Delayed Manifestations of Laparoscopic Bowel Injury

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Bowel injury (BI) is a complication of open and laparoscopic abdominal surgery associated with increased morbidity and mortality. If BI is missed at the time it occurs, it can have devastating consequences. Electrosurgery is used extensively in laparoscopic surgery and can cause thermal injuries that are harder to detect than mechanical injuries and may evolve over time. The medical literature of the past 10 years was searched for large series and compilation studies reporting overall incidence of and mortality from BI in laparoscopy, and the results of seven relevant articles, which included over 300,000 procedures, were analyzed and tabulated. The literature was then reviewed for additional information about the specific incidence and outcome of missed BI and the role of electrosurgical thermal sources in causing BI. BI is underreported, frequently missed at surgery, and results in significant morbidity and mortality that can be ground for malpractice claims against the surgeon. Thermal injury from electrosurgical instruments may be involved in a number of injuries in laparoscopic surgery. Nearly undetectable partial-thickness thermal injury may play a role in the atypical and delayed presentation of some cases of BI.

IATROGENIC BOWEL INJURY (BI) can occur in the course of both open and laparoscopic surgical procedures as the result of the inadvertent application of mechanical force, thermal energy, or a combination of both to the bowel wall. Partial-thickness injuries affect only the outer layers of the intestinal wall, whereas full-thickness injuries extend through all the layers and violate the intestinal lumen. The term enterotomy is widely used in the literature as a synonym of a full-thickness penetration of the bowel wall. Partial thickness injuries have the potential to either evolve into full thickness or heal over a variable period.

Surgeons are painfully aware that any procedure that involves lysis of peritoneal adhesions from previous surgery is potentially associated with the risk of BI. The risk of full-thickness injury has been shown to increase dramatically with the number of previous laparotomies[1] and in a recent prospective study of mostly open ventral hernia repairs one in eight patients who sustained the injury.[2] Laparoscopic surgery compounds the risk of BI associated with peritoneal adhesions, and laparoscopic attempts specifically aimed at lysis of adhesions have been reported to be associated with up to a 100 per cent incidence of BI.[3]

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BI is underreported in operative dictations and discharge summaries, and is not always tracked accurately at institutional level: even a prospective complication tracking system, specifically designed to capture all intraoperative complications in real time by using a trained nurse practitioner as independent observer in the operating room, missed three of the 36 injuries that occurred during the study.[4]

The negative impact of inadvertent BI is hard to understate. Patients who underwent abdominal surgery after one or more previous laparotomies and sustained a full-thickness BI experienced a 2-fold morbidity increase.[5] Patients who had a full-thickness BI in the course of their abdominal wall repairs were about three times more likely to require urgent surgical reintervention and parenteral feeding and experienced a length of stay that was more than double that of patients who did not.[2]

The consequences of a missed BI are even more devastating: Khoury et al.[6] reviewed 32 patients whose BI was not recognized at surgery and was diagnosed from one to 13 days later. Eighteen of the patients required an intensive care unit admission, 16 had a surgical site infection, 10 went into multisystem organ failure, seven developed intra-abdominal abscesses, and six were diagnosed with enterocutaneous fistulas. Seven of the patients died, but there was no significant difference in diagnostic delay between the patients who survived and those who did not. BI is elusive and may go unrecognized even under nearly

ideal circumstances: 8.5 per cent of the patients who sustained an injury during mostly open abdominal wall repairs in a recent prospective study designed to assess the incidence of the complication were diagnosed only after the procedure.[2] Delayed recognition of an enterotomy and its aftermath has been frequent ground for allegations of malpractice against surgeons, and a 1994 study by the Physician Insurers Association reported that late diagnosis was claimed in 75 per cent of the 615 claims for laparoscopic BI over a 1-year period.[7]

This study was designed to review the presently reported rates of BI in laparoscopic surgery, focusing on the frequency and outcome of missed injuries and the possible role of thermal energy in causing a delayed clinical presentation.

Methods

Using a PubMed search of the Medline database, the English literature of the past 10 years was searched to identify articles reviewing the incidence of BI and enterotomy in laparoscopic surgery. Studies involving a total of less than 1500 procedures were excluded, and only studies providing the occurrence rate of BI were included. Seven studies, five compilations and two cohort reviews, for over 350,000 laparoscopic procedures were selected using these criteria.

The index laparoscopic procedures were assigned to the basic or complex category using the classification provided by the Accreditation Council of Graduate Medical Education to log the operative experience of surgery residents, and the study results tabulated accordingly. The largest study reviewed is a compilation totaling 329,935 laparoscopic procedures, mostly in the basic category, and includes 107,285 cholecystectomies.[8] The limitations of the underlying data in the study are addressed in the footnotes to Table 1. The other four compilation studies are representative of the complex laparoscopy category, and are each focused on a specific anatomical region or indication such as ventral hernia repair,[9] colorectal resection,[10] surgery of the retroperitoneal organs,[11] and surgery for acute small bowel obstruction.[12] Of the two cohort studies, one is a combination of basic and advanced laparoscopic procedures[3] and the other is a review of ventral and incisional hernia repairs,[13] which fall in the complex laparoscopy category. All seven studies reported the enterotomy rate; six also included the incidence of missed injuries, five provided the overall mortality attributable to BI, and only four specifically

TABLE 1. *Laparoscopic Bowel Injury (BI): Incidence and Mortality*

		Overall BI (%)	Unrecognized BI (%)	Overall BI Mortality (%)	Unrecognized BI Mortality (%)
Basic lap	van der Voort, 2004[8]*	66/29,352† (0.22)	96/250‡ (38.4)	16/450§ (3.6)	3/26¶ (11.5)
	Binenbaum, 2006[3]‖	8/2,016 (0.39)	4/21 (19.04)	0/21 (0.0)	0/4 (0.0)
Advanced lap	Binenbaum, 2006[3]**	13/691 (1.88)			
	LeBlanc, 2007[9]††	72/3,925 (1.78)	13/72 (18)	2/72 (2.8)	1/13 (7.7)
	Schwartz, 2010[11]‡‡	94/14,447 (0.65)	43/94 (45.74)	1/94 (1.06)	1/43 (2.32)
	Sammour, 2011[10]§§	33/1,568 (2.1)	N/A	N/A	N/A
	O'Connor, 2012[12]¶¶	110/1,673 (6.6)	18/110 (16.36)	N/A	N/A
	Sharma, 2013[13]‖‖	33/2,346 (1.4)	5/33 (15.15)	2/33 (6.06)	2/5 (40)
Total	Basic	74/31,368 (0.23)	179/580 (32.4)	21/670 (3.13)	7/91 (7.69)
	Advanced	355/24,650 (1.44)			

* Study aggregates the results of 28 reviews for a total of 329,935 laparoscopic procedures, 107,285 of them cholecystectomies, and includes 450 bowel injuries. Most of the procedures fall in the basic laparoscopy category, but the study also includes 758 fundoplications with 6 injuries (0.8%) and 932 bowel resections with six injuries (7%).

† The denominator reflects that the extent of the bowel injury was clearly identified only in 17 of the 28 studies reviewed for a total of 29,352 procedures, in which only 66 of the 105 bowel injuries reported were explicitly classified as enterotomies.

‡ The denominator reflects that the timing of diagnosis was available only in 250 injuries. The numerator includes 13 injuries that were diagnosed after the index procedure but within 48 hours of it, and the Authors chose to exclude from the missed injury group.

§ The denominator reflects the Authors' choice to include all the 450 bowel injuries and not only the 66 explicitly classified as full thickness enterotomies when calculating the mortality rate.

¶ At least 3 of the 26 patients in whom the diagnosis was delayed over 48 hours died, since the Authors report that the diagnosis was made at autopsy in 3 cases.

‖ Cholecystectomy.

** Total includes 375 intestinal surgeries, 312 hernia repairs, and 4 lyses of adhesions.

†† Laparoscopic incisional and ventral hernia repair.

‡‡ Retroperitoneal organ laparoscopy: upper urinary tract, adrenals, and lymph nodes.

§§ Colorectal surgery, study limited to analysis of intraoperative events.

¶¶ Laparoscopic treatment of acute small bowel obstruction. Study does not include enterotomy-specific mortality data.

‖‖ Laparoscopic incisional and ventral hernia repair.

N/A Data not available or not consistently reported.

reported the mortality associated with its delayed diagnosis. The value of each variable was included in the aggregated results only when available and the underlying data were considered consistently reported.

Medline was mined for additional smaller studies reporting morbidity and mortality associated with missed injuries, and the medicolegal ramifications of diagnostic delays. The literature was also searched for additional articles on BI from electrosurgery to further define the role of thermal energy sources in missed BI's.

Results

The results are summarized in Table 1. The reported rates of enterotomy during basic laparoscopic procedures are between 0.2 and 0.3 per cent.[3, 8] More complex laparoscopic procedures are associated with a higher reported incidence of enterotomy, with rates between 1.4 and 2.1 per cent. At the two extremes of the spectrum, enterotomy complicated only 0.75 per cent of advanced laparoscopic procedures on retroperitoneal organs[11] but 6.6 per cent of those undertaken for acute small bowel obstruction.[12]

When enterotomies occur they may escape detection, and the diagnostic delay that ensues a missed injury is associated with 100 per cent morbidity. Of the laparoscopy series reviewed, the lowest rate of delayed recognition of enterotomy was 15.15 per cent.[13] The highest rate of unrecognized enterotomy was 45.74 per cent and was reported in the retroperitoneal procedures series.[11] When all the comparable data are aggregated, they show that enterotomy was missed in 32.4 per cent of the cases. After discarding the highest and the lowest reported rates, the mean missed enterotomy rate is relatively unaffected and remains at 17.02 per cent.

Mortality arising from inadvertent BI was inconsistently reported in all the studies reviewed. Only five studies[3, 8–11] provide comparable data, and show that 21 of 670 patients who sustained a BI died, with a 3.13 per cent overall mortality rate. The same studies indicate that seven of 91 patients whose enterotomy was missed at surgery died, with a 7.69 per cent mortality rate from unrecognized injury.

Data about the mechanism of injury were inconsistently reported and could not be meaningfully aggregated. In the early years of laparoscopy, enterotomy frequently occurred during the entry phase of the procedure and was the result of mechanical injury by Veress needles and trocars in up to 83 per cent of the cases.[14] More recent studies, however, show that in both basic and advanced laparoscopy most injuries occur during the dissection phase of the procedure, when the mechanical energy of sharp and blunt dissection is used in combination with the thermal energy generated by electrosurgery.[3, 11] It is often very difficult to ascertain whether an enterotomy was the result of mechanical force, thermal energy, or a combination of both, especially when the injury is discovered late. Only two studies address the topic, and thermal energy was thought to be the principal cause of the injury in 25.6 and 23.1 per cent of the cases, respectively.[8, 11] Thermal energy sources were postulated as a possible cause of the injury in eight of 29 patients in a study focused on missed enterotomy.[6] The histological changes occurring in rabbits' bowel after electrosurgical injury include coagulative necrosis, absence of capillary in-growth and fibroblastic muscle coat reconstruction, and absence of white blood cell infiltration except near the viable borders.[15] Histological changes consistent with an electrosurgical source were described in 6 of 66 injuries reviewed for medicolegal purposes.[16]

Electrosurgical devices can cause thermal tissue damage through a number of mechanisms, including 1) unintended direct application of the electrosurgical current to the tissues; 2) transmission through another conducive instrument, or coupling; 3) discharge through faulty insulation; 4) capacitive coupling, a phenomenon that occurs when the surrounding charge that is associated with the use of all the monopolar active electrodes is not allowed to flow back through the body tissues to the passive electrode and builds up in a metal part of the instrument that may then transfer this energy into the tissue and damage it.[17] Another potential source of thermal injury, antenna coupling, has been recently described.[18] Antenna coupling occurs when the active electrode acts as an active transmitting antenna and emits energy, which is captured without direct contact by an inactive wire in close proximity that functions as an electrically inactive receiving antenna.

Except for the inadvertent direct application of thermal energy, all the mechanisms of injury by electrosurgery involve coupling and energy discharge that are likely to occur outside the operator's limited field of view afforded by the laparoscope. In a 1993 survey of members of the American College of Surgeons, 85 per cent of the respondents reported using monopolar electrosurgery during laparoscopy, 18 per cent had personally experienced a complication related to electrosurgery, and 54 per cent knew another surgeon who did.[19]

The medicolegal ramifications of these facts were not lost on the Association of Trial of Lawyers of America. The association, that has since renamed itself The American Association for Justice, founded in 1995 a Laparoscopic Surgery Subgroup, which concluded that "most electrosurgical burns are not detected at surgery because they occur outside the surgeon's keyhole field of view," and noted that there was "no

standard training or credentialing for performing laparoscopic monopolar electrosurgery," and that the courts did not show any willingness "to exonerate physicians for accidental electrical discharge."[20]

A variable combination of persistent focal pain at a trocar site with abdominal distention, diarrhea, and leukopenia has been described as suggestive of an unrecognized laparoscopic BI.[21] Clinical presentation of a missed BI is however frequently muted and preceded by an insidious onset with vague and protean symptoms of difficult interpretation, such as abdominal distention and incisional discomfort, leading to diagnostic delays that may be significantly longer with electrosurgical injuries. Intestinal burns from electrosurgical devices were initially observed in conjunction with laparoscopic sterilization procedures and the first three cases of small bowel perforation secondary to laparoscopic tubal cauterization were reported in 1973.[22] In two cases, symptoms of acute peritonitis appeared one and three days after the initial procedure, but in the third case the patient presented a week after the procedure complaining of intermittent abdominal pain and abdominal distention and with radiological evidence of an ileus, and only after admission the patient developed fever and leukocytosis. An inverse relationship between the severity of tissue damage and the time interval from injury to perforation was hypothesized to explain the delayed presentation. Four patients with histological evidence of electrosurgical injuries that were not identified at surgery developed symptoms and were diagnosed only five to 15 days after the index procedure.[16] The average time from occurrence to diagnosis was 1.3 days for mechanical injuries and 10.4 days for electrosurgical injuries that went undetected at laparoscopy.[23] A negative immune modulating effect of laparoscopy has been described in an animal model and may contribute to masking clinical and laboratory evidence of peritonitis after laparoscopic BI.[24] A low index of suspicion for enterotomy is generally recommended, as is a low threshold for reexploration, and injury can in some cases be suspected on the basis of tachycardia alone.[9]

Conclusions

The reported rates of BI in laparoscopy may not accurately reflect the actual incidence of this potentially fatal complication due to underreporting. On the basis of the reported rates, however, BI seems to be a rare complication in basic laparoscopy; its incidence increases 5- to 10-fold but remains in the lower single digits for advanced laparoscopy, and rises dramatically only when laparoscopic lysis of adhesion is undertaken. Up to one in five inadvertent injuries is missed at the time of the original surgery. The ensuing diagnostic delay is uniformly associated with postoperative morbidity and dramatically increased costs, results in significant mortality, and frequently leads to malpractice claims against the surgeon.

Thermal energy delivered by electrosurgical instrument may play a significant role in a number of cases. Tissue damage from thermal energy sources may be nearly invisible, and its lateral extension and depth virtually impossible to assess by visual inspection, thus making electrosurgical injury more likely to be missed.

Under certain circumstances, thermal energy generated by electrosurgical instruments has the potential to cause a partial-thickness injury of the bowel such as the one illustrated in Fig. 1, with a picture taken about 48 hours after the index procedure. Tissue damage may be sufficient to cause early in the postoperative course ileus and a severe systemic inflammatory response without clear signs of peritonitis, in a clinical picture almost indistinguishable from the physiological response to surgical trauma. This insidious and atypical presentation may result in diagnostic delays until either a frank perforation becomes evident, or the injury heals and the unexpectedly prolonged ileus resolves. It may be argued that a diagnostic delay in this setting reflects more the subtle and evolving nature of the injury than negligence by the treating physicians.

Extensive literature details the myriad of safety measures aimed at decreasing the incidence of electrosurgical injuries. Tools quantifying thermal damage induced by electrosurgery in laparoscopy are being developed and may prove useful in adjusting safety guidelines,[25] but short of avoiding the use of electrosurgical devices altogether, no measure is likely to succeed in completely eliminating these injuries. On the contrary, newly popular techniques such as

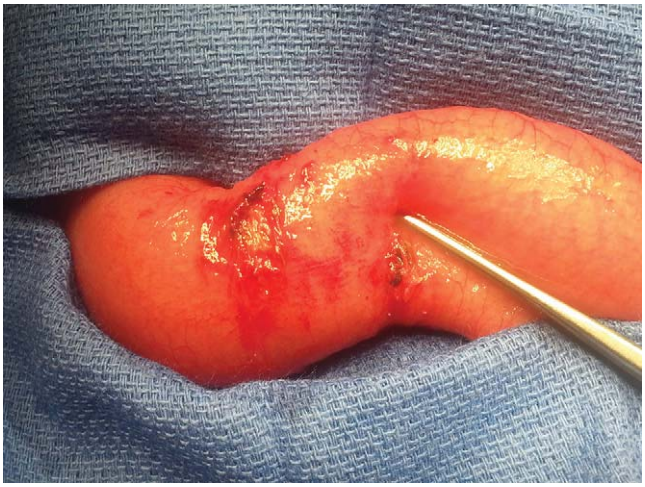

FIG. 1. Intraoperative photograph of partial thickness small bowel burns two days after laparoscopic electrosurgical injury.

single-port laparoscopic surgery may be more likely than standard multiport laparoscopy to result in an electrosurgical injury.[26]

Prospective studies of standardized nontransmural intestinal electrosurgical injury in an animal model could aid in the early identification of specific clinical predictors of its evolution into transmural injury. In the interim, because of its potentially devastating consequence, albeit rare, transmural electrosurgical injury must be suspected in any patient who unexpectedly fails to recover uneventfully after a laparoscopic procedure.

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