

Laparoscopy Is Sufficient to Exclude Occult Diaphragm Injury after Penetrating Abdominal Trauma

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Background: Occult diaphragm injury after penetrating thoracoabdominal injury can be difficult to diagnose and can remain occult for months to years. Delayed diagnosis is associated with the risk of hernia formation, strangulation, and high morbidity and mortality. Although laparoscopy has been proposed as a means of evaluating the diaphragm in these patients, prior studies did not include a confirmatory procedure or did not report long-term follow-up. Thus, true sensitivity and specificity remain unknown. The purpose of this study was to determine the sensitivity and specificity of laparoscopy for the detection of diaphragm injury after penetrating thoracoabdominal trauma. We hypothesized that laparoscopy alone is sufficient to exclude diaphragm

injury after penetrating thoracoabdominal trauma.

Methods: We conducted a prospective case series of 34 hemodynamically normal asymptomatic patients with thoracoabdominal penetrating injuries. All patients underwent diagnostic laparoscopy to evaluate the diaphragm for the presence of injury. All patients then underwent confirmatory celiotomy (n = 30) or video-assisted thoracoscopy (n = 4).

Results: All patients were men between the ages of 18 and 54 years. There were 37 stab wounds and 1 gunshot wound. The mean lowest preoperative systolic blood pressure recorded was 120 ± 18 mm Hg. Penetrating injuries were stratified by anatomic location (anterior,

18; posterior, 8; flank, 9; not specified, 3). There were 7 true-positive, 30 true-negative, no false-positive, and 1 false-negative result. Specificity, sensitivity, and negative predictive value were 100%, 87.5%, and 96.8%, respectively. The single missed injury occurred in a patient with hemoperitoneum from associated splenic injury that obscured the diaphragm and warranted celiotomy.

Conclusion: In asymptomatic hemodynamically normal patients with penetrating thoracoabdominal injury, laparoscopy alone is sufficient to exclude diaphragmatic injury.

Key Words: Laparoscopy, Thoracoabdominal, Trauma.

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The need to exclude diaphragmatic injury in asymptomatic patients with penetrating injuries to the thoracoabdominal region continues to be a topic of debate. Principles of nonoperative management for blunt abdominal trauma have been extended to include many patients with penetrating injuries. Some authors advocate expectant management with serial examination without additional diagnostic tests, with operations reserved for those who develop signs of continuing blood loss or increasing abdominal tenderness.^{1,2}

Isolated injury to the diaphragm is not associated with significant blood loss or development of peritonitis. Therefore, expectant management raises concerns about the potential for missed diaphragmatic injury in stable patients with penetrating wounds in proximity to the diaphragm. Because of pressure gradients across the diaphragm, these injuries are associated with herniation and a potential risk of strangula-

tion of abdominal viscera. Signs and symptoms may not occur during trauma center admission and may be delayed for a period extending as long as months to years.^{3–5} In one study, delayed recognition of incarcerated diaphragmatic hernia after stab wounds to the lower chest and upper abdomen was associated with a mortality rate of 36%.⁶

Previous studies on penetrating thoracoabdominal injury report an incidence of diaphragmatic injury ranging from 20% to 40%.^{7–10} Several reports have described the use of laparoscopy to exclude these injuries.^{11,12} However, most did not include a confirmatory celiotomy or thoracoscopy to definitively exclude missed diaphragmatic injury. The one study that included mandatory celiotomy after laparoscopic evaluation of the diaphragm included symptomatic patients as well as asymptomatic patients.⁷ Therefore, true sensitivity remains unknown.

The purpose of this study was to determine the sensitivity and specificity of laparoscopy for detection of occult diaphragmatic injury in asymptomatic, stable patients with penetrating wounds in proximity to the diaphragm. We hypothesized that diaphragmatic injury after penetrating thoracoabdominal trauma is common and that laparoscopy is sufficient to exclude diaphragm injury.

PATIENTS AND METHODS

This study was conducted at Parkland Memorial Hospital, a Level I trauma center, between October 2000 and January 2004. All asymptomatic, hemodynamically normal

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patients with penetrating thoracoabdominal injury were considered potential study candidates. Patients with any other indication for celiotomy were excluded. Thoracoabdominal wounds were defined as those occurring anywhere along the point of attachment of the diaphragm to the costal margin. The surface landmarks used to identify thoracoabdominal wounds were the nipples and costal margin anteriorly, and the scapular tips and costal margin posteriorly. The flank was included as part of the thoracoabdominal area and defined as the area between the anterior and posterior axillary lines. Patients who met these criteria were approached for informed consent. Patients unable to provide consent were excluded and managed according to usual trauma protocols at the discretion of the attending surgeon.

Preoperative evaluation included chest radiography in all patients and computed tomography or thoracic ultrasound in selected patients based on penetrating wound location or chest radiographic findings. After initial evaluation, all patients were taken to the operating room for exploratory laparoscopy under general anesthesia with the specific intention of evaluating the diaphragm.

A single 10-mm trocar was placed in the supraumbilical position using an open technique, and pneumoperitoneum was established. The diaphragm was evaluated using a 30-degree scope while placing the patient in a steep reverse Trendelenburg position. An additional trocar was placed, when needed, for retraction. Laparoscopy was carried out until the surgeon felt the evaluation of the diaphragm was sufficient to identify or exclude injury.

Regardless of findings, all patients then underwent a confirmatory procedure, either exploratory laparotomy (30 patients) or video-assisted thoracoscopy (4 patients). Laparoscopic findings and duration of procedure were recorded. One patient underwent confirmatory thoracoscopy 2 days after laparoscopy; all other patients underwent confirmation immediately after laparoscopy. Operative findings were noted and results compared with laparoscopic findings. Sensitivity, specificity, and positive and negative predictive values were calculated. This study was approved by the Institutional Review Board of the University of Texas Southwestern Medical School.

RESULTS

Thirty-four patients with 38 penetrating thoracoabdominal injuries were enrolled and completed study procedures. Mean age was 30.4 years (range, 18–54 years). All patients were men. Thirty-three patients sustained stab wounds and one patient suffered a gunshot wound. The majority of patients had anterior wounds (47%). The remainder were either flank (24%), posterior (21%), or unspecified (thoracoabdominal wounds without indication of posterior, anterior, or flank location) (8%). Thirty-five wounds were on the left side and three wounds were on the right. Clinical parameters including mean lowest systolic blood pressure, Revised Trauma Score,

Table 1 Injury Location

	Frequency (n = 38)	Diaphragm Injury (n = 8)
Anterior	18	6
Flank	9	0
Posterior	8	2
Unspecified	3	0
Right	3	1
Left	35	7

and time required to perform laparoscopy were recorded (Tables 1 and 2).

Radiographic evaluation consisted of chest radiography in all 34 patients, thoracic ultrasound in 7 patients with indeterminate chest films, and abdominal computed tomography in 2 patients with posterior or flank injury (Table 3). Two patients had peritoneal penetration without intra-abdominal injury. Four patients were found to have a nonbleeding liver laceration with minimal hemoperitoneum. One of these patients also had an injury to the transverse colon and an injury to the left hemidiaphragm. One patient had an injury to the superior epigastric artery with bloody egress into the peritoneal cavity, and another had an injury to the gonadal vein. The single patient with a gunshot wound had a splenic laceration with significant left upper quadrant hemoperitoneum obscuring the left hemidiaphragm. This patient was found to have a diaphragm injury at confirmatory evaluation (Table 4).

Seven of the eight diaphragm injuries noted at celiotomy were identified by laparoscopy. The single missed injury occurred in the patient with a gunshot wound and splenic injury with hemoperitoneum that prevented adequate visualization of the diaphragm and who required celiotomy for splenic repair. The overall prevalence of diaphragmatic injury

Table 2 Clinical Characteristics

	Range	Mean ± SD
Lowest systolic pressure (mm Hg)	95–150	122.6 ± 16.5
RTS	10–12	11.9 ± 0.3
Laparoscopy time (min)	5–26	13.0 ± 5.4

RTS, Revised Trauma Score.

Table 3 Radiographic Evaluation

	Frequency	Abnormal	Diaphragm Injury Present
CXR	34	5 (15%) (HTX/PTX)	1 (20%)
Thoracic U/S	7	2 (28%) (Fluid)	0
Chest CT scan	2	2 (HTX/PTX)	0

CXR, chest radiography; U/S, ultrasound; CT, computed tomographic; HTX, hemothorax; PTX, pneumothorax.

Table 4 Other Abdominal Injuries

Injury	Frequency
Peritoneal penetration	2
Nonbleeding liver laceration	4
Grade I colon laceration	1
Vascular injury*	2
Splenic laceration	1

* Vascular injuries included a superior epigastric artery laceration and a left gonadal vein laceration.

was 21% (8 of 38). Diaphragm injuries were more commonly left sided (seven of eight) and anterior (six of eight).

Overall sensitivity was 87.5% and specificity was 100%. Positive and negative predictive values were 100% and 96.8%, respectively. These results are summarized in Table 5.

DISCUSSION

The incidence of diaphragmatic injury was high, occurring in 21% of patients with penetrating thoracoabdominal injury. These results are similar to those reported in other series, including a retrospective multicenter review of 510 patients undergoing laparoscopy for penetrating abdominal trauma that described a 40% incidence of diaphragmatic injury in the subset of patients with thoracoabdominal injury.⁷⁻¹⁰ The very high risk of diaphragmatic injury in these patients raises concerns about the safety of nonoperative, expectant management of patients with penetrating wounds in proximity to the diaphragm. The consequences of missed injury may not be apparent for extended periods of time, and many of these patients are lost to follow-up.¹³ Madden et al. reported a 36% mortality in patients presenting with delayed sequelae, with most deaths caused by strangulation and perforation of the stomach or colon into the pleural cavity.⁶

Radiographic evaluation for diaphragmatic injury in patients with these injuries is unreliable. Of the five abnormal chest radiographs noted in our 34 patients, only one (20%) was associated with a confirmed diaphragm injury. None of the abnormal thoracic ultrasound or computed tomography studies were associated with a confirmed diaphragm injury.

Most prior reports on the use of laparoscopy after penetrating injury did not focus solely on the exclusion of injury to the diaphragm, and those that did focus on detection of diaphragmatic injury did not routinely perform celiotomy or other confirmatory test to definitively exclude diaphragmatic injury. Thus, the incidence of missed injuries cannot be re-

ported with certainty. In this study, all patients underwent a confirmatory diagnostic procedure. All diaphragmatic injuries were detected, with the exception of the one patient who sustained a gunshot wound, with significant hemoperitoneum preventing adequate visualization of the diaphragm. The 21% prevalence of diaphragm injury after penetrating thoracoabdominal trauma noted in this study suggests that celiotomy is necessary if the diaphragm cannot be adequately visualized at laparoscopy.

Video-assisted thoracoscopy (VATS) is an alternative option and, in addition, allows for evacuation of any associated hemothorax.^{14,15} Many of these patients require tube thoracostomy, which can usually be inserted through the same site at the completion of the procedure. However, VATS does not provide visualization of the peritoneal cavity, and if a diaphragmatic injury is found, abdominal injury cannot be excluded. Both procedures allow repair of simple diaphragmatic injuries.

Associated right-sided injuries, such as minor hepatic lacerations, can often be treated by means of laparoscopic placement of topical hemostatic agents.¹⁶ When injury to the extraperitoneal portion of the right diaphragm is suspected, it is important to visualize the bare area of the liver because herniation of the right lobe is possible and can be associated with pulmonary and hepatobiliary complications.¹⁷ The peritoneal reflection covering the bare area of the liver can be taken down using electrocautery. This often requires an extra laparoscopic port for downward retraction of the right lobe of the liver. Any sign of significant liver injury would be an indication for conversion to open exploration with control of hemorrhage and placement of adequate drainage.

We placed a tube thoracoscopy in the emergency department when pneumothorax or hemothorax was evident on chest radiography. Thus, pleural decompression was obtained before abdominal insufflation. It is important to be aware of the potential for hemodynamic compromise at the time of laparoscopy and abdominal insufflation secondary to unrecognized diaphragmatic injury.

In summary, the incidence of diaphragmatic involvement after penetrating thoracoabdominal injury is high, making nonoperative, expectant management of these patients potentially unsafe. Our findings support mandatory evaluation of the diaphragm with laparoscopy to exclude injury in all asymptomatic, hemodynamically normal patients. When patients have no evidence of intraperitoneal injury, the diaphragm can oftentimes be completely evaluated with laparoscopy. In the absence of significant hemoperitoneum or other factors preventing adequate visualization of the diaphragm, laparoscopy is a sensitive means of excluding occult diaphragmatic injury in these patients. When significant hemoperitoneum is encountered on laparoscopy or other factors are present that prohibit adequate evaluation of the diaphragm, conversion to an open exploration should be considered to fully visualize the diaphragm at risk and exclude additional injuries.

Table 5 Outcomes Table

	Diaphragm Injury		Total
	Present	Absent	
Laparoscopy			
Positive	7	0	7
Negative	1	30	31
Total	8	30	38

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