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Artículo:

Surgical endoscopy in the trauma patient

ARTÍCULO DE REVISIÓN

Surgical endoscopy in the trauma patient

Endoscopia quirúrgica en el paciente con trauma

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Resumen

Objetivo: **Revisar el impacto actual de la laparoscopia en la evaluación de pacientes con trauma toraco-abdominal.**

Recolección de los datos: **Revisión de la literatura (29 artículos).**

Selección de los datos: **Se seleccionaron los artículos más importantes relacionados con endoscopia quirúrgica en trauma.**

Resultados: **La evaluación de los pacientes con sospecha de lesión abdominal aún pone a prueba al cirujano de trauma a pesar de la disponibilidad de una variedad de modalidades diagnósticas invasoras y no invasoras. Desgraciadamente, ninguna de las herramientas de diagnóstico disponibles en la actualidad representa una técnica única y verdadera, y se requiere un juicio clínico seguro para formular un abordaje diagnóstico óptimo para cada paciente. Frecuentemente, se requiere más de un estudio para realizar una evaluación adecuada de un paciente con trauma abdominal potencial. La laparoscopia ha sido utilizada esporádicamente en los últimos 25 años en la evaluación de trauma abdominal; sin embargo, esta técnica se empleó más extensamente en el terreno del trauma sólo después de que la colecistectomía laparoscópica hizo ampliamente disponibles los equipos modernos de videoscopia. La laparoscopia ha demostrado ser útil para determinar el curso de las heridas por proyectil y por arma blanca del abdomen anterior. En muchos casos, los trayectos de heridas encontrados en estos pacientes han demostrado ser extraperitoneales y, por lo tanto, se evitó en estos pacientes una laparotomía no terapéutica o negativa. Ivatury, Fabian y otros han documentado a la laparoscopia como un excelente método para la evaluación del diafragma en pacientes hemodinámicamente estables que se presentan con heridas penetrantes toracoabdominales. En el área de trauma, es más limitada la experiencia con evaluaciones laparoscópicas de lesiones contusas de abdomen y**

Abstract

Objective: **To review current practice of laparoscopy in the evaluation of patients with suspected thoracoabdominal trauma.**

Data collection: **Selective review of the literature (29 articles).**

Data selection: **The most relevant papers dealing with surgical endoscopy in trauma were selected.**

Results: **Evaluation of patients with suspected abdominal injury continues to challenge the trauma surgeon despite the availability of a variety of noninvasive and invasive diagnostic modalities. Unfortunately, none of the diagnostic tools currently available is a true stand-alone technique, and sound clinical judgment is required to formulate the optimal diagnostic approach for each patient. Frequently, more than one study is required to provide adequate evaluation of a patient with potential abdominal trauma. Laparoscopy has been used sporadically over the past 25 years in the evaluation of abdominal trauma. However, this technique became more widely used in the trauma setting only after the popularity of laparoscopic cholecystectomy made modern videoscopic equipment widely available. Laparoscopy has proved useful in determining the course of anterior abdominal gunshot and stab wounds. In many instances, the wound tracts found in these patients have been demonstrated to be extraperitoneal, and therefore patients were spared a nontherapeutic or negative laparotomy. Ivatury, Fabian, and others have documented laparoscopy as an excellent method for the evaluation of the diaphragm in hemodynamically stable patients who present with penetrating thoracoabdominal wounds. Experience with laparoscopic evaluation of blunt abdominal injury and with therapeutic laparoscopy in the trauma setting is more limited, but several innovative and promising techniques have recently appeared in the literature.**

Conclusion: **As laparoscopic technology continues to improve and as more trauma surgeons become**

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con laparoscopia terapéutica pero, recientemente, han aparecido en la literatura diversas técnicas innovadoras y prometedoras.
Conclusión: **A medida que avanza la tecnología laparoscópica y entre más cirujanos de trauma se habilitan en técnicas de videoscopia, seguramente se incrementará el uso de la laparoscopia en la evaluación de trauma del tronco.**

Palabras clave: Endoscopia, cirugía de trauma, diagnóstico endoscópico.
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skilled in videoscopic techniques, utilization of laparoscopy in the evaluation of truncal trauma is certain to increase.

Key words: Endoscopy, diagnosis, thoraco-abdominal trauma
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Introduction

Evaluation of patients with suspected abdominal injury continues to challenge the trauma surgeon despite the availability of a variety of noninvasive and invasive diagnostic modalities. Unfortunately, none of the diagnostic tools currently available is a true stand-alone technique, and sound clinical judgment is required to formulate the optimal diagnostic approach for each patient. Frequently, more than one study is required to provide adequate evaluation of a patient with potential abdominal trauma. Sonography, computed tomography (CT), and diagnostic peritoneal lavage (DPL), as well as laparoscopy and routine exploratory laparotomy, are widely used in the evaluation of injured patients. Each of these diagnostic approaches possesses distinct advantages and disadvantages that must be kept in mind when the course to follow in the evaluation of patients with potentially life-threatening injuries is decided on. As with other areas of general surgery, laparoscopy plays an important role in the evaluation and treatment of these patients, but it is not applicable or appropriate in all cases.[1]

Sonography is inexpensive and portable and can accurately determine the presence of free fluid in the peritoneal cavity. Some organ-specific data and limited assessment of the retroperitoneum and thorax are provided by ultrasound. Unfortunately, most surgeons in the United States are not yet skilled sonographers, and the technique provides only limited organ-specific information. CT scan has been the *de facto* gold standard for the evaluation of abdominal trauma for the past decade. It has the advantage of providing detailed and accurate organ-specific information, but it is quite expensive and can miss isolated hollow viscus injuries. Additionally, patients who are unstable are not candidates for CT due to the inherent logistic problems associated with transportation of patients to the CT suite.[2-9]

DPL is extremely sensitive when used to detect even small amounts of blood in the peritoneal cavity. Unfortunately, trivial injuries such as minor hepatic or splenic lacerations will result in a positive DPL when traditional cell count criteria are used. In centers where DPL is used as the primary tool for abdominal assessment, a significant rate of negative and nontherapeutic laparotomy is accepted as a necessary evil. Additionally, DPL is an invasive technique and is associated with a definite, albeit small, complication rate.[10-13]

Laparoscopy has been used sporadically over the past 25 years in the evaluation of abdominal trauma.[1] However, this technique became more widely used in the trauma setting only after the popularity of laparoscopic cholecystectomy made modern videoscopic equipment widely available. Laparoscopy has proved useful in determining the course of anterior abdominal gunshot and stab wounds. In many instances, the wound tracts found in these patients have been demonstrated to be extraperitoneal, and therefore patients were spared a nontherapeutic or negative laparotomy. Laparoscopy has been documented by Ivatury, Fabian, and others as an excellent method for the evaluation of the diaphragm in hemodynamically stable patients who present with penetrating thoracoabdominal wounds.[14,15] Experience with laparoscopic evaluation of blunt abdominal injury and with therapeutic laparoscopy in the trauma setting is more limited, but several innovative and promising techniques have recently appeared in the literature.[1] As laparoscopic technology continues to improve and as more trauma surgeons become skilled in videoscopic techniques, utilization of laparoscopy in the evaluation of truncal trauma is certain to increase.

Patient Selection

The majority of injured patients are not candidates for laparoscopic examination. Patients with hemodynamic instability or obvious intraabdominal injury should be prepared for immediate exploratory laparotomy with a minimum of preoperative assessment. In our experience, only 15% of patients with suspected abdominal injury will benefit from laparoscopic evaluation.[16,17]

For patients with gunshot wounds, laparoscopy has proved most useful for evaluating the diaphragm and detecting peritoneal penetration in tangential wounds of the anterior abdominal wall. Care must be taken to prevent or immediately recognize the development of tension pneumothorax following the insufflation of pneumoperitoneum in patients with diaphragmatic injury. Timely placement of a tube thoracostomy will prevent the development of life-threatening tension pneumothorax and permit the completion of the laparoscopic examination. Discovery of peritoneal penetration or diaphragmatic in-

jury secondary to gunshot wound should prompt the surgeon to convert to formal exploratory laparotomy without delay. Patients with midabdominal gunshot wounds are not candidates for laparoscopy, even if they exhibit hemodynamic stability, due to the very high rate (greater than 90%) of significant intraabdominal injuries associated with wounds in this location.[18,19]

The percentage of patients with abdominal stab wounds who have significant intraabdominal injury is much less than that of patients with gunshot wounds to the abdomen. Therefore, a greater number of these patients are candidates for laparoscopic examination.[15,18,19] The purpose of laparoscopy in this group of patients is much the same as for gunshot wounds: to rule out peritoneal or diaphragmatic penetration. However, since the wounding potential of a stabbing instrument is significantly less than that of a bullet, simple peritoneal penetration is not necessarily an absolute indication for conversion to laparotomy. A more extensive assessment of the diaphragm, stomach, colon, and small bowel is indicated in this group of patients. The skilled laparoscopist can perform complete examination of the peritoneum without conversion to laparotomy and can perform laparoscopic repair of some limited injuries. We have performed laparoscopic repair of several isolated diaphragmatic or gastric lacerations secondary to stab wounds with excellent results.[16,17]

In our experience, the use of laparoscopy for evaluating both gunshot and stab wounds has reduced the rate of negative and nontherapeutic laparotomy. More importantly, laparoscopy has improved the diagnosis of occult diaphragmatic injury in patients with penetrating thoracoabdominal injury, thereby preventing the subsequent development of life-threatening intestinal herniation and strangulation.[16,17]

Laparoscopy for evaluating blunt trauma is less well defined than for assessing penetrating trauma. Few surgeons would suggest that laparoscopy is the best initial method for assessing the abdomen in the blunt-trauma setting. The efficacy of sonography and CT in the diagnosis of blunt injury has limited the role of laparoscopy to that of an adjunctive technique for the further assessment of solid organ injuries that have already been identified by sonography or CT.[2-9] Laparoscopy provides an excellent method for the real-time examination of hepatic or splenic lacerations to determine the presence of continued hemorrhage. When laparoscopy is performed as a prelude to exploratory laparotomy in patients initially treated with observation, the demonstration of hemostasis may alter the surgeon's plan to perform laparotomy in patients thought to have ongoing hemorrhage. Additionally, in patients with hemoperitoneum secondary to an isolated solid organ injury, blood may be removed from the peritoneal cavity by laparoscopy-guided suction catheters and may be processed for autotransfusion.[1,14-19]

Operative Technique

Standard videoscopic equipment and instruments are used in the evaluation of trauma patients. The examination is quite similar to diagnostic laparoscopy performed for the nontraumatic acute abdomen. As such, the telescope and operating ports must be located to provide optimal visualization of the entire peritoneal cavity. Insertion of a nasogastric tube and urinary catheter aids in obtaining optimal exposure. Frequently, a physical finding such as an entrance or exit wound or a radiographic study such as a positive CT scan will permit the surgeon to focus attention on the area of the abdomen at greatest risk for injury. However, every effort must be made to fully examine the abdomen and pelvis if missed injury is to be avoided. Several surgeons have reported satisfactory results with the 0-degree laparoscope, but we prefer the 30 degree-angled telescope and believe it essential for the optimal visualization of the posterior aspects of the diaphragm and the lateral aspects of the ascending and descending colon.[1,15,18,19]

The carbon dioxide pneumoperitoneum is initiated with a Veress needle placed through a 1-cm periumbilical position, limiting insufflation pressure to 8 to 10 mm Hg in patients with penetrating thoracoabdominal wounds. The rationale for this policy is to minimize the risk of tension pneumothorax, should the patient have a diaphragmatic laceration. Once these injuries have been excluded, pressures may be increased to improve exposure. In other patients, an insufflation pressure of 12 to 15 mmHg may routinely be used. The surgeon must closely monitor patients' pulse rate, blood pressure, respiratory status, and arterial oxygen saturation during insufflation of gas. Impaired venous return caused by the combination of moderate hypovolemia and pneumoperitoneum can produce profound hypotension. Additionally, patients with intraabdominal vascular injury are at theoretical risk for the development of gas embolism. Tension pneumothorax will develop in 5% to 10% of patients with diaphragmatic perforation when pneumoperitoneum is created. Alternatively, an intraabdominal retractor system designed for isopneumic (gasless) laparoscopy may be used to provide exposure. Most of these systems remain cumbersome, but they decrease the incidence of tension pneumothorax and gas embolism. Additionally, suction and irrigation are more easily accomplished in an isopneumic environment.[20]

After creation of the pneumoperitoneum, a 10-mm operating port is inserted through the umbilical incision. If extensive examination of the pelvis is required, the initial port should be placed in a supraumbilical position to permit optimal visualization and operative exposure. The 30-degree telescope is then introduced for initial examination of the abdomen. In patients with radiographic evidence of hemoperitoneum secondary to blunt trauma of the spleen or liver, the surgeon should expect to immediately encounter blood that must be removed prior to further examination. This may be accomplished through the use of laparoscopic suction/irrigation systems introduced into the abdomen through an additional 5-mm operating port. This additional operating port may also be used to introduce a grasper that is frequently required for manipulating the bowel or omentum.[17-19]

Tangential penetrating wounds to the anterior abdominal wall are readily assessed by laparoscopy. It is important to drape patients so that entrance and exit wounds are easily accessible during the procedure. A hemostat or probe may then be gently passed through the wound tract while the area is being visualized laparoscopically. Peritoneal penetration is readily documented by this maneuver. Lateral wounds may require mobilization of the colon to determine whether or not peritoneal penetration has occurred. Posterior wounds are not reliably assessed with laparoscopy.[15-17]

The liver is frequently injured in both blunt and penetrating trauma. The anterior, lateral, and medial aspects of the liver are easily visualized with a 30-degree laparoscope introduced through an umbilical port. Unfortunately, the posterior aspects of the liver are not well visualized. If injury is suspected secondary to a stab or gunshot wound, the peritoneum and diaphragm of the right upper quadrant must also be evaluated for penetration. The liver should be assessed for evidence of contusion, laceration, and hemorrhage. In the absence of associated injury, identification of a nonbleeding hepatic laceration is not an indication for conversion to exploratory laparotomy. A stable thrombus should not be manipulated or disturbed, as this may result in resumption of hemorrhage. If minor bleeding is found, hemostasis may be achieved by placing a hemostatic absorbable knitted fabric (e.g., Avitene, Surgicel) in the laceration. Cessation of bleeding must be documented prior to the completion of laparoscopy. We have frequently observed hepatic or splenic lacerations for as long as 30 minutes to assure that hemostasis was complete. Brisk or persistent hemorrhage that cannot be controlled laparoscopically is an indication for prompt conversion to an open procedure.[16,17]

The spleen is most commonly injured when blunt force is applied to the left upper quadrant, flank, or left hemithorax. Some surgeons have reported difficulty in obtaining laparoscopic exposure of the spleen because of its posterosuperior location in the abdomen, but with proper preoperative patient positioning and the use of ancillary operating ports for retraction and suction/irrigation, we have had excellent success in obtaining complete visualization of this organ. Prior to the draping of the abdomen, a towel roll, 1-L intravenous bag, or bean-bag support should be placed to elevate the patient's left flank 30 to 45 degrees in relation to the plane of the operating table. The patient should then be placed in the reverse Trendelenburg position so that gravity will aid in retraction of the stomach, transverse colon, splenic flexure, and omentum inferiorly. Gastric decompression via nasogastric tube is essential if optimal exposure of the left upper quadrant is to be obtained. If exposure is still inadequate, the operating table may be rotated further to the right. Because of the location of the spleen high in the left upper quadrant, the initial 10-mm port (laparoscope) should be placed in the midline, 3 to 5 cm superior to the umbilicus. This position gives excellent visualization of the spleen and also permits examination of the remaining quadrants of the abdomen. Additional 10-mm ancillary ports are placed in the right and left upper quadrants, respectively. A laparoscopic Babcock clamp introduced through the right upper quadrant port is then used to retract the fundus of the stomach medially and inferiorly. An additional grasper or suction catheter may be introduced through the left upper quadrant port. These maneuvers will usually provide excellent exposure of the spleen. However, if the posterior aspects of the spleen are not visualized, two additional techniques are helpful: (a) replacing the laparoscope in the left upper quadrant port and (b) placing an umbilical tape sling around the hilum of the spleen to facilitate anteromedial retraction. Use of this exposure technique has permitted performance of laparoscopic mesh splenorrhaphy. Hemostatic agents may be used for small or superficial lacerations, but a stable hematoma without evidence of ongoing hemorrhage should be left undisturbed. Failure to obtain complete hemostasis within 30 minutes should result in conversion to laparotomy.[1,14-19]

The stomach is at risk in any patient with penetrating trauma to the epigastrium. A 30-degree telescope placed through an umbilical port easily performs laparoscopic examination of the anterior wall of the stomach. Decompressing the stomach with a nasogastric tube is essential for optimal visualization. If caudal retraction is required for assessment of the gastroesophageal junction or the superior aspect of the gastric fundus, additional 10-mm ports should be placed at the level of the umbilicus lateral to the rectus muscles. Endoscopic Babcock or bowel clamps may then be used to provide the needed caudal retraction. Examination of the posterior fundus is obviously more difficult but may be done by dividing the gastrocolic ligament with cautery. While this plane is relatively avascular, ligation of identified dissector should be performed. Once the lesser sac has been entered through this route, the stomach may then be retracted anteriorly with Babcock clamps. The 30-degree telescope is then used to examine the posterior wall of the stomach, the lesser sac, and the pancreas. The presence of blood, fluid, or enteric contents in the lesser sac is an indication for exploratory laparotomy. A pancreatic hematoma is also an indication for formal exploration. Laparoscopic suture or stapled repair of limited (less than 2 cm) perforations of the anterior gastric wall have been reported in the literature and appear to be both safe and expedient. We prefer suture repair of these lacerations with 2-0 or 3-0 polytetrafluoroethylene sutures. However, if these repairs are to be performed, the surgeon must first be certain that no associated injuries are present.[16,17]

Complete examination of the colon and small bowel with laparoscopy is difficult in the trauma setting. The duodenum and significant segments of the colon are retroperitoneal and require extensive mobilization for adequate examination. Visualization of a hematoma in the area anterior or lateral to the duodenum is commonly associated with serious vascular, pancreatic, or duodenal injury and is therefore a finding that mandates open

exploration. In patients with flank wounds, the ascending and descending segments of colon are at risk for retroperitoneal perforation. These colon segments may be adequately visualized in many patients by taking down the white line of Toldt with endoscopic scissors or electrocautery. Once this is done, endoscopic bowel clamps may be used to lift the bowel anteromedially, permitting 360-degree assessment of the bowel wall. Identification of a traumatic colon perforation is an indication for open repair.[15,18,19]

Complete laparoscopic examination of the small intestine for the presence of small enterotomies is much more demanding than simply running the bowel in search of adhesions. Examination of the small bowel requires advanced laparoscopic skills that many trauma surgeons have not yet attained. The small bowel can be visualized in a significant number of patients by using endoscopic bowel clamps to sequentially bring loops of bowel into view. This procedure is repeated serially until the entire small intestine has been visualized. Care must be taken to examine the entire circumference of each segment of small bowel to ensure the discovery of small enterotomies. Due to the technical difficulty of small bowel examination, most reported injuries missed during trauma laparoscopy have involved the small bowel. In one early series, only 20% of small bowel injuries were identified during the initial laparoscopic examination. Therefore, alternative techniques for examining the small bowel have been developed. We have favored a minilaparotomy approach to examine the small intestine.[22] After a complete laparoscopic examination has failed to identify any significant injuries in a patient with a penetrating abdominal wound, the umbilical incision previously used to introduce the laparoscope is then extended to a total length of approximately 4 cm. Sequential segments of bowel 1 to 2 feet in length are then eviscerated through the minilaparotomy incision for direct examination. This procedure provides for almost complete direct examination of the small bowel in slender patients but is more difficult to perform in the obese. Small enterotomies identified by this technique may then be repaired extracorporeally with standard suture technique. The minilaparotomy incision is then closed in standard fashion.[22]

Cardiac Tamponade

Surgical drainage of the pericardium has been done by both the subxiphoid and the transthoracic approaches. Most general surgeons use the subxiphoid approach when drainage of fluid alone is needed. When pericardiectomy is required for constrictive pericarditis, infected tamponade, or cardiac injury, the transthoracic approach is used to permit better exposure of the pericardium. Median sternotomy or left thoracotomy are also used when preventing contamination of the abdomen with infected material is desired or when intrathoracic injuries are undetermined.[23,24]

In the acute setting, cardiac tamponade can be difficult to diagnose in the multiply injured patient. The thoracoscopic approach to hemotamponade should only be attempted when it is clear that there is no cardiac or great vessel injury. Significant bleeding from injuries to these structures can overwhelm the resources available for thoracoscopy. Cardiac and great vessel injuries require traditional open thoracotomy.[25-27]

Injury to the heart and / or great vessels can be determined by transesophageal ultrasound. Ultrasound has the additional advantage of allowing direct visualization, should preoperative drainage of pericardial fluid be necessary to attempt hemodynamic stabilization prior to going to the operating room.[28]

Other causes of tamponade such as uremic pericarditis or hemorrhage from metastatic pericardial implants can be diagnosed using transthoracic echocardiography without the need for using transesophageal probes.[29]

Thoracoscopic Pericardiectomy to Relieve Cardiac Tamponade

The patient is placed in a right lateral decubitus position. The thoracoscope is placed in the midaxillary line at the fourth intercostal space. Two operating sites are chosen to allow approximately a 30- to 60- degree angle between operating sites. One should be placed anteriorly between the midclavicular line and anterior axillary line in the fourth to fifth intercostal space. The posterior port should be placed in the fifth to sixth intercostal space at the midaxillary line.[25-27]

After deflation of the left lung, the pericardium can be well visualized in most patients. If the lung hinders visualization of the pericardium, the inferior pulmonary ligament may be incised, enabling the lung to be retracted cephalad. Being made of pleural folds, this ligament is avascular and, if desired, can be cut without need of electrocautery.[25-27]

Visually, the phrenic nerve is easily identified in thin patients with little pericardial fat. However, in patients whose phrenic nerve is not visualized due to pericardial fat, blunt dissection should be carried out to identify the nerve's course to avoid injury. This dissection can be performed using graspers or dissectors to gently spread the pericardial fat to expose the nerve. Since fat tends not to dissect off the pericardium well, identification of the phrenic nerve in two to three isolated spots will suffice to determine its course over the pericardium. The phrenic nerve is generally over the posterior third of the pericardium, running in a superior to inferior course.

The pericardium should be incised anterior to the phrenic nerve to avoid injury. Since the pericardium is usually distended, it can be difficult to grasp with forceps, graspers, or hemostats. If this cannot be accomplished, a knife or a pair of scissors should be used to carefully nick the pericardium. Once the pericardium has been decompressed, it can then be grasped, pulled away from the heart, and incised for several centimeters using a pair of scissors. Excising a portion of pericardium should make a defect of at least 2 to 4 cm^2. Again, this should be done carefully to avoid injury to the heart and the phrenic nerve. With inflammatory pericardial processes, such as suppurative or hemotamponade from mediastinal bleeding,

it is vital to excise a portion of the pericardium to prevent its edges from sealing together again.[25-27]

Once the pericardiectomy has been accomplished, a chest tube can be inserted through one of the operative sites and visually placed in a dependent position. The size of the chest tube should be proportional to the thickness of the pericardial fluid. Thus, the thicker the fluid, the larger will be the diameter of the chest tube.[26]

The chest incisions should be closed in layers. The muscle layer should be closed with an 0 to 2-0 polyglycolic acid suture. The subcutaneous layer should be closed with 2-0 to 3-0 polyglycolic acid suture. We generally close the skin with a running subcuticular 3-0 to 4-0 Monocryl suture. The chest tube should be secured with a heavy permanent suture such as 0 nylon.

Continued Thoracic Hemorrhage

In addition to damaging intrathoracic structures, penetrating chest trauma can cause injury to intercostal or internal mammary vessels. When cardiac and great vessel injuries have been ruled out, thoracoscopy is an ideal way of treating continued bleeding from injured intercostal or internal mammary vessels.[27]

Thoracoscopy for the Evaluation and Treatment of Continued Thoracic Hemorrhage

Patient positioning is critical. The injured vessel should not be placed in a true dependent position. If it is so placed, blood will pool at the injury site, obscuring visualization and hindering treatment. Thus, a true decubitus position may not be the best for injuries close to the midline, such as internal mammary vessel injuries. In these cases, patient positioning slightly toward the posterior will obviate this potential problem.

With the patient placed in the appropriate decubitus position, placement of the camera and the operative sites must be chosen to allow the best access to the injured intercostal or internal mammary vessels. With the availability of angled and flexible thoracoscopes, it is best to choose the closest site to the expected injury for the thoracoscope. Operative access should be placed at a 45- to 90-degree angle from the injury to permit ease of operative management. Generally, two operative sites are needed, one for grasping and one for clipping and suctioning.

The lung is deflated, and the thoracic cavity is inspected for obvious sites of hemorrhage. If the main bleeding site is an unsuspected pulmonary or great vessel injury, conversion to open thoracotomy should be performed.[25-27]

If the main bleeding site is an internal mammary or intercostal vessel, incision of the pleura at the site of injury may be needed, since the vessels course in an extrapleural position. The intercostal vessels are more easily visualized anterior to the axilla, coursing more directly under the pleura. Since most patients are stabbed or shot in the anterior chest, exposure is facilitated by the anatomy of the intercostal vessels in this location. Exposure can easily be achieved using a pair of scissors to incise the pleura along the inferior margin of the rib. In many penetrating injuries, the pleura has been injured to a large enough extent that combined with the dissection done by bleeding from the injured vessel the pleura will be separated from the underlying vessels. Thus, excellent exposure of the injured vessels is performed by the injury itself.

The internal mammary vessels run along the lateral margin of the sternum, usually 1 to 1.5 cm from its lateral border. Injury causing significant bleeding usually occurs at or above the fifth intercostal space, since at the sixth intercostal space the internal mammary arborizes into multiple branches.

Once the vessel or vessels have been exposed, the cut ends can be doubly clipped using an endoscopic clip applier. This is a good technique for the well developed internal mammary. Grasping the end of the vessel and applying electrocautery current may also be an effective and less expensive alternative that is useful for most intercostal vessels. Following control of intercostal or internal mammary bleeding, inspection of the rest of the thoracic cavity is done to look for other injuries. Retained blood should be evacuated. If blood clots are present that cannot be removed by conventional suction, curved and straight ring forceps are ideal for grasping and removing clot from the pleural space. Irrigation with normal saline can assist in removal of blood from recesses within the pleural space.[25-27]

Closure of the thoracic incisions should be performed in layers to ensure an airtight seal. A separate muscle and subcutaneous closure should be performed with polyglycolic acid suture or an equivalent. A chest tube, usually 28 French or greater, can be inserted through one of the operative sites to evacuate retained blood. The chest tube should be secured to the chest wall with an 2-0 or 0 nylon or silk suture.

Retained Hemothorax

It is not uncommon for the initial thoracostomy tube placed for hemothorax to incompletely evacuate the hemothorax. This may become problematic because the retained hemothorax can prevent full reexpansion of the lung, become infected, causing empyema formation, and/or lead to lung collapse as it lyses. With a retained hemothorax, operative removal should be considered when the estimated volume reaches 300 to 500 ml. Consideration for thoracoscopic evacuation of the hemothorax should be made within the first 3 to 5 days. Waiting longer than this can make removal quite difficult due to hematoma organization and adherence of the clot to the pleura and lung.[25-27]

Thoracoscopic Technique for Removal of Retained Hemothorax

With the patient in the appropriate decubitus position, the thoracoscope and instrumentation positions should be chosen to enter the pleural space at a point removed from the retained hemothorax. The approach should be to place the camera at a site that is far enough away from the clot that it can easily be surveyed with the tho-

racoscope. Thus, a thoracoscope position at third to fourth intercostal spaces above the edge of the retained hemothorax in the anterior axillary line proves to be advantageous.[25-27]

Positioning of the first, and often the only necessary, operative port one to two interspaces above and posterior to the retained hemothorax provides the best operative access. Placement of the operative port should be done with thoracoscopic guidance.

After deflation of the ipsilateral lung, the lung is assessed for adherence to the clot using gentle probing and lifting of the lung away from the clot with forceps. If the lung is adherent to the retained hemothorax, direct finger dissection or use of a sponge stick with ring forceps is usually successful in separating the lung from the clot.[25-27]

Curved ring forceps are best suited to grasping and removing retained clot, since they provide a large enough surface area that the clot is less likely to fragment. Use of a suction curette provides a large enough opening to aspirate clot relatively easily out of the pleural space. Normal wall suction pressure should be used, rather than the higher pressures used for therapeutic abortions, to avoid disastrous "suction biopsy" of the lung or heart. Once the majority of clot has been removed, copious irrigation with warm normal saline and repeated suctioning should remove most of the remaining small clots. The pleural space should then be inspected for sites of continued bleeding. If a bleeding site, such as an intercostal vessel, is seen, thoracoscopic therapy as described previously can be used. Significant bleeding from major vascular structures or the lung should not be repaired thoracoscopically, until advanced thoracoscopic skills are developed.

The lung should be assessed to make sure it is not restricted by chronic inflammatory reaction and rind formation. Should this be the case, the ring forceps can be used to peel away the rind, permitting full lung expansion.

The thoracic incisions should be closed in layers to ensure an airtight seal. A separate muscle and subcutaneous closure should be performed with polyglycolic acid suture or an equivalent. A chest tube, usually 28 French or greater, can be inserted through one of the operative sites to evacuate retained blood. The chest tube should be secured to the chest wall with a 2-0 or 0 nylon or silk suture.[25-27]

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