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A Prospective Analysis of Diagnostic Laparoscopy in Trauma

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Objective

This study was performed to assess current and potential future application for laparoscopy (DL) in the diagnosis of penetrating and blunt injuries. Efficacy, safety, and cost analyses were performed.

Summary Background Data

Diagnostic peritoneal lavage (DPL) and computed tomography (CT) have been the mainstays in recent years for diagnosis of equivocal nontherapeutic laparotomy, whereas CT is not helpful for the vast majority of penetrating wounds. DL may be a useful adjunct to fill in these gaps.

Methods

Hemodynamically stable patients with equivocal evidence of intraabdominal injury were prospectively entered into the protocol. DL was performed under general anesthesia; patients with wounds penetrating the peritoneum or blunt injury with significant organ injury underwent laparotomy.

Results

Over 19 months, 182 patients (55% stab, 36% GSW, 9% blunt) were studied. No peritoneal penetration was found at DL in 55% of penetrating wounds with 66% of the remainder having therapeutic laparotomy, 17% nontherapeutic laparotomy, and 17% negative laparotomy. Therapeutic laparotomy was performed in 53% of blunt injuries after DL. Tension pneumothorax occurred in one patient and one had an iatrogenic small bowel injury. Charges for DL were $3,325 per patient compared with $3,320 for a similar group undergoing negative laparotomy before this protocol.

Conclusions

DL is a safe modality for trauma. With current technology, DL is most efficacious for evaluation of equivocal penetrating wounds. Significant cost savings would be gained by performance under local anesthesia. Development of miniaturized optics, bowel clamps, retractors, and stapling devices will reduce overall costs and permit some therapeutic applications for laparoscopy in trauma management.

Diagnostic techniques for potential intraabdominal injury have evolved with the development of new concepts and advancing technology. It takes several years of clinical application before a precise niche for an examination is defined, and occasionally an otherwise good concept finds no long-term merit.[1] Further, no single modality is applicable to all situations and all mechanisms of injury. Some injuries have continued to be elusive in the face of

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diagnostic advances. These include duodenal, pancreatic, and diaphragmatic injuries. Diagnostic peritoneal lavage (DPL) and computed tomography of the abdomen (CTA) have been applied for approximately 25 and 10 years, respectively, and have been the most widely used techniques over that time frame.

After introduction by Root in 1965, DPL developed into the standard for diagnosis of blunt injury.[2] It can define the presence though not the source of intraperitoneal hemorrhage. The accuracy of DPL has been reported to be greater than 95% and has proven to be highly reproducible among centers.[1,3] Oversensitivity has proven to be a problem. It takes only approximately 30 ml of blood to produce a RBC count of 100,000/mm^3 when diluted with a liter of crystalloid solution. Thus, positive lavage commonly results in nontherapeutic laparotomy due to nonbleeding minor liver and spleen lacerations. This can also result, though less frequently, with grossly positive lavage ($\geq$10 cc blood aspirated).

CTA offers the advantage of anatomically defining the source of hemorrhage. Development of more sophisticated scanners coupled with extensive clinical application have permitted a reasonably high degree of confidence in nonoperative management of a significant percentage of solid visceral injuries;[4–7] many of these injuries would have previously yielded nontherapeutic laparotomy with DPL. However, presence of ongoing hemorrhage can only be assessed by observing the patient's clinical status inevitably resulting in increased transfusion requirements for some patients. CTA provides reasonably good definition of retroperitoneal injuries that are usually not detected by DPL, though pancreatic injuries can be missed if scanning occurs within a few hours of injury. The diagnosis of diaphragm injury remains a dilemma for both DPL and CTA.[1,8]

Penetrating wounds create a different problem. CTA is not reliable since hollow visceral injuries occur in almost 50% of patients. Mandatory exploration, local wound exploration, observation, and DPL have all been used for managing the patient with an equivocal physical examination. Most institutions rely on a policy of near mandatory exploration for gunshot wounds to the torso below the nipple line, but 20% of these will have tangential wounds to only the abdominal wall.[9] A much lower number of stab wounds penetrate the peritoneum so that mandatory exploration results in up to 70% having negative laparotomy. Observation with repeat examination has been supported from a recent experience that noted only 11% delayed laparotomy rate.[10] A drawback is the necessity for 1 to 2 days of hospitalization and some morbidity associated with delayed operation for hollow viscus injury. DPL has been used with different cell counts considered positive. When 100,000 RBC/mm^3 is considered positive, a 11% false-negative rate has been found. When the criteria for positivity was dropped to 10,000 RBC/mm^3, a 14% false-positive rate was noted.[11] Most clinicians would admit the patient for observation even in the face of negative DPL. Local wound exploration of stab wounds followed by laparotomy when the anterior fascia is violated has been our institutional approach and has resulted in almost a 50% negative laparotomy rate.

Laparoscopy was first reported for diagnostic use in trauma by Gazzaniga in 1975.[12] It has been sporadically used over the ensuing years. The explosive application of laparoscopy by general surgeons in recent years has resurrected realization of its potential use for evaluation of blunt and penetrating injury. For blunt trauma, it may not only determine the source of hemorrhage but also define the degree of organ injury as well as ongoing bleeding. Finding no peritoneal violation by penetrating wounds could potentially permit hospital discharge after laparoscopy. However, it is not clear whether visualization would be adequate to define all injuries. There are potential serious complications of laparoscopy for trauma, including gas embolization associated with venous injuries and tension pneumothorax with diaphragm disruption. The costs of trochars and other laparoscopic equipment are not insignificant, although decreasing length of hospitalization might counterbalance that expense. Laparoscopy will undoubtedly have a place in our diagnostic scheme for abdominal trauma which must be defined. This clinical research trial was undertaken to address the issues of efficacy, safety, and expense to further define the place for diagnostic laparoscopy (DL) in management of the trauma patient.

METHODS

This prospective evaluation of DL was initiated April 1, 1991. Candidates for the study included patients with both penetrating and blunt mechanisms of injury. Exclusions included those who had undergone previous laparotomy, those with posterior stab wounds, and patients who were suspected to have peritoneal penetration and/or intra-abdominal injury. Data collection included demographics, mechanism of injury, organs injured, OR time, anatomic site of penetrating entrance, and complications of laparoscopy.

Patients with stab wounds to the anterior or lateral abdominal wall were candidates for study. They were first evaluated by wound exploration under local anesthesia. If the anterior fascia was violated, they were admitted to the study for DL. Before initiation of this protocol, those patients underwent mandatory exploration. Stable patients with lower thoracic (nipple line to costal margin) stabs with or without known pleural penetration and potential diaphragmatic penetration were included. Tube thoracostomy was performed before DL when chest radiograph showed hemo/pneumothorax. Patients

with gunshot wounds and who were thought by physical examination to likely have tangential passage of the missile through the abdominal wall without peritoneal penetration were included. Entrance wounds were on the anterior, lateral, or posterior torso or gluteal region. Patients with blunt injury were a less homogenous group. This cohort included stable patients with either positive DPL or liver/spleen injury indicated by CTA, especially those requiring general anesthesia for repair of an associated injury. Patients with equivocal abdominal examination and without undergoing other diagnostic modalities were also included.

Laparoscopy Technique

All examinations were performed in the operating room under general anesthesia. The anesthesiologists routinely used both pulse oximetry for oxygen saturation measurement and end-tidal carbon dioxide (CO_2) sensors. The abdomen was prepped after nasogastric intubation and urinary bladder catheterization. With the patient in the Trendelenburg position, a Verres needle was inserted in the infra-umbilical position and CO_2 insufflation done. Generally, 3–4 l of CO_2 were required to maintain an intraabdominal pressure $\leq$ 15 cm H_2O. A 12-mm trochar was inserted at the site of the Verres needle and a 10-mm 0° angle laparoscope placed through it for initial evaluation. The area of suspected peritoneal violation from penetrating injuries was inspected. The protocol initially called for mandatory laparotomy with evidence of peritoneal violation to avoid missed injuries. Hence, extensive exploration was not always carried out. In the case of blunt injury, intraperitoneal blood was suctioned and the solid viscera inspected for degree of injury and hemorrhage. When diaphragm or lower abdominal exploration was required, additional 5-mm trochars were placed in the upper or lower abdomen for insertion of probes, graspers, and suction/irrigators. A 5-mm laparoscope was often used to evaluate the posterior recesses of the diaphragm. The operating table was liberally rotated from left to right and head to foot to facilitate exposure by shifting of the abdominal contents.

Definitions

Relative to penetrating injuries, several definitions are required for findings of both laparoscopy and laparotomy. *Negative laparoscopy* was absence of peritoneal penetration. *Positive laparoscopy* was presence of peritoneal penetration. *Negative laparotomy* was absence of intraabdominal injury. *Nontherapeutic laparotomy* found organ injury that did not require intervention, e.g., nonbleeding minimal liver or spleen injuries. *Therapeutic laparotomy* required surgical correction of organ injury.

Retrospective Analysis of Negative Laparotomy

To determine complications and hospital charges associated with negative laparotomy for penetrating trauma in our institution, a review of the year immediately before this study (April 1, 1990 through March 31, 1991) was undertaken. This data was used for a comparison of DL versus our prior approach of mandatory laparotomy for stab wounds penetrating the anterior fascia and for truncal gunshot wounds.

RESULTS

Over the 19-month period ending October 31, 1992, 182 patients underwent DL for trauma. Males accounted for 82% of the population. The mean age was 32 (range: 14–70). During this same period, 634 patients underwent laparotomy after injury, but were not evaluable laparoscopically. Thus, 22% of patients with possible abdominal injury underwent DL. Mechanisms of injury for the DL population included stab wounds 55%, gunshot wounds 36%, and blunt injury 9%; for those undergoing laparotomy without DL, stab wounds accounted for 14%, gunshot wounds for 52%, and blunt injury 34%. During the study, 52% of stab and 17% of gunshot wounds were evaluated by DL. A percentage of blunt injuries evaluated by DL could not be calculated because an undetermined but significant number were evaluated by only CTA, DPL, or a combination of the two.

At the time of DL, 97 (53%) patients had either no peritoneal penetration (penetrating trauma) or no significant injury (blunt trauma) and did not undergo laparotomy. No intraabdominal complications or missed injuries were noted in any patients in that group. Laparotomy was performed in 85 (47%) patients: 59 (70%) had therapeutic laparotomy, 13 (15%) had nontherapeutic laparotomy (trivial injuries); and 13 (15%) had negative laparotomy (peritoneal penetration without organ injury). There were no deaths in this series.

Stab Wounds

Table 1 illustrates the anatomic locations of the stab wounds. Eighty-one percent were in the upper abdomen and half of the wounds were in the left upper quadrant. We do not believe this represents a selection bias for laparoscopy, but probably reflects that most assailants were right-handed. No peritoneal penetration occurred in 49%. Of the 51% with peritoneal penetration, 31% underwent therapeutic laparotomy, 6% nontherapeutic laparotomy, and 13% negative laparotomy; two patients (4%) had superficial liver injuries identified and were observed nonoperatively without subsequent problems.

Table 1. LOCATION AND MANAGEMENT OF STAB WOUNDS IN 99 PATIENTS*

	E	RUQ	LUQ	RLQ	LLQ	Total
Negative laparoscopy	6	13	24	3	3	49
Laparotomy	1	9	27	8	5	50
Therapeutic	0	6	17	5	3	31
Nontherapeutic	0	2	3	0	1	6
Negative	1	1	7	3	1	13
Total	7	22	51	11	8	99

* E = epigastrium; RUQ = right upper quadrant; LUQ = left upper quadrant; RLQ = right lower quadrant; LLQ = left lower quadrant.

Table 3. LOCATION AND MANAGEMENT OF GUNSHOT WOUNDS IN 66 PATIENTS*

	RUQ	LUQ	RLQ	LLQ	Total
Negative laparoscopy	15	9	8	9	41
Laparotomy	10	10	0	5	25
Therapeutic	9	9	0	1	19
Nontherapeutic	1	1	0	1	3
Negative	0	0	0	3	3
Total	25	19	0	14	66

* RUQ = right upper quadrant; LUQ = left upper quadrant; RLQ = right lower quadrant; LLQ = left lower quadrant.

One patient had a 2-cm diaphragm laceration repaired by sutures placed laparoscopically. The organs injured in the 37 patients with laparotomy are listed in Table 2. There were a total of 49 organ injuries, 1.3 per patient. Of the 11 (35%) patients with diaphragm injuries, four were isolated injuries and four were minor solid viscus injuries that were managed by cauterization and topical hemostatic techniques. Eighteen hollow visceral injuries occurred. Two patients had major vascular injuries, aorta and iliac vein, which were contained by hematoma at the time of DL. The average length of hospitalization was 3.9 days for the entire stab wound population: 6.0 days for therapeutic laparotomy, 6.1 for negative and nontherapeutic laparotomy, and 1.9 days for negative DL. Of the 49 patients with negative DL, 16 had tube thoracostomy or associated injuries and their average hospitalization was 3.8 days compared with 1.0 day for the others.

Gunshot Wounds

The locations of gunshot wound entry are demonstrated in Table 3. Similar to stab wounds, two-thirds of these wounds were in the upper torso, but as opposed to stab wounds there was no propensity to either side. Negative DL occurred in 62% (44% for stab wounds), whereas 29% underwent therapeutic laparotomy and 5% nontherapeutic laparotomy. The organs injured in the 22 with laparotomy are listed in Table 4. There were a total of 42 organ injuries, 1.9 per patient. The injury pattern is actually similar to that with stab wounds. Thirteen of the patients sustained diaphragm injuries, with none of these being isolated and seven patients had liver injuries requiring only cauterization or topical hemostatic agents. The average hospitalization for the group was 6.1 days, 8.6 for those requiring laparotomy. The length of stay was 4.3 days for the 40 patients with negative DL, 9.7 days for 12 patients requiring tube thoracostomy or having associated injuries, compared with 1.1 days for the remaining 28 patients.

Table 2. ORGANS INJURED AND LOCATION OF INJURY IN 99 STAB PATIENTS*

	E	RUQ	LUQ	RLQ	LLQ	Total
Diaphragm	0	3	7	1	0	11
Liver	1	6	5	1	0	13
Spleen	0	0	3	0	0	3
Stomach	0	0	3	0	0	3
Small bowel	0	2	3	3	2	10
Colon	0	1	3	0	1	5
Pancreas	0	0	1	0	0	1
Vascular	0	0	0	1	1	2
Kidney	0	0	1	0	0	1
Total	1	12	26	6	4	49

* E = epigastrium; RUQ = right upper quadrant; LUQ = left upper quadrant; RLQ = right lower quadrant; LLQ = left lower quadrant.

Blunt Injury

Thirteen of these 17 patients sustained multiple-system injury. The mean injury severity score was 19 (range: 1–36). Abdominal CT scan or diagnostic peritoneal lavage (DPL) had been performed before laparoscopy in 16 patients. Laparoscopy was performed in these patients because the initial diagnostic study (CT or DPL) demonstrated intraabdominal injury but was not severe enough to mandate laparotomy. Laparoscopy was performed in eight patients immediately before operative management of other injuries (orthopedic and neurosurgical) to dictate whether laparotomy should be undertaken before those other procedures were performed. Three patients had no injuries. Four had minimal hemoperitoneum without active hemorrhage and were nonoperatively managed. One of these required splenorrhaphy the following day because of dropping hematocrit (2 U of blood transfused). Nine (53%) underwent therapeutic laparotomy: three splenorrhaphy, one splenectomy, two hepatorrhaphy, one with liver and spleen repair, one ruptured gallbladder, and one ruptured small bowel. One patient underwent nontherapeutic laparotomy for a minor liver injury.

Table 4. ORGANS INJURED AND LOCATION OF INJURY IN 66 GUNSHOT WOUND PATIENTS*

	RUQ	LUQ	RLQ	LLQ	Total
Diaphragm	8	5	0	0	13
Liver	9	3	0	0	12
Spleen	0	1	0	0	1
Stomach	0	3	0	0	3
Small bowel	0	4	0	2	6
Colon	0	4	0	0	4
Pancreas	0	1	0	0	1
Vascular	0	1	0	0	1
Kidney	0	0	0	0	0
Bladder	0	0	0	1	1
Total	17	22	0	3	42

* RUQ = right upper quadrant; LUQ = left upper quadrant; RLQ = right lower quadrant; LLQ = left lower quadrant.

Complications of Laparoscopy

There were four complications. The first occurred in a patient with a stab wound. While running the small bowel, an enterotomy was made with a grasper. Laparotomy was required for small bowel repair, and the patient had no other injuries. The second patient sustained a right-sided thoracoabdominal stab wound and had a chest tube placed preoperatively. During CO_2 insufflation for laparoscopy, the patient became acutely hypotensive and the systemic oxygen saturation dropped. A diagnosis of tension pneumothorax was made and a second chest tube was inserted with immediate relief of tension and normalization of blood pressure and oxygenation; the initial chest tube had occluded by angulation. Laparotomy was performed with repair of a 1–2 cm diaphragm laceration and cauterization of a superficial liver injury, and the patient recovered uneventfully. The third complication was insufflation of the properitoneal space and inability to attain pneumoperitoneum. The patient underwent a negative laparotomy. The fourth complication was the previously mentioned blunt trauma patient who required splenorrhaphy the day following DL.

Negative Laparotomy (Retrospective Analysis)

From April 1, 1990 through March 31, 1991, 94 patients underwent exploratory laparotomy for penetrating trauma with negative findings: 55 stab and 39 gunshot wounds. Complications developed in eight patients: pneumonia occurred in two patients, ileus (>5 days) occurred in two patients, one patient needed a second laparotomy for bowel obstruction, a wound infection developed in one patient, delirium tremens developed in one patient, and one had empyema. The average length of hospitalization was 4.6 days (range: 1–22).

Financial Analysis

This analysis compared the hospital charges and health care costs associated with DL to negative laparotomy for penetrating injury. It is based on the 90 penetrating trauma patients who had negative DL. Those patients would have undergone laparotomy before this study. In addition to the charges incurred with laparoscopy in the 90 patients who avoided laparotomy because of negative DL, laparoscopic fees were added to the 75 patients who required laparotomy, because these patients would previously have undergone laparotomy *without* laparoscopy. The charges associated with negative laparotomy are derived from the lengths of hospitalization incurred by the negative laparotomy groups described in the prior section. Those lengths of stay were extrapolated to the 90 negative DL patients for comparison of charges between the two approaches. Table 5 demonstrates the cost comparison. Although the charges per negative study are essentially identical at $3,300 per patient, the overall approach would annualize to roughly $50,000 more for DL because of the charges associated with laparoscopy in those patients subsequently requiring laparotomy.

DISCUSSION

The focus of this clinical trial was to define the current place for laparoscopy in the diagnosis of abdominal injury, and to get some idea of future applications. To accomplish this, the advantages and drawbacks encountered in this experience were reviewed.

In the case of penetrating wounds, the presence or absence of peritoneal penetration was clear. However, not all patients with peritoneal penetration actually required laparotomy. Thirty-one percent (38% stab, 24% GSW) with penetration had no significant injury. At the initiation of the study, we were conservative and required laparotomy for penetration to avoid missed injury. Furthermore, at study initiation, laparoscopic bowel clamps were not developed, hence one iatrogenic small bowel injury occurred when the bowel was being run using graspers used for cholecystectomy. A recent report noted that only 20% of bowel injuries were noted by laparoscopy in patients with penetrating injuries.[13] It is not clear how thorough those investigators evaluated the abdomen once intraabdominal penetration was observed. Different companies have developed laparoscopic clamps specifically for handling bowel, spurred largely

Table 5. COMPARISON OF FINANCIAL CHARGES OF DIAGNOSTIC LAPAROSCOPY VS. EXPLORATORY LAPAROTOMY IN THE 90 PENETRATING TRAUMA PATIENTS WITHOUT PERITONEAL PENETRATION

Diagnostic Laparoscopy			Negative Laparotomy		
Operating Room* × 60 min.	=	$ 1,350.00	Operating room × 60 min.	=	$900.00
Disposable equipment†	=	700.00			
Recovery room	=	150.00	Recovery room	=	150.00
Hospital stay × 1 day	=	250.00	Hospital stay × 4.6 days	=	1,150.00
Anesthesia fee‡	=	500.00	Anesthesia fee	=	500.00
Surgery fee‡	=	375.00	Surgery fee	=	620.00
		$ 3,325.00 (per patient)			$ 3,320.00 (per patient)
		×90 patients			×90 patients
		$ 299,250.00			
Disposable equipment§	=	$ 280.00			
OR charges	=	450.00			
		$ 730.00			
		×75 patients			
		$ 54,750.00			
Total charges	=	**$ 354,000.00**	**Total charges**	=	**$ 298,800.00**

* Includes charges for laparoscopy and video.
† Based on average of 1.5 trochars and 1 grasper/clamp per case.
‡ Based on Medicare fee schedule.
§ Based on 1 trochar per case for patients requiring laparotomy following laparoscopy.
The 75 patients requiring laparotomy following laparoscopy are included to ascertain the total financial impact of laparoscopy.

by advances in laparoscopic colon resection. Limited experience in our hands has demonstrated them to be effective for bowel evaluation. Future analyses of DL should use these instruments to determine if nontherapeutic and negative laparotomies can be safely reduced. Regardless, DL eliminated laparotomy in 90 (55%) of 165 penetrating trauma patients who would have undergone laparotomy in our trauma center with the standard diagnostic approach used before this protocol.

We are not convinced that DL has a significant role in the diagnosis of blunt injury given the current status of development. In contrast with penetrating wounds, where DL was applicable for 22% of the population, only a small fraction of blunt trauma seemed practical for this study. The spleen is difficult to evaluate laparoscopically. Best results were with the 5-mm laparoscope inserted subcostally. Perhaps 30° or 45° angle or flexible laparoscopes may be of additional advantage. A second major drawback is inability to reasonably evaluate the retroperitoneal structures. CTA is a much more versatile tool for blunt trauma evaluation. The retroperitoneal structures can be fairly well evaluated and to some degree the anatomy of solid visceral injuries can be delineated.[14] An approach to blunt trauma that has evolved and become widely accepted is use of CTA for the hemodynamically stable patient, especially one requiring CT for other injuries including head, pelvis, and spine, reserving DPL for unstable or marginally stable patients with the presence of gross blood dictating emergent laparotomy. DPL is also useful for evaluation of blunt small bowel injury. But, there are certain circumstances in which DL may be helpful. There is no reliable radiologic method to evaluate the diaphragm, and diaphragm rupture is one of the more common causes of false-negative DPL.[1] DL can rapidly resolve the issue as was demonstrated in a patient found to have eventration in this study. There are also occasions when urgent surgery is required for associated injuries. DL can be utilized to assess hemorrhage in the face of injuries documented by CTA or for primary diagnosis if time constraint does not permit initial CTA. Acalculous cholecystitis is an occasional problem in the critical care patient. Ultrasound and HIDA scan have received some support in the literature,[15,16] but other reports demonstrate less enthusiasm.[17] DL can resolve the diagnostic dilemma as well as permit definitive therapy if the patient has not undergone prior laparotomy.

A disadvantage of DL is that it is an invasive procedure. There are potential complications of tension pneumothorax and gas embolization in trauma patients. There were 24 diaphragm injuries in this experience, and tension pneumothorax developed in one patient. One other case of tension pneumothorax has been reported in association with diaphragmatic injury, and in that series there were 17 diaphragm injuries.[13] Both cases were immediately diagnosed and managed uneventfully by tube thoracostomy, but these cases demonstrate the importance of compulsive monitoring and cognizance of the

possibility. There were 27 liver injuries and three major vascular injuries in this study, and no gas embolization was apparent. In the 315 prior cases of DL for trauma reported in the surgical literature, there has been no documentation of embolization.[12,13,18–20]

An important criticism of DL as performed in this study was the requirement for general anesthesia. This leads to two areas of difficulty. First, it adds to potential morbidity, which although it is low, can be of major significance due to aspiration or other airway problems. Second, it substantially adds to the cost of the procedure. There was recent suggestion that DL would decrease costs associated with screening for penetrating trauma laparotomy.[20] Cost may be the foremost issue in defining the place for laparoscopy in trauma. Operating and recovery room fees coupled with anesthesia fees accounted for 60% of the cost of DL in this report. If performed under local anesthesia, the charges would have been $950 per patient. DPL costs approximately $350 including hospital and surgical fees at our institution. CTA costs are approximately $1,000 (hospital charges plus interpretation fees). DL has been reported for trauma evaluation using local anesthesia and a 5-mm laparoscope.[21] This would significantly add to the use of the technique. Not only would costs be less, but it could be more conveniently performed in the resuscitation area. In this study, we were reluctant to attempt this without first developing confidence in the general concept. Future technologic developments including miniaturization of the optics will likely make performance under local anesthesia more practical.

Therapeutic applications for laparoscopy in trauma will likely be available in the near future. Management of penetrating upper abdominal injuries should be an initial area of investigation. Liver and diaphragm injuries each occurred in 23 (14% of penetrating trauma patients with approximately half of these patients overlapping with both injuries). Late in the series, one patient had suture repair of the diaphragm performed laparoscopically. It took approximately 2 hours and was technically trying, demonstrating both the possibility and impracticality of this type of repair with current technology. However, stapling devices have been developed for laparoscopic herniorrhaphy. With modifications of staple length, diaphragm repair could become practical. Minor to moderate liver lacerations would also likely be amenable to electrocoagulation or argon beam coagulation via a trochar. Such advances into therapeutics would have major cost implications. Morbidity and lengths of hospitalization would be reduced. Laparoscopy could ultimately result in major reductions in health care costs associated with the management of penetrating abdominal injuries. However, to proceed in a safe and responsible manner, those types of applications must be closely scrutinized under the eye of planned laboratory and clinical investigation.

CONCLUSIONS

With current technology, DL appears most applicable for the management of those stab and gunshot wounds with a reasonable likelihood of not producing significant intraabdominal injury. The technique is safe, though cognizance of possible development of tension pneumothorax is important. Use in blunt trauma is more limited but appears applicable for some patients requiring operative repair of other injuries which will require prolonged operative time. Costs are substantial but will likely be significantly reduced with future advances. These include: 1) miniaturization of optics to make performance under local anesthesia practical, 2) improved clamps and retractors to permit safe bowel evaluation possible, thus eliminating nontherapeutic laparotomy, and 3) stapling devices and laparoscopic coagulation might allow for therapeutic applications in 30% of stable patients with penetrating wounds.

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Discussion

DR. DAVID V. FELICIANO (Atlanta, Georgia): Dr. Fabian and his colleagues from Memphis have attempted to answer the question, Is diagnostic laparoscopy in trauma a technique in search of an indication? They prospectively studied 182 patients, 91% of them with penetrating wounds, and none of these patients had overt indications for laparotomy after sustaining abdominal trauma. Their results are interesting. For example, in the stab wound group, absence of peritoneal penetration was noted in 49% of patients. Also negative and nontherapeutic laparotomies were decreased to 19% in the stab wound group, 5% with gunshot wounds and 6% with blunt trauma. There were only four complications in this series, and one of these, of course, was the need for a delayed operation because of missing or underestimating the extent of a splenic injury. This is a preliminary study. The patient group is a mixed bag and the incredible costs of laparoscopy certainly leaves some questions in the mind of this reviewer. Tim, I'd like to ask the following: In the patients with stab wounds, would you consider modifying your next protocol by trying to determine if the peritoneum rather than just the anterior fascia had been penetrated on local wound exploration? This can be done in 50 to 75% of asymptomatic patients with stab wounds to the anterior abdomen and would have had a significant impact on your study, particularly since patients without peritoneal penetration don't need diagnostic laparoscopy and don't need admission. Second, if the unnecessary laparotomy rate is 10 to 15% in other series in which local wound exploration and lavage are used for diagnosis after anterior abdominal stab wounds, and the delayed laparotomy rate is only 5 to 7% in series of lavages or observation alone, can you honestly say that this technique with its inherent $3,300 cost is better than the other two time-tested techniques? Third, was your laparoscopy in the patients with gunshot wounds the same as in patients with stab wounds, that is, did you really examine every organ or did you just take a quick peek with a laparoscope and say, "Oh, oh, a bullet went through this patient." I could not find this in the manuscript. And finally, just between you and me, Tim, and the other active trauma surgeons in the room, are you going to keep using this technique in asymptomatic patients with penetrating wounds now that your prospective study is over? Is this really better and more cost effective than observation alone for the same length of hospitalization? I congratulate Dr. Fabian on another nice prospective study.

DR. H. DAVID ROOT (San Antonio, Texas): This is an important paper. I think it's important because it is a very careful, candid exploration of the potential application of laparoscopic techniques in the evaluation of the stable postinjury patients in whom intraabdominal injury may have occurred. I think we all are continuing to search for answers in this area. In fact we're in quite an era of change where now even with discovery of information of injury, i.e., signs of blood from DPL or CT scan, or signs of known visceral injury, we're watching and waiting to let the patient declare whether the bleeding will stop, whether the hollow viscus is really ruptured and peritoneal signs develop. We're in this era of change and reassessment of the natural history of injury. So I think this paper, this interim study, is an important one to tell all of us — and we have not embarked upon a study using diagnostic laparoscopy — where this may fit into this continuing puzzle of discovering significant injuries of the intraabdominal cavity. The questions that I have about this, and I think that the former discussant mentioned one of them, what problems have you had with probing the tracts of these stab victims to the peritoneal level and looking for peritoneal penetration? This has been our technique and, combined with DPL, it's been possible to rule out a large number of nonpenetrating injuries. Would you consider opening the lateral peritoneum and looking for retroperitoneal stab wounds? I think this is one application that would be very helpful. For instance, in a lateral stab wound patient the question comes up, has the colon been injured? Opening the peritoneal reflection, looking behind the ascending/descending colon might be of great help. Have you considered that? Can you now, with the new instruments, safely and completely run the small bowel? Are you comfortable with that at the present time? And of course the disadvantage that you mentioned was the requirement for general anesthesia in the operating room. I think that it loses a great deal of potential advantage when you have to do that because there isn't anything really wrong with doing a small laparotomy instead of doing this procedure if you have to take the patient to the OR and put them to sleep. So I think that we're awaiting the results of using the fine fiberoptic techniques that you described that are in development. I think this would put it into an area of great advantage. What do you suggest for evaluation of pancreatic injuries? This is a puzzle that we've all had. CT doesn't help. DPL doesn't help. We don't have a good way of evaluating the pancreas. You described limitations of evaluating the spleen because of angulation and technical reasons. How bad is this? Can we rely upon diagnostic laparoscopy for the spleen? Finally, I think the authors are to be congratulated on this carefully done study. This kind of data is very