

# Management of Perforating Colon Trauma

## Randomization Between Primary Closure and Exteriorization

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During a 44 month trial, 268 patients with wounds of the colon were entered into a prospective, randomized, nonblinded study. Consideration for primary closure demanded that: preoperative shock was never profound, blood loss was less than 20% of estimated normal volume, no more than two intra-abdominal organ systems had been injured, fecal contamination was minimal, operation was begun within eight hours, and wounds of colon and abdominal wall were never so destructive as to require resection. Once such criteria had been satisfied, colon wound management was dictated by last digit in the randomly assigned hospital number; odd indicated primary closure; even, exteriorization of the wound or primary closure with protection by a proximal vent. Results obtained in 139 determinant patients eligible for randomization revealed that primary closure (67 patients) had a lower infection rate of the incision (48% vs 57%,  $p > 0.05$ ) and a still lower infection rate for the abdomen proper (15% vs 29%,  $p < 0.05$ ) on comparison to the 72 patients with a randomized colostomy. Morbidity otherwise for the randomized colostomy was tenfold greater than if a primary closure had been performed. Average postoperative stay was six days longer ( $p < 0.01$ ) if a colostomy had been created, exclusive of subsequent hospitalization for colostomy closure; while the total extra cost for management of the colon wound by colostomy was approximately \$2,700.00. Although immediate mortalities were identical, one late death occurred following colostomy closure. These data not only confirm the safety of primary closure for colon wounds in selected cases, but also indicate that such should become the preferred method of treatment whenever specific criteria have been met.

**D**URING RECENT YEARS, there has been increasing interest in primary closure of traumatic perforations of the colon.<sup>2,4,8,10-12,18,19,24</sup> Numerous claims have been made for both practicality and safety, yet no prospectively designed or randomly assigned treatment comparison has been published. Almost always the wound for primary closure has been a highly selected one. Results obtained from suture of relatively minor

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wounds with minimal contamination, brief delays from time of infliction to time of operation, few associated injuries, and occurrence in overall good risk patients have been contrasted to what follows exteriorization of relatively destructive colon wounds that have significant contusion and/or massive contamination, undergo operative care after a considerable lapse of time, are part of multiple organ system trauma, and present in relatively poor risk patients.

Accordingly, it was deemed appropriate to evaluate primary closure of colon wounds in a prospective and more objectively designed study. Only through randomization of treatment methods between truly equivalent groups could a valid assessment be made in regard to comparative safety, morbidity, and total medical costs.

### Design of Study

Between 1 July 1975 and 28 February 1979, all patients admitted to the Trauma and Pediatric surgical services at Grady Memorial Hospital became potential candidates for study of colon wound outcome. Management of blunt as well as penetrating abdominal trauma came under the direction of a single faculty member, although individual patient care was rendered by 32 different resident teams.

There was almost uniform adherence to a policy of initial energetic fluid resuscitation with 5% glucose in lactated Ringer's solution, whole blood and/or blood components being administered as the patient's condition warranted. Cephalothin (2 g intravenously/4 hours) was begun in the emergency clinic and was similarly continued at least until laparotomy had been completed and the patient had been discharged from the recovery

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room. Without exception, operation was begun as soon as cardiovascular stability had been achieved or, instead, immediately whenever major intra-abdominal vascular trauma was suspected.

At surgery, after bleeding had been controlled and all contaminating gastrointestinal perforations had been isolated, wounds of the colon were assessed for ability to be randomized and thereby considered for primary closure. If any one of seven criteria were met, an obligatory colostomy was performed (Table 1). These determinant findings reflected the severity of blood loss, the extent of colon and associated organ injury, degree of fecal contamination, and delay in obtaining surgical correction. If, however, randomization could be applied, patients with hospital numbers ending in an odd digit had primary closure of their colon wound in two layers, *i.e.*, an inner of interrupted chromic catgut or polyglycolic acid and an outer layer of interrupted 4-0 silk. Randomization to colostomy and the obligatory colostomy had essentially identical management: either exteriorization of the colon wound as a colostomy itself or primary closure of the large bowel perforation as described above plus protection by a proximal loop colostomy. No matter which treatment method was used, an anal sphincter stretch was routinely performed just prior to transfer of the patient from the operating room. Never before the second, yet almost always by the fifth postoperative day, the exteriorized colon loop was opened with a portable cautery, that is, except for the uncommon case of a primarily matured end enterostomy when obligatory colostomy had been dictated.

Baseline information was recorded for each of the three treatment groups so as to determine equivalency according to age, race, sex, mode of injury, preoperative fluid requirements, delay prior to operation, level of colon injured, and any other obvious factor. Results were evaluated for specific treatment groups by a comparison of raw mortality rates, cause of deaths, infection rates for both the peritoneal cavity and the surgical incision, complications directly attributable to the method of colon wound management, duration of hospitalization, major events associated with subsequent colostomy closure (if performed), and overall cost of medical care.

TABLE 1. Criteria For Obligatory Colostomy

1. Shock preoperative BP <80/60
2. Hemorrhage intraperitoneal blood loss >1000 ml
3. Organs >2 intra-abdominal organ systems injured
4. Contamination significant peritoneal soilage by feces
5. Time operation begun >8 hours after injury
6. Colon wound so destructive as to require resection
7. Abdominal wall major loss of substance/mesh replacement

TABLE 2. Mode of Colon Injury

	Randomized Closure	Randomized Colostomy	Obligatory Colostomy
Patients	67	72	129
Gunshot	49	53	118
Stab	15	17	5
Shotgun	2	1	4
Blunt	1	1	2

## Results

After a period of 44 months, 268 patients had been enrolled in the study. Of these, 129 required obligatory colostomy; while 139 failed to meet such criteria and thus could be randomized (Table 2). A primary closure was performed in 67, with 72 patients having randomization to colostomy.

No significant differences were noted in age, race, or sex in any of the groups or in mode of injury or level of colon involved between the two randomized treatment methods (Table 2). Nevertheless, patients assigned to an obligatory colostomy had a greater frequency of injury caused by either a gunshot or shotgun.

Fluid repletion averaged 207 ml for blood and 1640 ml for crystalloid, with little variation if randomization could be applied; while the same figures were 2245 ml and 2970 ml, respectively, for cases with an obligatory colostomy. Similarly, the interval from injury to operation was 3.96 hours if wound care could be randomized, but was 5.25 hours when obligatory colostomy was dictated. Such similarities between the randomization groups and their consistent differences on comparing to the obligatory colostomy group appeared to signify the equivalency of the injuries sustained by the former two and the greater degree of colon or associated trauma and contamination present in the latter.

Only one death occurred in each of the randomization groups, and neither of these was related to the colon wound or its specific management (Table 3). The resultant 1% mortality contrasted strikingly with that obtained in patients who had more destructive, shock-

TABLE 3. Immediate Cause of Death (268 Patients with Penetrating Wounds of the Colon)

Bleeding diathesis	3
Renal failure	3
Respiratory insufficiency	3
Sepsis	3
Pulmonary embolism	3*
Cerebral injury	2†
Irreversible shock	1
Stress ulceration	1
Myocardial infarction	1
Uncertain	1

\* One patient with randomized colostomy.

† One patient with randomized closure.

TABLE 4. Infection of the Surgical Incision

	Randomized Closure	Randomized Colostomy	Obligatory Colostomy	Total Cases
Patients	67	72	129	268
Wound infection	32	41	91	164
Infection rate	48%	57%	71%	61%

associated, multiorgan system injuries. The 19 deaths in that group gave a mortality rate of 15%, and three of these fatalities were due to peritoneal sepsis initiated by their colon wound. Other causes of death are listed in Table 3.

Infection of the surgical incision was greater, but not significantly so, on statistical analysis, if randomization had selected colostomy, 57%, not primary closure, 48% (Table 4). However, infection of the incision was even more common if an obligatory colostomy had been performed, *i.e.*, 71%. Peritoneal infection, on the other hand, was considerably more frequent whenever a colostomy had been performed (Table 5). A significant difference was noted between those patients assigned a randomized primary closure (15%) and those with a randomized colostomy (29%,  $p < 0.05$ ) or those with an obligatory colostomy (34%,  $p < 0.01$ ).

Development of intraperitoneal sepsis appeared to be considerably more common in cases where both an abdominal drain had been inserted and the colon wound had been managed by some form of colostomy (Fig. 1). Differences in peritoneal infection rate between primary closure and randomized colostomy ( $p < 0.001$ ) or obligatory colostomy ( $p < 0.01$ ) were dramatic if a peritoneal drain had been used. The same statistically significant differences were not found on reanalysis of infection rates for the surgical incision, even though presence of a drain uniformly was associated with a greater likelihood of infection developing in the wound (Fig. 2).

Complications of colon wound management were related to permanence of bowel repair and problems that could be directly attributed to the colostomy itself (Table 6). The only complication of primary repair was a minor fecal fistula which healed spontaneously after

TABLE 5. Infection Within the Peritoneal Cavity

	Randomized Closure	Randomized Colostomy	Obligatory Colostomy	Total Cases
Patients	67	72	129	268
Peritoneal infection	10	21	44	75
Infection rate	15%	29%	34%	28%

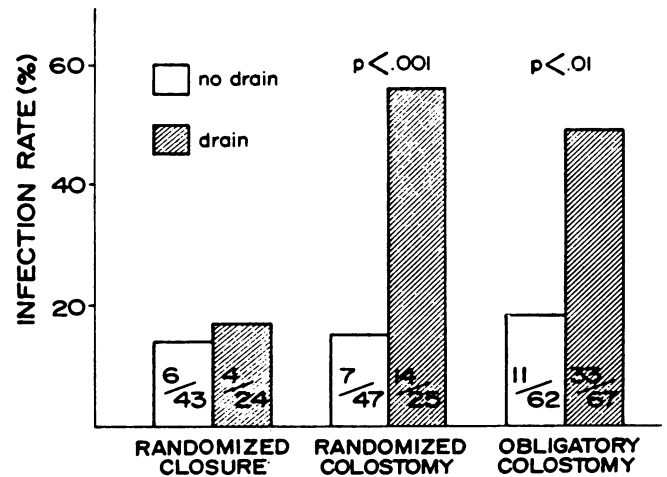


FIG. 1. Incidence of intraperitoneal infection with respect to presence of a colostomy and/or abdominal drain.

three weeks of attentive wound care. Following randomized colostomy, a similar relatively innocuous fecal fistula developed, but there were in addition eight other specific complications of the colostomy that occurred in six of the patients. Such morbidity due solely to colon wound management was 10% (Table 6). A colostomy morbidity of 28% was noted in those patients managed by an obligatory colostomy. Thus, no matter what the indication for colostomy, a significantly greater complication rate ensued when compared to results obtained from primary closure of the colon wound ( $p < 0.01$ ).

Hospitalization was consistently prolonged by use of a colostomy. On comparison of randomized treatment groups, primary closure resulted in a 16.6 day hospital stay, while randomized colostomy required a total of 22.3 days ( $p < 0.01$ ). A hospitalization of

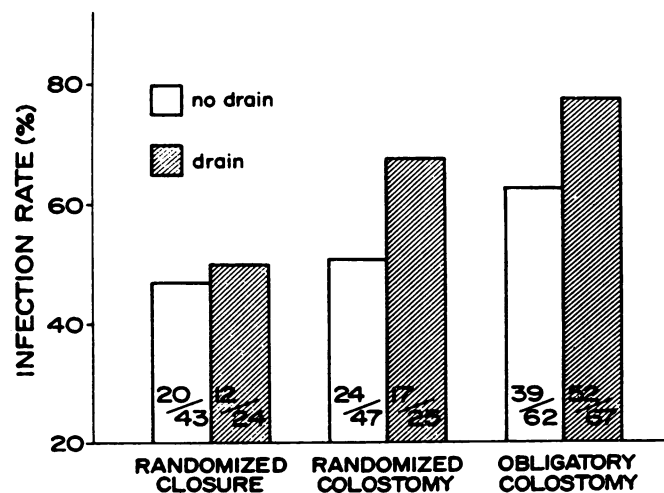


FIG. 2. Incidence of infection of the surgical incision with respect to presence of a colostomy and/or abdominal drain.

28.9 days was noted in patients with an obligatory colostomy, although such an extended stay was almost always the product of massive local trauma and multiple organ system involvement.

The colostomy was closed during a later hospital admission in 153 patients. Of the 72 who had a randomized colostomy, 62 have had such closed. The average duration of this second hospitalization was 11 days for a randomized colostomy, 12.2 days if the colostomy had been prescribed by one of the seven criteria. Unfortunately, one patient died of a pulmonary embolus following closure of his randomly assigned colostomy.

Tabulation of average expenditures revealed that an extra \$2,695.00 was spent for hospital care if the patient had been randomized to colostomy instead of primary closure of the colon wound (Table 7). Included in this financial assessment were prolonged initial hospitalization, colostomy appliances, second hospitalization, preoperative work up and colon preparation, and fees attendant to the colostomy closure itself.

### Discussion

The first documentation of a perforating wound of the colon is found in the Book of Judges.<sup>6</sup> The eventual outcome in this case, *i.e.*, death, was the same as what was almost uniformly noted during the many centuries to follow.<sup>5,7,17</sup> Although Lembert in 1827 was the first to record the successful closure of a small bowel perforation,<sup>9</sup> repair of colon wounds consistently failed up until the time of World War I.<sup>5,7,17</sup> Even elective operations on the colon were attended by significant mortalities due to wound and intraperitoneal sepsis, as well as disruption of the bowel suture line.<sup>3,13,16,17</sup> Closed techniques for bowel anastomosis, exteriorization of the site selected for re-establishing bowel continuity with a special clamp (*e.g.*, Mickulicz, Rankin, etc.), and protection of such suture lines by creation

TABLE 6. *Complications of the Colon Wound and its Specific Management*

	Randomized Closure	Randomized Colostomy	Obligatory Colostomy
Total patients	67	72	129
Fecal fistula	1	1	7
Colostomy necrosis	—	1	3
Colostomy retraction	—	2	5
Colostomy prolapse	—	1	3
Peristomal infection	—	3	11
Stenosis of stoma	—	1	3
Peristomal hernia	—	—	2
Total complications	1	9	34
Patients with complications	1	7	28
Incidence of colon complications	1%	10%	22%

TABLE 7. *Additional Hospital Costs (Per Patient with a Randomized Colostomy)*

Prolongation of initial hospitalization (5.7 days)	\$ 456.00
Colostomy appliances, etc.	\$ 123.00
Additional outpatient visits (4)	\$ 24.00
Second hospitalization for colostomy closure (11.0 days)	\$ 880.00
Preoperative workup (barium enema, etc.)	\$ 97.00
Bowel preparation (medications, etc.)	\$ 31.00
Miscellaneous laboratory and medication charges	\$ 136.00
Operating room and recovery room charges	\$ 125.00
Anesthetic fees and supplies	\$ 163.00
Surgical fee	\$ 660.00
Total extra expense per patient	\$2,695.00

of a proximal colostomy were among the many and varied surgical maneuvers developed to deal with this problem.<sup>3,13,16,17</sup>

During the first World War, an occasional soldier survived following the primary repair of his colon perforation.<sup>5,24</sup> No significant improvement in this high mortality was obtained, however, until the time of World War II, when exteriorization of colon wounds was almost routine and antibiotics became available for control of the ever-present complicating intraperitoneal sepsis.<sup>1</sup> Obligatory exteriorization of the colon wound was first suggested by Ogilvie<sup>1,5,7</sup> and soon became uniform practice in both the British and American armies during the North African Campaign of 1942.<sup>1,5,7</sup> The resultant mortalities for such abdominal trauma fell to less than 30%. Continued application of these principles, plus rapid evacuation and thus earlier operation, immediate availability of blood for transfusion, more definitive management of major vascular trauma, antibiotics, and better overall supportive care for the battle casualty decreased the mortality further, down to 10%, during the Korean and Vietnam conflicts.<sup>5,24</sup>

Beginning in the early 1950's, few reports of success in carrying out primary closure of selected colon wounds began to appear in the surgical literature.<sup>3,4,8,10-12,18,19,24</sup> The only comparative studies, however, were those contrasting the results obtained from primary closure of relatively minor, minimally contaminated, usually isolated traumatic colon perforations with the outcome following exteriorization of destructive, massively contaminated, often neglected large bowel wounds in the shocked, multiple trauma patient.<sup>3,4,8,10-12,18,19,24</sup> Uniformly, primary closure appeared more and more attractive. A notable exception was the prospective, randomized comparison of colon wound exteriorization versus primary closure of the perforation with protection by a proximal loop colostomy.<sup>8</sup> Morbidity and mortality statistics were essentially equal between the two treatment groups in this study.

Application of a technique using delayed primary wound closure, not just for the surgical incision but also for the colon perforation, was given a trial by several investigators.<sup>14,20,22</sup> Although continuation of bowel exteriorization could be avoided in more than half of the cases, a relatively large number of wounds were not conducive to such management and, even when criteria for selection were met, considerably demanding local wound care was generally required. Accordingly, this method has achieved popularity in only a few trauma centers.

The question still remains, however, is routine colostomy ever necessary? Why cannot primary colon repair be practiced in the majority of cases? Traumatic perforations of the small bowel have almost uniformly been repaired by primary closure or primary resection, while a colon wound in the same patient has been religiously exteriorized or its closure protected by a proximal colostomy. Certainly the degree of fecal contamination of the peritoneal cavity is identical if both occur in the same patient. Prior animal experiments have demonstrated that there is absolutely no difference in healing capacity between the large and small bowel.<sup>15</sup> Both have almost identical leak rates. The only real variable, then, appears to be what is contained within the intestinal lumen proper.

Unobstructed small bowel contents are relatively sterile when contrasted to the high density mixed-bacterial flora contained in feces.<sup>21</sup> Thus, any suture line failure will lead to continued peritoneal soilage by major pathogens whenever colon contents escape, yet the additional bacterial challenge is minimal in cases with a small bowel leak. Colostomy thereby appears to be always warranted if there is any doubt that a primary colon repair will disrupt, for consequences of a subsequent and persisting fecal spill into the peritoneal cavity are indeed life-threatening.

Possibly more attention should be directed toward the present state of the bowel itself. Significantly inflamed tissues, advanced infection with anaerobe participation, distal obstruction, presence of a local foreign body, abnormal tissues as a result of tumor or irradiation, and an impaired blood supply can individually prevent wound healing. Under any one of these separate circumstances, the bowel should be routinely exteriorized or the repair protected by a proximal enterostomy, irrespective as to whether the perforation involves the small intestine or colon. The same factors are similarly operative.

Results from the present prospective, randomized

study of truly equivalent patient groups support the practicality of selective primary closure of traumatic colon perforations. The method is equally safe, carries a lower morbidity, has a reduced infection rate (especially of the peritoneal cavity when concomitant drainage is necessary), requires a shorter duration of hospitalization exclusive of the obviated readmission for colostomy closure (with its 28% morbidity),<sup>23</sup> avoids the unpleasant experience with a colostomy, permits an earlier return to normal activities, and is considerably less costly in overall medical expenditure.

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#### DISCUSSION

DR. JOHN L. SAWYERS (Nashville, Tennessee): Dr. Stone is known for his prospective, randomized studies, and he certainly has not failed us today. We are indebted to him for performing a prospective, randomized study on injuries to the colon, comparing closure with exteriorization of the colon. He has had an enormous experience with injuries to the colon in a relatively short period of time. He has carefully defined the criteria that must be established to consider a patient for primary closure of a colonic injury, and he has certainly demonstrated that in these patients primary closure can be performed safely and with lower morbidity than exteriorization.

We have also studied different methods of managing injuries to the colon in civilians, comparing primary closure with colostomy, and also with a third method, exteriorized primary repair. Our knife and gun club is smaller than that in Atlanta, so we have a smaller number of patients than Dr. Stone, but we also found that 50% of our patients can have primary closure of the injured colon performed safely and effectively. Dr. Stone found a similar percentage.

In fact, in a report from the Tulane service in New Orleans a few years ago, and in a recent report from Jacksonville, Florida, exactly 50% of the civilians with injuries to the colon had a primary repair. This is an amazingly consistent percentage in Southern cities.

Exteriorized primary repair is a method that can be applied to some of the patients in the other half of that group. I would like to show you a slide about this method, which is not new; it was described by Mason in 1945.

(slide) These are the results in patients who had exteriorized primary repair and show our first 23 patients. Eighteen of these patients had an uneventful recovery, with interiorization of the primary repaired colon in six to ten days. Only three patients had major complications, with no deaths. Five patients had to have the loop opened as a colostomy, in three because the wound broke down, and in two because in our early experience we had exteriorized the colon too tightly over the glass rod.

(slide) If the exteriorized repaired colon remains intact, it can be put back into the peritoneal cavity in seven to ten days. If the repaired colon breaks down, then a formal colostomy can be done. We believe this method can be applied to the treatment of some of the patients about whom the surgeon is concerned about primary closure. This method of exteriorized primary repair offers a safe alternative to colostomy.

DR. FRANCIS C. NANCE (New Orleans, Louisiana): Dr. Stone has contributed greatly to the dialogue on the proper treatment of colon injuries. (slide) In a prospective way he has confirmed data that have been repetitively reported, not only from Charity Hospital, but from many other institutions: the complication rate among patients treated without colostomy, with primary repair, is lower.

(slide) The hospital stay is shorter, not even considering the readmission for colostomy closure. (slide) Even the mortality is lower among those patients.

All of the previous studies suffer from the defect of not being prospective and randomized studies. Dr. Stone's study does help to identify those patients who can be treated safely by primary suture.

This problem of using colostomy for colon injury started with Ogilvie in the Western Desert. If you read Ogilvie's report, the

mortality for those patients who had primary suture was, in fact, lower than for the patients who had colostomy. That same observation can be made about the data collected by the United States Army in World War II, but surgeons came back from World War II enthusiastically using colostomy for all colon injuries. Dr. Alton Ochsner was the first to point out that the enthusiasm had gone too far.

We can all be grateful to Harlan Stone for finally showing that there is a group of patients who can be managed safely by suture.

I have some questions I would like to ask Dr. Stone. First, I would like to quibble a little bit with his technique of randomization. Using an odd and even number system allows the surgeon to decide in advance whether or not he will enter the patient in the study, because he will know what the randomization procedure will be; that can be used as a criticism.

I wonder why Dr. Stone did not break right and left colon injuries apart. Some people feel there is a difference, and I wonder if he would address that issue.

I would like to know specifically what Dr. Stone's skin wound management was. The incidence of infection here is high, as it is in all services, and I wonder how the skin wound was managed.

Finally, I would like Dr. Stone to speculate on what the results of a randomized study of this excluded group of patients would have been. Would there have been the same difference in mortality and morbidity among those patients if all patients had been entered into the study?

DR. ROBERT J. FREEARK (Maywood, Illinois): Our experience is somewhat in conflict with those reported today. These differences may reflect a special population which was certainly not randomized on the basis of the favorable circumstances reported by the authors. I would like to comment in regard to the treatment of the nonrandomized group.

(slide) I apologize for submitting old data, but I think the opportunity to learn from such cases will never again occur. This is in an era, 1965 to 1970, in a rather large series at the Cook County Hospital, in which the average time interval from injury to the colon to arrival in the operating room was something over five hours. Virtually none of these patients received any preoperative antibiotics.

The study involves 415 patients with injuries to the colon, two-thirds of whom sustained gunshot wounds. Taking out those who died in the first 24 hours, in which the management of the colon wound could not really be evaluated, and eliminating those with injuries below the peritoneal reflection, in which there is general agreement in regard to management, we ended up with (slide) this group of 391 patients. Relative to the various areas of the colon, 55% of the 93 injuries to the right colon were repaired and dropped back with only the addition of intraabdominal drains. The other 45% had some form of exteriorization, either a proximal colostomy, exteriorization, or repair with a proximal colostomy.

Similar percentages in the other areas of the colon are shown. The relatively low percentage (25%) of primary repairs in the transverse colon is a reflection of the high incidence of associated injuries that go with a gunshot wound through the transverse colon. Such wounds result from missiles that frequently injure the duodenum and pancreas, and the resident staff who operated upon these patients was quite clearly interested in getting those colons out of the abdomen and not "chancing" a primary repair.