Review

Surgical Endoscopy
Ultrasound and
Interventional Techniques

Surg Endosc (1999) 13: 3–9

Analysis of thoracoscopy in trauma

R. T. Villavicencio,[1] J. A. Aucar,[2] M. J. Wall, Jr.[2]

[1] Department of Surgery, 497 Scaife Hall, University of Pittsburgh, Pittsburgh, PA 15261, USA
[2] Department of Surgery, Baylor College of Medicine and The Ben Taub General Hospital, Houston, TX, USA

Received: 28 March 1998/Accepted: 29 May 1998

Abstract
Background: The role of video-assisted thoracic surgery (VATS) in trauma has yet to be established. Up to the time of this writing, reviews of thoracoscopy in trauma have been primarily descriptive rather than analytic. This article analyzes the results of thoracoscopy (nonvideo and VATS) in trauma.
Methods: Analysis was done by reviewing 28 nonoverlapping studies since the introduction of thoracoscopy in 1910, with a combined total of more than 500 patients.
Results: Diagnostically, thoracoscopy has been used primarily to evaluate diaphragmatic injury, continued chest tube bleeding, and suspected cardiac injury. Thoracoscopy has a 98% (188/191 patients) accuracy rate in diagnosing diaphragmatic injuries. Therapeutically, thoracoscopy has been used primarily to control chest tube bleeding, evacuate retained hemothoraces, and evacuate empyemas. Thoracoscopy is 90% (89/99 patients) effective in evacuating retained hemothoraces, 86% (19/22 patients) effective in evacuating empyemas, and 82% (33/40 patients) effective in controlling chest tube bleeding. Thoracoscopy benefits include preventing 62% (323/514) of trauma patients from having a thoracotomy or laparotomy. Risks include a 2% (11/534 patients) procedure-related complication rate and a 0.8% (4/471 patients) missed injury rate. Technical failure rates are 10% (10/99 patients) and 4% (7/199 patients) in evacuation of retained hemothoraces and evaluation of diaphragmatic injuries, respectively.
Conclusions: Analysis suggests that thoracoscopy (nonvideo and VATS) can be applied safely and effectively in the care of the injured patient.

Key words: Thoracoscopy — Trauma — VATS

In 1910 Hans Christian Jacobaeus from Sweden first reported using a cystoscope to examine the pleural and pericardial cavities in humans with nontraumatic conditions [16]. In 1919 Dr. Lilienthal in New York recommended creating an artificial pneumothorax in a case involving a thoracic gunshot wound to identify the bullet position as being in either the lung or diaphragm [35]. It was believed that on radiographic examination, a bullet in the lung would recede during induction of an artificial pneumothorax. In 1924 Dr. Edwards in England reviewed the use of thoracoscopy in surgery, but its application to trauma care was not reported [10]. In 1946, Branco in Brazil used thoracoscopy in five cases of acute hemothorax from penetrating trauma to avoid thoracotomy and reported how trocar sites could be used to aspirate blood for autotransfusion [6]. In 1974, Senno in New York reported using a bronchoscope as a thoracoscope to visualize bleeding from a stab wound in one patient [31]. In 1981, a thoracoscope was used for diagnosis and therapy in 36 cases of penetrating trauma including a case of blunt aortic rupture [17]. In 1993, video-assisted thoracic surgery (VATS) was introduced into trauma care in a series evaluating diaphragmatic injury [30].

Diagnostic and therapeutic VATS applications in trauma must be evaluated in the context of existing modalities (Table 1). To date, VATS applications in trauma have been primarily for diagnosis and not therapy, in both the acute and subacute settings. Due to the potential benefits of a patient experiencing less pain and having a shorter recovery with VATS, it may be preferred over a thoracotomy because large incisions are associated with significant morbidity and hospitalization whether major injuries are found or not. Consequently, VATS has been applied in blunt and penetrating trauma. A summary of reported indications and contraindications is listed in Table 2. In addition to the listed contraindications, VATS should not be used initially for injuries that may be treated with thoracostomy tubes, nor for injuries (esophagus, aorta) in which accurate contrast studies are initially available.

This review analyzes the results of thoracoscopy (nonvideo and VATS) in 28 trauma studies with a combined total of more than 500 patients.

Correspondence to: R. T. Villavicencio

Table 1. Diagnostic tools for thoracic trauma: strengths and weaknesses

	Strength	Weakness
Physical exam	Expeditious, safe, and inexpensive Potential for serial examination	Diagnosis of diaphragmatic injury
DPL	—	Diagnosis of diaphragmatic injury
CT	Evaluate entire body simultaneously Differentiate intrapulmonary from pleural fluid	Diagnosis of diaphragmatic injury Expensive Controversial need for contrast
Ultrasound	Expeditious, safe, and inexpensive Detection of pericardial fluid and aortic injury Potential for serial examination	Diagnosis of diaphragmatic injury
Laparoscopy	Diagnosis of diaphragmatic injury Diagnose and possibly treat associated abdominal injury(s)	Diagnosis of intrathoracic injury Risk of tension pneumothorax Expensive Difficult to perform in busy ER
Chest tube	Expeditious, safe, and inexpensive Therapeutic for hemo/pneumothorax	Nondiagnostic for bleeding source
VATS	Evaluation of lung, chest wall, diaphragm, mediastinum, and pericardium Potential for treatment	Requires operating room Expensive
Subxyphoid pericardial window	Diagnosis of cardiac injury	Evaluation of associated thoracic injury(s)
CXR	Expeditious, safe, and inexpensive Diagnosis of foreign body location, bony injury, and hemo/pneumothorax Potential for serial examination	Diagnosis of diaphragmatic injury
Contrast study	Diagnosis of esophageal injury Diagnosis of aortic injury	Time consuming Patient must be stable
EKG	Expeditious, safe, and inexpensive Potential for serial examination	Rhythm may be nondiagnostic for type of cardiac injury
Pericardiocentesis	Expeditious and inexpensive	Unreliable in acute tamponade Potentially harmful
Laparotomy	Diagnose and treat diaphragmatic injury Diagnose and treat associated abdominal injury(s)	Long incision Potentially longer hospitalization Risk of unnecessary laparotomy
Thoracotomy	Diagnose and treat thoracic injury(s)	Long incision Potentially longer hospitalization Risk of unnecessary thoracotomy

CT, computed tomography; CXR, chest x-ray; DPL, diagnostic peritoneal lavage; EKG, electrocardiogram; ER, emergency room

Results

Diagnostic efficacy

As determined by the number of studies, VATS has been used primarily to evaluate diaphragmatic injury and secondarily to assess continued chest tube bleeding (Tables 3 and 4). This section focuses on the diagnosis of diaphragmatic injury. Evaluation of continued chest tube bleeding will be reviewed together with its management in the following section on therapeutic efficacy.

The literature published between 1975 and 1997 contains 15 reports involving a total of 199 patients in which VATS or nonvideo thoracoscopy was used to evaluate suspected diaphragmatic injury (Table 4). Seven of these studies were prospective, eight retrospective, and none randomized. Injuries consisted of 134 stab wounds (67%), 21 gunshot wounds (10%), 22 nonspecified penetrating wounds (11%), and 23 blunt injuries (12%).

On presentation, the majority of patients, having no definite evidence of diaphragmatic injury, underwent surgery within 24 hours of injury. Of the 199 suspected diaphragmatic injuries, 84 were confirmed by laparotomy or thoracotomy. Thoracoscopy correctly diagnosed 82 of 84 injuries. Nine of the 84 injuries were repaired with the use of VATS. Three procedure-related complications occurred in the 199 patients [30]. Overall, thoracoscopy in these 15 studies had a sensitivity of 100%, a specificity of 97%, and an accuracy of 98% (Table 4). In one study of diaphragmatic injuries mandating laparotomy after VATS to confirm thoracoscopic findings, in which intraoperative VATS findings were blinded to the abdominal surgeons, VATS had 100% sensitivity, specificity, and accuracy as compared with 88% sensitivity, 100% specificity, and 96% accuracy for laparotomy [34].

Therapeutic efficacy

Therapeutic VATS in trauma has been used to primarily (a) evaluate and control continued chest tube bleeding, (b) evacuate retained hemothoraces, and (c) evacuate empyemas (Table 5). Forty patients from 10 studies have been evaluated for continued chest tube bleeding, defined usually as drainage of more than 1,500 ml in 24 h [22, 33, 39], 200 ml/h or more for several hours [17, 23, 24, 31, 32, 38], or both. Five additional patients from one study who presented with acute hemothorax from penetrating trauma as evalu-

Table 2. Reported indications and contraindications for VATS in trauma

Indications	Contraindications
Evaluation and control of continued chest tube bleeding [17, 22, 23, 24, 33, 38, 39]	Hemodynamic instability [22, 24, 30, 37]
Early evacuation of retained hemothoraces [12, 22, 24, 25, 33, 39]	Inability to tolerate single-lung ventilation or lateral decubitus position [12, 22]
Evacuationand decortication of empyemas [12, 14, 22, 24, 29, 33]	Obliterated pleural space [12]
Evaluation and treatment of suspected diaphragmatic injury [16, 17, 20, 22, 30, 33, 37, 39]	Indication for emergency thoracotomy or sternotomy (i.e., uncontrolled high volume air leak, cardiac tamponade, major hemorrhage) [22, 24, 30, 37]
Evaluation and treatment of persistent air leak [22, 23, 39]	Bleeding diathesis [12]
Evaluation of pleural cavity opacification [23, 24, 26]	
Removal of foreign body [4, 7, 38]	
Evaluation of mediastinal injury [39]	

Table 3. Diagnostic thoracoscopic applications in trauma: review of the literature

		Diagnostic applications[a] (no. of patients)			
Reference	No. of patients in study	Continued chest tube bleeding	Suspected cardiac injury	Widened mediastinum	Persistent air leak
6	5	5	—	—	—
31, 32	2	2	—	—	—
17	36	7	—	—	—
33	11	1	—	—	1
29	8	—	—	—	1
36	1	—	1	—	—
9	2	—	2	—	—
13	1	—	—	—	1
39	41	6	—	1	1
22	42	6	—	—	5
27	108	—	108	—	—
24	50	11	—	—	—
7	1	—	1	—	—
38	5	1	2	—	1
23	12	1	—	—	4
TOTAL		40	114	1	14

[a] Excludes evaluation of diaphragmatic injury presented in Table 4

ated thoracoscopically were not included among the 40 patients in the 10 studies because the use of chest tubes was not mentioned, nor was the rate of bleeding specified [6].

Overall, thoracoscopic control of bleeding and avoidance of a thoracotomy was successful in 33 (82%) of 40 cases: 5/5 [6], 6/7 [17], 4/6 [22], 1/1 [23], 11/11 [24], 1/2 [31, 32], 1/1 [33], 1/1 [38], and 3/6 [39] patients (Table 5). In these studies, continued chest tube bleeding arose from intercostal vessels and lung lacerations and was controlled thoracoscopically by electrocautery, endoclips, or suture. For intercostal vessel bleeding, sutures were also placed from outside the skin after the bleeding site was localized thoracoscopically. Conversion to a thoracotomy was required when ligated intercostal vessels retracted beneath the pleura and when significant bleeding obscured its origin [39]. No procedure-related complications occurred in the 40 patients.

Another therapeutic application of VATS is the evacuation of posttraumatic empyemas. Thirty patients from 6 studies [12, 21, 22, 24, 29, 33] have been treated with the use of VATS, although the actual number may be less than 30 due to overlapping of a few patients between references [12] and [33]. The mean postinjury day of operation varied among the studies: 4 [22], 10.3 [33], and 23.7 days [29]. Excluding reference [21], which does not specify how many posttraumatic empyema cases required conversion to a thoracotomy, VATS was successful in 19 (86%) of 22 cases (Table 5). Several authors have reported a 100% therapeutic success rate: 1/1 [22], 1/1 [24], 8/8 [29], and 6/6 patients [33]. Two procedure-related complications (trapped lung and persistent air leak) occurred in the 30 patients [29]. Several other procedure-related complications occurred in these studies, but it is unclear whether they occurred in the empyema cases [12, 21].

The use of VATS in the evacuation of posttraumatic retained hemothoraces is reported in eight studies [12, 21, 22, 24–26, 33, 39] with 99 patients, although the actual number may be less than 99 due to overlapping of a few patients between references [12] and [33]. Evacuation of retained hemothoraces by VATS in these studies occurred after failed management with thoracostomy tubes. In three studies, retained hemothorax was defined additionally as clot estimated to be more than 500 ml or occupying at least one-third of the involved thoracic cavity by computed tomography (CT) scan [12, 22, 39]. In only one study was a mean evacuation volume (mean, 1,200 ml; range, 500–2600 ml) reported [22]. Mean postinjury day to operation varied among the studies: 4.3 [25], 4.5 [12], 4.8 [1], 5.3 [33], 10 [26], and 10.8 days [39]. Evacuation by VATS was successful in 89 (90%) of 99 cases (Table 5): 9/13 [1], 17/19 [12], 3/3 [14], 7/7 [21], 11/12 [22], 3/3 [23], 18/18 [24], 2/3 [25], 1/2 [26], 3/3 [33], 2/2 [38], and 13/14 patients [39]. Three procedure-related complications (transient arterial oxygen desaturations, which corrected after resumption of bilateral lung ventilation) occurred intraoperatively [12]. Postoperatively, two pneumonias and one wound infection were reported in one study [12], and one persistent loculated pneumothorax was reported in another study [1]. In still another study two procedure-related complications (inadvertent diaphragmatic injuries during the creation of intercostal access) occurred, but it is unclear whether they occurred in patients with retained hemothoraces [21].

The following therapeutic VATS applications have been reported in trauma: electrocauterizing, suturing, or endoclipping of bleeding intercostal vessels [11, 17, 22, 39]; stapling or suturing of diaphragmatic lacerations [3, 19, 20, 22, 39]; evacuating of retained hemothoraces or empyemas [12, 21, 22, 25, 29, 33, 39]; stapling of visceral pleura or lung parenchymal lacerations causing a persistent pneumothorax [13, 22, 38]; electrocauterizing of bleeding lung tissue [38]; pleuradesis of persistent pneumothoraces [22, 39]; removing of foreign bodies [1, 4, 7, 22, 26]; pleuradesis of symptomatic pleural effusions [18]; ligating of a thoracic

Table 4. Accuracy of thoracoscopy in diagnosing diaphragmatic injury: review of the literature

Reference	No. of suspected injuries evaluated by thoracoscopy	No. of injuries present[a]	No. diagnosed by thoracoscopy	No. repaired by VATS	No. failed[b] cases	TP[b]	TN	FP	FN
16	11	3	2	0	5	2	4	0	0
17	12	6	6	0	0	6	6	0	0
2	7	7	7	0	0	7	0	0	0
30[c]	14	9	9	0	0	9	5	0	0
18	4	1	1	0	0	1	3	0	0
28[d]	55	19	22	0	1	19	30	3	0
37	28	9	9	0	0	9	19	0	0
8	2	2	2	0	0	2	0	0	0
34[c]	26	8	8	0	0	8	18	0	0
39	19	10	9	7	1	9	9	0	0
22	14	7	7	1	0	7	7	0	0
9	1	1	1	1	0	1	0	0	0
4	1	0	0	0	0	0	1	0	0
1	3	0	0	0	0	0	3	0	0
23	2	2	2	0	0	2	1	0	0
TOTAL	199	84	85	9	7	82	106	3	0

Overall sensitivity: 82/(82 + 0) = 100
Overall specificity: 106/(106 + 3) = 97
Overall accuracy: (82 + 106)/(82 + 106 + 3 + 0) = 98
Failure rate: 7 failed cases/199 patients = 4%[e]

[a] Number of diaphragmatic injuries present confirmed by subsequent laparotomy, laparoscopy, or thoracotomy
[b] Failure to adequately visualize diaphragm excluded these patients from sensitivity, specificity, and accuracy analysis; TN/TP, true negative/positive; FN/FP, false negative/positive
[c] Study design mandated a laparotomy or laparoscopy after thoracoscopy to confirm thoracoscopic findings
[d] Two patients lost to follow-up and excluded from analysis
[e] VATS or nonvideo thoracoscopy was used in 199 total patients among the 15 listed references in Table 4

Table 5. Therapeutic thoracoscopic applications in trauma: review of the literature

	Therapeutic successes without conversion to thoracotomy (no. of successful operations/no. of cases)				
Reference	Control chest tube bleeding	Evacuate retained hemothorax	Evacuate empyema	Remove foreign body	Control persistent air leak
6	5/5	—	—	—	—
31, 32	1/2	—	—	—	—
17	6/7	—	—	—	—
25	—	2/3	—	—	—
33[a]	1/1	3/3	6/6	—	0/1
29	—	—	8/8	—	1/1
26	—	1/2	—	0/1	—
13	—	—	—	—	1/1
21	—	7/7	NS/8	—	—
39	3/6	13/14	—	—	1/1
12[a]	—	17/19	3/6	—	—
22	4/6	11/12	1/1	4/4	5/5
24	11/11	18/18	1/1	—	—
4	—	—	—	1/1	—
1	—	9/13	—	1/1	—
7	—	—	—	1/1	—
14	—	3/3	—	—	—
38	1/1	2/2	—	2/2	1/1
23	1/1	3/3	—	—	4/4
TOTAL	33/40	89/99	19/22[b]	9/10	13/14
% Success	82	90	86	90	93

[a] These two studies have seven overlapping patients
[b] Excludes reference 21
NS, not specified

duct with conventional instruments [24]; lung decortication [14, 24]; and lysis of adhesions causing a trapped lung [29].

Costs and hospitalization

No study has analyzed thoracoscopic costs or charges in trauma. In one study there was no significant difference in length of stay between patients treated with thoracoscopy and those undergoing thoracotomy for continued chest tube bleeding, diaphragmatic injury, or retained hemothorax [39].

Risks

Procedure-related complications, missed injuries, delay to definitive treatment, and technical failures are the main safety risks of using VATS in trauma (Table 6). Excluding three references [12, 25, 29] involving evacuation of retained hemothoraces and empyemas, Table 6 demonstrates that 0.8% (4/471) of patients evaluated with VATS or non-video thoracoscopy (primarily for suspected diaphragmatic injury, continued chest tube bleeding, and suspected cardiac injury) had missed intrathoracic injuries. Table 6 also demonstrates that 2% (11/534) of all patients had a procedure-related complication. The following VATS complications have been reported in trauma: persistent air leak or persistent loculated pneumothorax [1, 29], trapped lung [29], empyema and subphrenic abscess [30], premature ventricular contractions due to cardiac compression by instruments [30], and transient arterial oxygen desaturations [12].

Safety concerns also include technical failures that prevent a complete thoracoscopic examination in patients undergoing evacuation of retained hemothoraces or evaluation of diaphragmatic injuries. The technical failure rate with the use of VATS or a thoracoscope to evaluate diaphragmatic injuries is 4% (7/199 patients) (Table 4). These failures usually occurred as a result of poor visualization from incomplete lung deflation, dense adhesions, bleeding, or clotted blood. Similarly, technical failures during evacuation of retained hemothoraces have been primarily due to dense adhesions, incomplete lung deflation, and inability to establish dual endotracheal intubation and single lung ventilation. These failed operations occurred on postinjury days 4 [1], 7 [25], 8 [1], 9 [39], 13 [26], 20 [1], and 32 [22].

Additional unsuccessful thoracoscopic interventions in another study included one patient who later required a thoracotomy and another who required additional nonoperative procedures [12]. These 10 failures in 99 patients with retained hemothoraces results in a 10% failure rate (10/99 patients) (Table 5).

Despite these failures, all studies recommend early VATS evacuation of retained hemothoraces to avoid complications such as fibrothorax and empyema. Several authors described a window period for VATS evacuation of less than 3 days [25], 4 to 10 days [24, 26], or less than 10 days [22]. It is reported that bleeding may stop by the fourth postinjury day with a clot forming, which minimizes the risk of rebleeding and allows adequate visualization [24, 26]. After the tenth postinjury day, clotted blood is reportedly difficult to remove, and adhesions prevent lung collapse [22, 26]. Successful evacuation has been reported as late as postinjury days 8 [33], 15 [39], and 35 [39].

Table 6. Thoracoscopic complications and missed injuries in trauma: review of the literature

Reference	Year	Blunt or penetrating	No. of patients in study	No. of patients with missed injuries	Procedure-related complications
6	1946	P	5	0	0
31	1974	P	1	0	0
32	1975	P	1	0	0
16	1975	P	11	3	0
17	1981	P	36	0	0
2	1983	P	7	0	0
30	1993	P	14	0	3
18	1993	B	4	0	0
25	1993	P	3	NA	0
33	1994	B/P	11	0	0
28	1994	P	52	0	0
29	1994	P	8	NA	2
37	1994	P	28	0	0
19	1994	P	1	0	0
36	1995	B	1	0	0
8	1995	B	2	0	0
9	1995	P	2	0	0
34	1995	B/P	26	0	0
21	1996	Not specified	15	0	2[d]
39	1996	B/P	41[a]	1	0
38	1996	P	5	0	0
14	1996	P	3	0	0
13	1996	B	1	0	0
20	1996	B	1	0	0
12	1997	B/P	25	NA	3
22	1997	B/P	42	0	0
27	1997	P	108	0	0
24	1997	B/P	50	0	0
4	1997	P	1	0	0
1	1997	B/P	16[c]	0	1
7	1997	P	1	0	0
23	1997	B	12	0	0
TOTAL			534	4	11 11/534 (2%)
TOTAL[b]			471	4/471 (0.8%)	

[a] Fourteen patients with retained hemothorax from total study population of 41 have been excluded
[b] Excludes references 12, 25, 29, and 14 patients from reference 39, and 13 patients from reference 1, which involve retained hemothoraces and empyemas
[c] Thirteen patients with retained hemothorax from a total study population of 16 have been excluded
[d] Unclear if these complications occurred in trauma patients in this study
NA = not applicable because these studies involve retained hemothorax and empyema

Benefits

Benefits of VATS include safe and effective management of injuries that would otherwise require a thoracotomy or laparotomy. Table 7 summarizes the number of laparotomies and thoracotomies prevented using thoracoscopy. All the patients in Table 7 underwent thoracoscopy. Patients in the Thoracotomies or Laparotomies Prevented column did not have a thoracotomy or laparotomy because they had minor injuries or no injuries. All these patients had no missed injuries, were managed without a thoracotomy, and were

Table 7. Prevention of thoracotomy and laparotomy using thoracoscopy: literature review

Reference	Blunt or penetrating	No. of patients in study	Thoracotomies or laparotomies prevented
6	P	5	5
16	P	11	4
17	P	36	23
2	P	7	0
30	P	14	2
18	B	4	3
25	P	3	2
28	P	52	30
33	B/P	11	10
29	P	8	8
37	P	28	19
9	P	2	2
8	B	2	0
34	B/P	26	NA
21	P	15	7
39	B/P	41	31
12	P	25	21
22	B/P	42	32
24	B/P	50	12
4	P	1	1
1	B/P	16	12
7	P	1	1
14	P	3	3
38	P	5	5
23	B	12	9
13	B	1	1
20	B	1	1
19	P	1	1
26	B/P	6	1
36	B	1	0
27	P	108	75
31	P	1	1
32	P	1	1
TOTAL		514	323
(excluding [34])			323/514 (62%)

NA, not applicable due to study design mandating laparotomy after thoracoscopy

discharged home. The not applicable (NA) notation indicates a study that mandated a laparotomy after thoracoscopy as a confirmatory procedure. Table 7 demonstrates that VATS and nonvideo thoracoscopy helped prevent 62% (323/514) of patients with a variety of thoracic injuries from having a thoracotomy or laparotomy. In a patient who requires a thoracotomy, VATS may still be beneficial by determining the location, shape, and extent of the incision.

Discussion

In the care of the injured patient, VATS is establishing several roles. Although studies are few, VATS has diagnostic accuracy rates similar to those of traditional diagnostic procedures in evaluating diaphragmatic injury [34]. Diagnostically, thoracoscopy has been used primarily to evaluate diaphragmatic injury, continued chest tube bleeding, and suspected cardiac injury. Thoracoscopy has a 98% (188/191 patients) accuracy rate in diagnosing diaphragmatic injuries. Therapeutically, thoracoscopy has been used primarily to control chest tube bleeding, evacuate retained hemothoraces, and evacuate empyemas. Thoracoscopy is 90% (89/99 patients) effective in evacuating retained hemothoraces, 86% (19/22 patients) effective in evacuating empyemas, and 82% (33/40 patients) effective in controlling chest tube bleeding.

Thoracoscopy benefits include preventing 62% (323/514) of trauma patients from undergoing a thoracotomy or laparotomy. Risks include a 2% (11/534 patients) procedure-related complication rate and a 0.8% (4/471 patients) missed injury rate. Technical failure rates are 10% (10/99 patients) and 4% (7/199 patients), respectively, for evacuating retained hemothoraces and evaluating diaphragmatic injuries. Analysis suggests that VATS, in stable patients, can safely and effectively diagnose diaphragmatic injury, evacuate retained hemothoraces and empyemas, and evaluate and control continued chest tube bleeding.

In conclusion, with its beginnings in the early 1900s, VATS is developing safe and effective applications in trauma. To further establish these and new applications such as providing exposure for anterior spinal fusion in trauma patients [5], basic requirements must continually be met and algorithms followed. The first requirement is that a surgeon have basic thoracoscopic skills and be able to treat injuries with an open thoracotomy. Second, a surgeon should be familiar with the reported risks, indications, and limitations of thoracoscopy. Third, the equipment must be available and easy to use. A surgeon considering the use of VATS for suspected diaphragmatic injury may initially follow trial algorithms that mandate a laparotomy or thoracotomy after VATS to confirm the diagnostic accuracy of thoracoscopic findings. After becoming familiar with the techniques, the surgeon may then follow practice algorithms. For reference, two VATS algorithms for hemothorax [21] and blunt and penetrating trauma [24] have been published. The developmental path of VATS in trauma is unknown but should be periodically analyzed to ensure its safety and efficacy.

References

1. Abolhoda A, Livingston DH, Donahoo JS, Allen K (1997) Diagnostic and therapeutic video assisted thoracic surgery (VATS) following chest trauma. Eur J Cardiothorac Surg 12: 356–360
2. Adamthwaite DN (1983) Penetrating injuries of the diaphragm. Injury 14: 151–158
3. Badhwar V, Mulder DS (1996) Thoracoscopy in the trauma patient: what is its role? J Trauma 40: 1047
4. Bartek JP, Grasch A, Hazelrigg SR (1997) Thoracoscopic retrieval of foreign bodies after penetrating chest trauma. Ann Thorac Surg 63: 1783–1785
5. Baulot E, Trouillod P, Ragois P, Giroux EA, Grammont PM (1997) Anterior spinal fusion using thoracoscopy: a safe procedure. Revue de chirurgie orthopedique et reparatrice de I appareil moteur 83: 203–209
6. Branco JMC (1946) Thoracoscopy as a method of exploration in penetrating injuries of the chest. Dis Chest 12: 330–335
7. Boyce KE, Edwards JG, Rajesh PB (1997) Video-assisted thoracoscopy in the evaluation of penetrating thoracic trauma. Ann R Coll Surg Engl 79: 233–234
8. Carey JE, Koo R, Miller R, Stein M (1995) Laparoscopy and thoracoscopy in evaluation of abdominal trauma. Am Surg 61: 92–95
9. Chen MK, Schropp KP, Lobe TE (1995) The use of minimal access surgery in pediatric trauma: a preliminary report. J Laparoendosc Surg 5: 295–301
10. Edwards AT (1924) Thoracoscopy in surgery of the chest. Brit J Surg 12: 69–75
11. Graeber GM, Jones D (1993) The role of thoracoscopy in thoracic trauma. Ann Thorac Surg 56: 646–648
12. Heniford BT, Carrillo EH, Spain DA, Sosa JL, Fulton RB, Richardson

JD (1997) The role of thoracoscopy in the management of retained thoracic collections after trauma. Ann Thorac Surg 63: 940–943
13. Hermansson U, Konstantinov I, Traff S (1996) Lung injury with pleuropericardial rupture successfully treated by video-assisted thoracoscopy: case report. J Trauma 40: 1024–1025
14. Ilic N (1996) Functional effects of decortication after penetrating war injuries to the chest. J Thorac Cardiovasc Surg 111: 967–970
15. Jackson AM, Ferreira AA (1975) Thoracoscopy as an aid to the diagnosis of diaphragm injury in penetrating wounds of the left lower chest. Injury: Br J Accident Surg 7: 213–217
16. Jacobaeus HC (1910) Possibility of the use of the cystoscope for investigation of serous cavities. Munch Med Wochenschr 57: 2090–2092
17. Jones JW, Kitahama A, Webb WR, McSwain N (1981) Emergency thoracoscopy: a logical approach to chest trauma management. J Trauma 21: 280–284
18. Kem JA, Tribble CG, Spotnitz WD, Rodgers BM, Daniel TM (1993) Thoracoscopy in the subacute management of patients with thoracoabdominal trauma. Chest 104: 942–945
19. Koehler RH, Smith RS (1994) Thoracoscopic repair of missed diaphragmatic injury in penetrating trauma: case report. J Trauma 36: 424–427
20. Kurata K, Kubota K, Oosawa H, Eda N, Ishihara T (1996) Thoracoscopic repair of traumatic diaphragmatic rupture: a case report. Surg Endosc 10: 850–851
21. Landrenau RJ, Keenan RJ, Hazelrigg SR, Mack MJ, Naunheim KS (1996) Thoracoscopy for empyema and hemothorax. Chest 109: 18–24
22. Lang-Lazdunski L, Mouroux J, Pons F, Grosdidier G, Martinod E, Elkaim D, Azorin J, Jancovici R (1997) Role of videothoracoscopy in chest trauma. Ann Thorac Surg 63: 327–333
23. Lesser T, Bartel M (1997) Stellenwert der thorakoskopic beim thoraxtrauma: erste erfahrungen. Zentralbl Chir 122: 661–665
24. Liu DW, Liu HP, Lin PJ, Chang CH (1997) Video-assisted thoracic surgery in treatment of chest trauma. J Trauma 42: 670–674
25. Mancini M, Smith LM, Nein A, Buechter KJ (1993) Early evacuation of clotted blood in hemothorax using thoracoscopy: case reports. J Trauma 34: 144–147
26. McManus K, McGuigan J (1994) Minimally invasive therapy in thoracic injury. Injury 25: 609–614
27. Morales CH, Salinas CM, Henao CA, Patino PA, Munoz CM (1997) Thoracoscopic pericardial window and penetrating cardiac trauma. J Trauma 42: 273–275
28. Nel JH, Warren BL (1994) Thoracoscopic evaluation of the diaphragm in patients with knife wounds of the left lower chest. Br J Surg 81: 713–714
29. O'Brien J, Cohen M, Solit R, Lindenbaum G, Finnegan J, Vemick J (1994) Thoracoscopic drainage and decortication as definite treatment for empyema thoracis following penetrating chest injury. J Trauma 36: 536–539
30. Ochsner MG, Rozycki GS, Lucente F, Wherry DC, Champion HR (1993) Prospective evaluation of thoracoscopy for diagnosing diaphragmatic injury in thoracoabdominal trauma: a preliminary report. J Trauma 34: 704–710
31. Senno A, Moallem S, Quijano ER, Adeyemo A, Clauss RH (1974) Thoracoscopy with fiberoptic bronchoscopy. J Thoracic Cardiovascular Surg 67: 606–611
32. Senno A, Moallem S, Quijano ER, Tan BY, Clauss RH (1975) Fiberoptic thoracoscopy: New York State. J Med 75: 51–56
33. Sosa JL, Puente I, Lemasters L, Ginzburg E, Sleeman D, McKenney M, Martin L (1994) Videothoracoscopy in trauma: early experience. J Laparoendosc Surg 4: 295–300
34. Spann JC, Nwariaku FE, Wait M (1995) Evaluation of video-assisted thoracoscopic surgery in the diagnosis of diaphragmatic injuries. Am J Surg 170: 628–631
35. Stewart WH, Stein A (1919) Roentgen ray study of the abdominal organs following oxygen inflation of the peritoneal cavity. Am J Roentgenology 6: 533–541
36. Thomas P, Saux P, Lonjon T, Vigglano M, Denis JP, Giudicelli R, Ragni J, Gouin F, Fuentes P (1995) Diagnosis by VATS of traumatic pericardial rupture with delayed luxation of the heart: case report. J Trauma 38: 967–970
37. Uribe RA, Pachon CE, Frame SB, Enderson BL, Escobar F, Garcia GA (1994) A prospective evaluation of thoracoscopy for the diagnosis of penetrating thoracoabdominal trauma. J Trauma 37: 650–654
38. Waller DA, Bouboulis N, Forty J, Hasan A, Morritt GN (1996) Video-assisted thoracoscopy in the evaluation of penetrating thoracic trauma. Ann R Coll Surg Engl 78: 463–465
39. Wong MS, Tsoi, Henderson VJ, Hirvela ER, Forest CT, Smith RS, Fry WR, Organ Jr CH (1996) Videothoracoscopy: an effective method for evaluating and managing thoracic trauma patients. Surg Endosc 10: 118–121