of the bladder which is injured.

Complications are exceedingly common; generally the pelvis is fractured, frequently the hollow viscera are injured—the small intestine or colon.

The missile may be arrested inside the lumen of the bladder, and this is most likely to occur when the projectile enters the full bladder. If the bladder is empty when hit there is more likelihood of there being entrance and exit wounds.

We have seen a non-penetrating bullet wound of the abdominal wall, sustained by a man with a full bladder, produce a large intraperitoneal rupture of the posterior wall of the bladder.

Clinical Features.

The clinical features are generally disguised by the fact that they are complicated by the signs and symptoms of other wounded viscera; occasionally there has been an opportunity of observing an uncomplicated case.

The features are those of a slowly developing peritonitis with at first local pain over the bladder and afterwards general abdominal pain. If the patient can void urino haematuria will probably be present. Urine, however, may be discharged into the peritoneal cavity in such quantity that none is passed by the urethra.

When the wound is extraperitoneal, dullness appears above the pubis and there is tenderness and rigidity over the lower abdomen. The infiltration spreads in the pelvis and escapes by the sciatic notch into the buttock, by the obturator foramen into the upper part of the thigh, or along the inguinal canal into the scrotum.

The use of the cystoscope is not of diagnostic value as distension of the viscus cannot be obtained.

Subjectively there is pain, tenesmus, and frequent desire to pass water with inability to do so; often a few drops of blood are passed after much straining. Rectal spasm may also be present. Urine mixed with blood may escape from the wound.

Treatment.

In the intraperitoneal variety the abdomen is opened and explored, the tear in the bladder wall sutured and drainage of the pelvis established. We afterwards tie in a urethral catheter in order to prevent overdistension of the viscera, and so avoid strain upon the sutures.

When the rupture is extraperitoneal a suprapubic incision is made down to the bladder and the anterior wall examined. If the rupture is easily accessible the wound is sutured and a suprapubic drain inserted in the bladder. If the rupture is inaccessible, the bladder is drained suprapubically, and if necessary a counter drain is inserted in the perineum.

TABLE V.—Results of Bladder Wounds.

Total cases, 14.

Bullet wounds ...	...	...	...	11
Bomb and shell wounds ...	...	...	...	3
Complicated wounds ...	...	...	...	13
Treatment:				
Suprapubic cystotomy ...	...	...	...	10
Suture ...	...	...	...	4
Results:				
Recoveries ...	...	...	...	4
Died ...	...	...	...	10

WOUNDS OF KIDNEY AND URETER.

Morbid Anatomy.

A certain proportion of kidney wounds are slight, more especially those in which the edges or poles are affected. When the centre of the body of the kidney is injured, the damage is severe and the kidney may be found to be ruptured into several portions. But the apparent triviality of the kidney wound is sometimes no guide to the organic disintegration which occurs; even in the slightest wounds the organ often shows extensive microscopical changes of minute necrosis and haemorrhage.

The bleeding is not as a rule excessive, unless some of the larger vessels have been divided; as a rule it ceases spontaneously.

Generally blood is present in the urine; occasionally the pelvis of the kidney and the upper end of the ureter becomes blocked by blood clot and this sign is then in abeyance.

Haemorrhage from the kidney extends widely over the retroperitoneal tissues, and if an infection develops in this region the result may very easily be fatal.

Clinical Features.

The first indication that the kidney has been damaged is generally got from the position of the wound. One would reasonably expect haematuria to occur, but, as we have pointed out, under certain conditions this sign may be absent. When the wound is uncomplicated, involving the kidney alone, the physical signs are those of a retroperitoneal injury; the general condition is good, the pulse rate being only slightly increased. The local signs are those of partial fixation and rigidity of the abdominal wall, tenderness on palpation usually confined to one-half of the abdomen, and occasionally the presence of fluid, demonstrated by percussion in one or other flanks.

Treatment.

Generally speaking there are three possible operative procedures which one may be called upon to perform: (1) Simple drainage; (2) suturing the kidney; (3) nephrectomy.

Simple drainage will be the operation of choice in the majority of cases; we would modify any former remarks by saying that in many cases in which formerly we would have removed the damaged organ we now rely upon efficient drainage, leaving a nephrectomy, if necessary, until a later date. To expose the viscus we employ a vertical posterior incision. Suture of the damaged kidney we have only employed in one instance—the viscus was almost severed into two halves by a horizontal tear on its posterior surface; with a view to saving the organ, and as the bleeding was not severe, the two halves were stitched with interrupted catgut sutures. The result was unsatisfactory, for sepsis developed with disastrous results.

The indications for nephrectomy are extreme laceration of the kidney, and haemorrhage from the larger renal vessels. As it is very often necessary to examine the abdominal viscera in addition to dealing with the kidney, we

originally removed the kidney through an anterior incision. We believe that this operation is associated with very considerable shock, and that it is advisable first to explore the abdomen anteriorly, afterwards removing the damaged kidney through a lumbar incision.

TABLE VI.—Results of Kidney Wounds.

Total cases, 29.

Bullet wounds ...	...	...	...	8
Shell and bomb wounds ...	...	...	...	21
Pure kidney wounds ...	...	...	...	12
Complicated kidney wounds ...	...	...	...	17
Right kidney affected ...	...	...	...	16
Left kidney affected ...	...	...	...	11
Both kidneys affected ...	...	...	...	2
Treatment:				
Drainage operations ...	...	...	...	21
Suture operations ...	...	...	...	2
Nephrectomy ...	...	...	...	6
Results:				
Recoveries ...	...	...	...	17
Died ...	...	...	...	12

Wounds of the right kidney are more fatal than wounds of the left kidney. This is shown by the following table:

Died, 12 cases.

Right kidney ...	...	...	...	8
Left kidney ...	...	...	...	2
Both kidneys ...	...	...	...	2
Drainage operations ...	...	...	...	21
Died ...	...	...	...	7
Nephrectomy operations ...	...	...	...	6
Died ...	...	...	...	3

WOUND OF URETER.

We have had two instances of this injury, and we offer no comment beyond briefly describing the cases.

CASE I.

The man was shot at close range by a machine gun bullet. On operation there were found to be eight perforations in the small intestine. In addition to blood, the abdominal cavity contained a quantity of fluid, apparently urine; this was found to have escaped from a wound of the left ureter, when it passed into the pelvis. As the patient's general condition was grave, no attempt was made to repair the ureter wound, but a drainage tube was sutured in position, and drainage was also established in the flank. After the second day there was no discharge of urine, and the patient made an uneventful recovery.

CASE II.

A man was wounded by a shrapnel bullet which entered just below the left anterior superior spine of the ilium. The entry to the peritoneal cavity was found on the left lateral wall of the true pelvis close to the commencement of the rectum.

Four perforations were found in the ileum with considerable damage to the mesentery of the gut. Resection and lateral anastomosis was done. A shrapnel bullet was removed from the recto-vesical pouch. The abdomen was closed, and the entry wound in the left side was drained with a large tube.

For the first two days following the operation clear urine came away in quantity through the wound in the left side. No urine was discharged after this time, and the patient made a complete recovery.

WOUNDS OF SPLEEN.

Morbid Anatomy.

Wounds of the body of the spleen pass through the organ without producing extensive damage. There is a small central perforation with radiating fissures.

When either pole of the spleen is wounded the damage is more extensive, and sometimes one or other pole is entirely torn off.

In one instance we have met with a curious type of injury to the spleen. The man was wounded by a rifle bullet in the lowest rib at the posterior axillary line. Upon opening the abdomen the cavity was found to be full of blood, the spleen was disorganized into a mass of bleeding pulp, the lower ribs were fractured and their sharp ends had been driven into the spleen, and the repeated movement of respiration had continued the damage thus begun. The damage was so extensive that splenectomy was necessary.

When the wound involves the hilum the bleeding is intense; in other situations it has a tendency to cease spontaneously, and it is very readily controlled.

Wounds of the spleen are nearly always complicated by wounds of one or more of the neighbouring viscera—the left kidney, the left pleural cavity, and the splenic flexure

of the colon. It is interesting to note that wounds of the spleen and the stomach are very rarely associated.

Clinical Features.

The clinical features are best described by quoting the history of two uncomplicated cases, one observed early, the other late. The first case was observed about six hours after the injury was sustained. The general condition was wonderfully good, the pulse being only 88; there was some muscular rigidity along the left side of the abdomen; the abdominal cavity contained a quantity of free fluid; the temperature was normal. These signs, together with the entrance and exit wounds, were the only clinical evidences. The second case was different in so far as forty-eight hours had elapsed since the receipt of the injury; during that time haemorrhage had been continuous. When admitted the patient was pulseless, there were all the evidences of intense haemorrhage, the abdomen was distended, rigid, and contained a large amount of fluid.

Treatment.

The treatment of wounds of the spleen varies according to the degree of damage sustained. A small penetrating wound unassociated with much bleeding is better left uninterfered with. Wounds accompanied by extensive destruction of the organ, or complicated by severe bleeding—for example, wounds of the hilum—are best treated by removal of the organ. The middle group of cases are those with a limited wound of the region associated with moderate bleeding; the local treatment of these consists in arrest of the haemorrhage and, if possible, closure of the wound in the spleen; these *desiderata* can be attained by the use of sutures and packing.

In gaining access to the spleen we have generally used an incision parallel to the costal margin.

TABLE VII.—Results of Spleen Wounds.
Total cases, 14.

Bullet wounds ...	...	...	...	...	7
Bomb and shell wounds ...	...	...	...	...	6
Fragment of earth ...	...	...	...	...	1
Treatment:					
Suture ...	...	...	...	...	9
Splenectomy ...	...	...	...	...	5
Results:					
Recoveries ...	...	...	...	...	9
Died ...	...	...	...	...	5

WOUNDS OF PANCREAS.

We have had only one instance of undoubted wound of the pancreas, and we quote the case without remark.

There was a bomb wound of the left loin. The abdomen showed all the signs of injury to the abdominal viscera, the signs being most marked in the upper abdomen; there was persistent sickness.

The abdomen was opened in the middle line; there was some free blood in the peritoneal cavity. Examining the stomach, the gastro-hepatic omentum was found to be perforated and the lesser curvature of the stomach torn; the coronary artery was divided and bleeding. The posterior wall of the stomach was exposed but no perforation was found. There was a quantity of free blood in the lesser sac of the peritoneum. On examining the pancreas it was found to be perforated through and through, immediately to the lateral side of the aorta; the projectile was finally found embedded in the left lobe of the liver.

A rubber tube was sutured to the anterior wall of the pancreas and brought to the surface above the stomach through the gastro-hepatic omentum. No complications developed and the patient made a good recovery.

WOUNDS OF LIVER, GALL BLADDER, AND DUCTS.

In discussing wounds of this region we shall bring a series of cases under review, but it must be understood that only a certain proportion of these required operation.

Morbid Anatomy.

The close relation of the right pleura and lung to the right lobe of the liver is responsible for the fact that a wound of the liver is very frequently accompanied by damage to the overlying lung or pleura. This fact is important, as the latter condition is apt to be overlooked. We have seen a case in which the lung wound had been unnoticed until the degree of fluid in the right pleura actually endangered the patient's life. It would appear to be unusual to have much destruction or disruption of the liver tissue; probably for this reason the occurrence of

post-traumatic jaundice is uncommon. There is generally an escape of blood into the peritoneal cavity, and occasionally it can be demonstrated in the retroperitoneal tissues.

We have only two instances to record of wounds of the ducts—a case in which the cystic duct was divided close to its entry into the gall bladder, and a wound of the common duct. Duct wounds are so frequently accompanied by injury to large vessels that the result is generally fatal before they can be given surgical assistance.

We have on two occasions met with wounds of the gall bladder—once with a wound of the cystic duct, and once with a wound of the common bile duct.

Clinical Features.

The clinical features may be remarkably scanty. If the wound has involved the lung and pleura the pulmonary signs frequently disguise the abdominal features. Generally pain is complained of over the liver and beneath the right scapula. The pulse, temperature, and more especially the respiration, are increased. There is usually some rigidity of the upper part of the abdominal wall; we have observed that the rigidity is increased and becomes more generalized when there is a considerable effusion of blood into the peritoneal cavity. By percussion an effusion can sometimes be demonstrated in the right iliac fossa. One would expect greater interference with the excretory function of the liver than is actually the case. On only one occasion have we seen a large effusion of bile into the peritoneal cavity. Post-traumatic jaundice is exceptional, and when it occurs it generally indicates a septic change secondary to the wound. There is no alteration in the bile contents of the faeces, and the urine is free from bile.

Treatment.

We have only operated on such cases as showed progressive haemorrhage, or which, from the clinical features, we suspected to be complicated by wounds of other viscera. In one instance we operated for a wound of the cystic duct. In another instance a late operation was necessary on account of the accumulation of bile in the peritoneal cavity.

We have employed Kocher's paracostal incision or the angled incision recommended by Mayo Robson; both incisions have given excellent access. The operation has generally been confined to investigation, plugging, and drainage.

TABLE VIII.—Results of Liver Wounds.
Total cases, 33.

Bullet wounds ...	...	...	...	...	15
Shell wounds ...	...	...	...	...	15
Shrapnel bullet wounds ...	...	...	...	...	2
Bayonet wounds ...	...	...	...	...	1
Pure wounds of liver ...	...	...	...	...	15
Complicated with wounds of thorax ...	...	...	...	...	8
Complicated with wounds of abdominal viscera ...	...	...	...	...	11
Results:					
Recoveries ...	...	...	...	...	19
Died ...	...	...	...	...	14

GENERAL REMARKS.

We are convinced that in the vast majority of cases of penetrating wounds of the abdomen operative measures offer the best chance of success. We would qualify the statement by excluding from the category uncomplicated wounds of the liver and certain wounds of the kidney and spleen. When the wound affects the hollow viscera of the abdomen we are satisfied that it is only as the rarest exception that a spontaneous recovery occurs. When these cases arrive in hospital they are almost universally in a state of intense collapse. We have therefore found it advisable to wait for a period of from one to two hours, until the increased shock of the journey has subsided. To this rule we make one exception—those cases which show evidences of rapid or progressive haemorrhage; in such cases the risks attendant on immediate operation are undertaken. We have occasionally found that these patients arrive in hospital having been very heavily dosed with morphine, which greatly militates against their eventual recovery; very rarely should the amount of half a grain be exceeded. We believe that this is an important detail in the pre-operation treatment of these patients.

During the interval of waiting it is difficult to decide whether or not active stimulant measures should be

adopted. These cases are generally complicated by some degree of haemorrhage, and stimulant measures in all probability tend to increase the bleeding. We therefore limit the pre-operation stimulation to getting the patient thoroughly warm and administering 1 c.cm. pituitary extract hypodermically.

During the operation every precaution is taken to minimize the degree of shock. The theatre is thoroughly heated, the table is provided with a hot-water bed. Lately we have found it advantageous to operate on these cases while they are in the Trendelenburg position.

Immediately before the operation commences the administration of subcutaneous saline by a Lane's bag is begun, and it is continued throughout the operation; 3 to 4 pints of fluid are frequently given in this way. We have tried several different methods of anaesthesia. We have had good results from the use of spinal anaesthesia, but there is difficulty in obtaining the freshly prepared anaesthetic, and it would appear that this is an important detail. In two instances we have had patients collapse suddenly after the administration of this anaesthetic. More lately, and on the suggestion of a paper by Yandell Henderson, we have employed closed ether anaesthesia. His paper adduced evidence that by this method of anaesthesia shock is considerably lessened.

We have made great use of the method of warmed ether administration, using the apparatus supplied by Mayer and Meltzer. During the past four months we have had considerable opportunity for using ether intratracheal anaesthesia. In surgery of the upper abdomen we have found it very pleasant to work with, but we do not favour it as a general routine in abdominal surgery. There is a type of case which is, we believe, suitable for intravenous ether anaesthesia, namely, cases which are obviously very coiled, and yet which demand urgent operation. Our experience of this method, however, in this type of case does not exceed some six cases.

Operative Technique.

Briefly, the operative technique which we have employed is as follows:

The abdomen is opened in what would appear to be the most suitable situation, and generally in the middle line. A large incision is employed. If the abdominal cavity contains a large quantity of blood, enough of this is rapidly swabbed away with a long roll of dry gauze to clear the view. A systematic examination of the various viscera is now carried out. We begin by picking up the caecum and recognizing the ileo-caecal junction; we work back rapidly along the whole length of small intestine, examining not only the gut but also its mesentery. The large intestine is reviewed, special attention being paid to the various flexures. If necessity arises the stomach on both aspects, the duodenum, the liver, and spleen, are examined. It is a wise precaution to palpate both kidneys, especially the left kidney, in cases of damage to the spleen. The pancreas is reviewed during the examination of the posterior wall of the stomach. The pelvic viscera are examined last, and to facilitate their examination the residual haemorrhage is more completely cleared away.

Where areas of obvious soiling and sepsis are present we mop away the infecting material, afterwards swabbing the part with warm eusol. We have entirely given up systematic washing out of the peritoneal cavity.

Drainage is called for less often than one would expect. We entirely close up all wounds of solid viscera and the majority of cases of wounds of the stomach and small intestine, exception, of course, being made where there is very obvious soiling.

In wounds of the colon, however, the question of drainage is on an entirely different footing; these wounds cannot be drained too thoroughly, more especially the fixed portion of the colon, the ascending and the descending; the drainage should be established as much as possible in the loin. Unless it is already infected, great care should be taken to avoid opening and so infecting the retrocolic tissues.

When the seriousness of the patient's condition demands great celerity, we close the abdominal wall with through-and-through sutures of silkworm gut, guarded when they pass over the wound junction with small pieces of capillary rubber tubing; in the insertion of these we employ a Doyen's handled needle.

Throughout the operation speed is an important factor, coupled with every possible avoidance of shock.

As regards the post-operative treatment, special attention is paid to the administration of fluids, for choice by continuous rectal salines and by subcutaneous infusions.

We have noticed that acute dilatation of the stomach is an occasional complication in the post-operative history. It occurs subsequent to intraperitoneal wounds, and also secondary to retroperitoneal wounds and infection. About forty-eight hours after the operation the patient complains of epigastric distension and a feeling of sickness, frequent mouthfuls of stomach contents are evacuated, and, later, large quantities of foul fluid containing bile and retained pancreatic juice are vomited. The signs and symptoms somewhat suggest a general septic peritonitis, but the distension and discomfort are at first, at any rate, localized to the epigastric region.

In its early stages the complication is easily arrested by stomach lavage, and if signs of repeated sickness come on we at once pass the stomach tube. The process may have to be repeated several times before relief is complete.

In operating on these cases we have purposely avoided the use of gloves, for by doing so we believe that we have diminished the length of time taken up by the operation.

In dealing with the post operative treatment, mention must be made of our experience of Sampson Handley's operation for peritonitis. Sampson Handley originally recommended the operation in cases suffering from pelvic peritonitis secondary to appendicitis and producing a condition which he called "ileus duplex," the obstruction being in the lower ileum and the pelvic colon. The operation consists in anastomosis of the lower ileum to the pelvic colon, or, under certain conditions, of the lower jejunum to the transverse colon, a caecostomy being done in each instance. After certain cases of wounds of the intestine a slowly developing peritonitis appears; it is most marked in the pelvis, and pathologically it produces a condition of ileus very similar to that which Sampson Handley describes. In four cases we have performed the suggested operation, in three cases anastomosing the lower ileum to the pelvic colon, and in one instance the lower jejunum to the transverse colon.

In one case the peritonitis was so intense and so general that the patient succumbed on the following day. In the other three cases the patients survived for five to seven days after the operation. For about three days there was an improvement, the bowels moving and sickness being arrested, but from this point the peritonitis appeared to re-establish itself and to progress with results eventually fatal. The operation was of temporary benefit, but it did not arrest the eventual development of the inflammation.

The diagnosis of perforating wounds presents little difficulty, and in any case of doubt it is well to err on the safe side, opening and exploring the abdomen.

Wounds of the back and loins invading the retroperitoneal space are the type which most frequently simulate true perforating wounds; they may be excluded by the fact that in these cases the general condition is good, that the pulse rate shows only a moderate increase, that there is not the same degree of rigidity as is found in true perforating wounds, and that there is not the same tenderness on palpation of the abdominal wall.

PROGNOSIS.

The prognosis of these cases depends upon a great variety of features. Some of the features which affect the prognosis are entirely incidental; take, for example, such an instance as the following:

Some time ago a party of Australians were caught in billets under heavy shell fire. Six of them suffering from abdominal wounds were admitted under our care; five of the cases suffered from penetrating wounds of the small and large intestine, the sixth from a penetrating wound of the stomach. Within twenty-four hours after operation every one of these cases developed infection with a gas-producing organism; the infection was in the intraperitoneal tissues. All the intestinal cases died, only the stomach case survived.

It was interesting to note that these patients were all men who had fought in the Gallipoli campaign, and all of them wore the same uniform as they had used in Gallipoli; it was apparently highly infected with organisms, and it was from the carrying in of portions of torn uniform by the shell fragments that the fatal infection developed. This

experience illustrated one of the accidental features which affects the prognosis of abdominal wounds.

This is an interesting fact: it has been our experience that uncomplicated wounds of the small intestine which are suitable for treatment by the operation of suture all recover; the operation is no more serious than an appendectomy. Lately we had a case which showed fifteen perforations throughout the length of the small intestine, but all were suitable for suture, and an uneventful recovery was made.

Stomach wounds offer quite a good prognosis when they are uncomplicated, but unfortunately this last desideratum is very rarely present.

Wounds of the colon, even when uncomplicated, demand a grave prognosis. The gravity arises from the liability which there is of infection of the retrocolic and retro-peritoneal tissue.

In uncomplicated wounds of the solid viscera a good prognosis may be given.

But, as we have said in a former paper, there is this fact to be recognized, that one must be prepared for repeated most bitter disappointments; yet, when a series of cases is reviewed, the gains seem infinitely greater than the losses. The prognosis, of course, very largely depends on the degree of the injury sustained; but an even more important factor is the length of time which has elapsed since the injury was sustained. Early operation offers the best and surest chance of ultimate success. In reviewing the statistics of the results of such operations as these it is impossible to consider the question *en masse*. Each individual case must be considered, for the chances of success depend upon so many factors that it varies enormously in different instances.

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ABDOMINAL INJURIES IN A CASUALTY CLEARING STATION.

BY

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In civil life, when a surgeon was confronted with an acute abdomen, his advice, if he saw the case in time, would always have been unhesitatingly "exploratory laparotomy." In fact, that term stood for diagnosis, treatment, and prognosis, all in one. Out here we hesitate. Some of the cases get well under expectant treatment, and it is then never known for certain what, if any, injuries they have had; others die, and even if *post-mortem* examinations reveal the causes of death, one cannot be sure what would have been the result of operative interference.

There seems, however, no reason to depart from our previous pre-war attitude. We have learnt a good deal, and advanced considerably, thanks to the work of Surgeon-General Bowlby, Colonel Wallace, and others in this field. An abdominal injury now means to most of us "see and treat," not "wait and see." Even if the patient be *in extremis*, there is a better chance by operation. There is often none after waiting. Even in the presence of advanced peritonitis an operation with drainage has occasionally succeeded, and the suggestion of high enterocolostomy put forward by Mr. Sampson Handley in the BRITISH MEDICAL JOURNAL (April 8th, 1916) seems a distinct advance on the treatment of peritonitis by drainage alone.

In many cases there is merely a continuous haemorrhage going on, and, when that is so, the chance of recovery, even in the most serious case, is good, once the haemorrhage is arrested. Ether anaesthesia and saline always bucks a patient up a little, and haemorrhage from abdominal injuries is by far the commonest cause of death within the first twenty-four hours. Peritonitis is a later danger, arising from rupture of a hollow viscus, or infection of the effused blood, and except in wounds of the stomach and upper part of the small intestine, where the contents are acid and irritating, peritonitis does not produce at first painful and alarming symptoms or so great shock as does simple haemorrhage. The escape of the contents of the

small intestine lower down, and of the colon, is rare in cases seen early in the casualty clearing stations—say during the first twenty-four hours. It seems as if the bowel were so completely paralysed by the blow caused by the rapid transit of the missile that no movement takes place for at least twenty-four hours, and infection only in the track of the wound is found on opening the abdomen. So slight may be the change in position of the bowel that the injured part is almost with certainty located at once, on opening the abdomen, lying just beneath the wound. Perhaps the morphine usually administered in the field ambulance helps to produce this effect, while the motor ambulance journey from the front may help occasionally to cause escape of bowel contents. Wounds of the stomach, the contents of which are often aseptic, may get sealed up by omentum or otherwise during this period of quiescence, and such wounds may heal without operative treatment if the patient is kept quiet and food withheld, but it is a hazardous chance to take.

INDICATIONS FOR LAPAROTOMY.

The indications for laparotomy would seem to be pain and rigidity of the recti, and marked shock or signs of haemorrhage. When these symptoms are marked, the diagnosis of serious intra-abdominal lesion is certain in nine cases out of ten, and in the tenth or doubtful case no harm will come from exploring. But there are ways and ways of exploring, and one of the most deadly is to evacuate the whole contents of the cavity all at once. It is an excellent method of finding the damage quickly, but it is equally quick in killing the patient by shock.

Pain varies in degree, but haemorrhage pure and simple into the peritoneal cavity has seemed to cause more pain and greater early mural rigidity than any other condition. It is not easy to explain this almost constant feature. There is practically no immediate peritonitis in pure blood effusion. The intestines, away from the point of injury, are normal in appearance in every case. There are no flakes of lymph, and yet the patient may have been alarming the whole ward by his shouts and moans, and have his recti as tense as boards. The amount of blood in the peritoneal cavity is often extraordinary, and bleeding is generally still going on. This last feature is in part due to the pumping effect of respiration in producing a vacuum at every inspiration. For the abdominal cavity becomes a rigid closed cylinder into which the blood is sucked from the wounded vessels by each upward movement of the piston—the diaphragm. Nature's method of minimizing this pumping effect may be to keep the walls of the cavity taut. Wounds of the liver, colon, and spleen give rise to most speedy haemorrhage, but one may find the abdomen full of blood from rupture of one vessel in the omentum or mesentery. The facial expression and pallid appearance is that of haemorrhage more than of shock or of peritonitis—the well known "facies hippocratica." The abdominal wall, tense and retracted at first, becomes later full and plump, suggesting to the eye an ascitic condition. Dullness in the flanks and fluid in the pelvis may be made out, if searched for. The pulse is small, thready, and rapid. Everything suggests urgency. Nothing is to be gained by delay, and these cases are sent to the operating theatre as soon as it can be got ready. One cannot but deplore the loss of time due to the distance the patient has had to travel, the consequent great loss of blood and the shock of a cold and rough journey from the trenches to the casualty clearing station, and speculate on the advantages to these cases of a similarly equipped station a mile or two behind the firing line.

OPERATION.

In the majority of cases I now prefer to enter by the wound, which is made the centre of the incision. The incision itself goes obliquely downward, in the line of the nerve supply, when the wound is outside the rectus, and vertically downwards when in the area of the recti. An elliptical cut excises the wound first completely down to the peritoneum, and sufficiently wide to give a clean edge. The end of the elliptical incision is prolonged, giving an opening 7 in. to 9 in. towards the exit wound, which may even require to be extended in one or both directions later. I do not hesitate to divide both recti straight across if necessary, and to do this quickly I fix the muscles to their sheaths above and below with safety pins before dividing