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Tracheal lacerations after endotracheal intubation: a proposed morphological classification to guide non-surgical treatment☆,☆☆

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Abstract

Objective: Postintubation tracheobronchial lacerations (PITLs) are traditionally managed surgically. We sought to evaluate the rationale for non-surgical management of PITL. **Methods:** From January 2003 to November 2008, 30 patients with PITL were observed in our institution. PITL were graded as follows: Level I — mucosal or submucosal tracheal involvement without mediastinal emphysema and without oesophageal injury; Level II — tracheal lesion up to the muscular wall with subcutaneous or mediastinal emphysema without oesophageal injury or mediastinitis; Level IIIA — complete laceration of the tracheal wall with oesophageal or mediastinal soft-tissue hernia without oesophageal injury or mediastinitis; Level IIIB — any laceration of the tracheal wall with oesophageal injury or mediastinitis. All patients with Level I, II and IIIA PITL were treated conservatively with endoscopic instillation of fibrin glue (Tissucol®, Baxter Healthcare, Deerfield, MA, USA). **Results:** All patients with Level I ($n = 3$), II ($n = 24$) and IIIA ($n = 2$) PITL were successfully treated conservatively. The patient with a Level IIIB injury underwent posterolateral thoracotomy repair of the trachea. No mortality was reported. Mean hospital stay was 12.9 days. Flexible bronchoscopy at 7, 28, 90 and 180 days showed no abnormalities. Complete healing was attained in all patients by day 28. **Conclusions:** Level I or II PITL should be managed non-surgically. When adequate respiratory status is present, Level IIIA PITL can be managed conservatively in selected institutions only, because these injuries are high-risk injuries. Any PITL associated with injury involving the oesophagus or with mediastinitis (Level IIIB) must be treated as soon as possible by surgery.

Keywords: Endotracheal intubation; Tracheal laceration; Iatrogenic disease; Fibrin glue; Conservative treatment

1. Introduction

Postintubation tracheobronchial lacerations (PITLs) are rare but potentially life-threatening complications. The overall reported incidence is approximately 1 per 20 000 endotracheal intubations, although certain postmortem studies indicate an incidence as high as 15% of cases following emergency intubation [1]. Risk factors include double-lumen intubations (with an incidence of PITL ranging from 0.05% to 0.35% of intubations), emergency intubation, lack of anaesthesiologist experience, inappropriate use of a stylet, older age, female gender (because of the smaller size of airways) and associated pathological conditions of the trachea, such as tracheomalacia or tracheal stenosis [1—4].

Most PITLs occur in the pars membranacea of the cervicothoracic trachea, whereas tracheal injuries caused by high-pressure or -volume ventilation occur in the pars membranacea and in the pars cartilaginea of the tracheal bifurcation and tracheobronchial region [5—7]. Symptoms of tracheal injuries include soft tissue or mediastinal emphysema, pneumothorax, dyspnoea and haemoptysis. Diagnosis is achieved by tracheobronchoscopy, which reveals the site and extent of the lesion.

In terms of treatment, very superficial lesions are usually treated conservatively, while surgery is seen as something of a gold standard whereby lesions are repaired through right-sided posterolateral thoracotomy or a cervical approach [8,9]. However, accumulating evidence challenges this conventional approach, with more surgeons choosing to adopt a medical approach to management.

As yet, the criteria for guiding which patients will benefit from medical treatment remain poorly defined, and there is a growing need for clear guidance.

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Based on a review of the literature and our own series of 30 cases of PITL, we propose a morphological classification for PITL, on which to base a multidisciplinary management protocol for the treatment of PITL.

2. Materials and methods

Between January 2003 and November 2008, all patients experiencing PITL at our institution entered our observational study. We excluded patients with tracheobronchial lacerations arising from chest trauma, tracheostomy or thoracic surgery, as such injuries are distinguished by a different morphology and require different management.

Diagnosis was carried out by bronchoscopy. Observations included the length and the location of tracheal laceration (with careful evaluation of upper and lower limit of the injury), the morphology of the injury and the depth of transmural involvement. All patients underwent computed tomography (CT) scan of the chest to detect associated signs, that is, pneumothorax, pneumomediastinum and mediastinitis (Fig. 1). Diagnosis and treatment took place within 24 h of sustaining the injury. Following diagnosis, all patients commenced broad-spectrum intravenous antibiotics.

According to the morphology of the tracheal injury, lesions were classified as linear (or superficial) tears, substance losses or tracheal limb. Depending upon the depth of the tracheal wall involvement, lesions were staged as follows:

- Level I — mucosal or submucosal tracheal involvement without mediastinal emphysema and without oesophageal injury;
- Level II — tracheal lesion up to the muscular wall with subcutaneous or mediastinal emphysema without oesophageal injury or mediastinitis (Fig. 2);

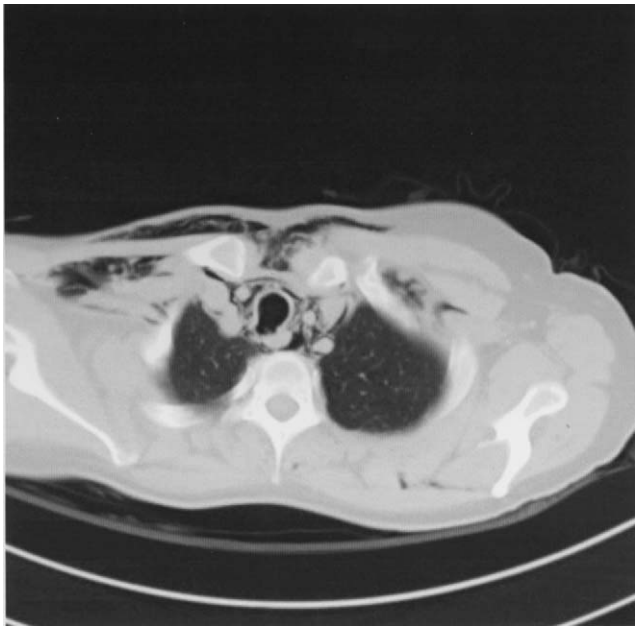

Fig. 1. CT scan of a Level II postintubation tracheobronchial laceration.

Fig. 2. Endoscopic view of a Level II postintubation tracheobronchial laceration.

- Level IIIA — complete laceration of the tracheal wall with oesophageal or mediastinal soft-tissue hernia without oesophageal injury or mediastinitis; and
- Level IIIB — any laceration of the tracheal wall with oesophageal injury or mediastinitis.

Depending upon their level of PITL injury, patients were managed either conservatively with medical treatment or surgically. Patients with Level I, II or IIIA lacerations underwent bronchoscopic application of 1—2 ml of fibrin sealant (Tissucol®, Baxter, Deerfield, MA, USA) onto the lesion, covering it with a complete layer (Fig. 3). Tissucol was applied through a catheter inserted in the operative channel of the bronchoscope with the endoscopic applicator provided by the manufacturer. Where possible, the procedure was performed with spontaneous ventilation under local anaesthesia with a flexible bronchoscope, with other patients undergoing treatment under mechanical ventilation followed by extubation as soon as clinically indicated. Patients with Level IIIB lacerations underwent repair through right posterolateral thoracotomy. Antibiotic therapy, cough-suppression medication and total parenteral nutrition were provided to all patients until bronchoscopic confirmation of PITL healing on postoperative day 7. Follow-up through outpatient clinic visits took place at approximately 28, 90 and 180 days after operation (Fig. 4).

As this was an observational study of an approved medical device routinely used in clinical practice at our institution, ethics approval was not required in Italy, as dictated by the local laws. All patients provided informed consent.

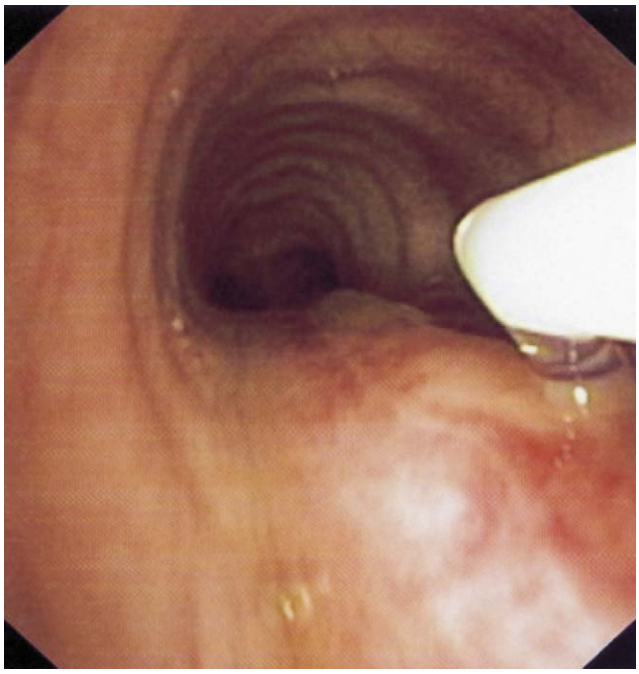

Fig. 3. Covering of a Level II postintubation tracheobronchial laceration with fibrin glue.

3. Results

Thirty patients with PITL were observed in our institution over an almost 6-year period (mean age 52.5 [±19.3] years; two males) (Table 1). Eight patients developed PITL following emergency intubation; the other 22 cases of PITL were

Fig. 4. Endoscopic view of a Level II postintubation tracheobronchial laceration at 90 days following instillation of fibrin glue, showing healing.

Table 1
Summary of PITL patient characteristics.

Characteristics	
Sex (female:male)	28:2 (93% female)
Age, mean ± SD [range], years	52.5 ± 19.3 [12–82]
Body mass index, mean ± SD [range] (kg m^{-2})	25.4 ± 1.7 [22.8–30.1]
Emergency surgery:elective surgery at time of PITL	8:22 (27% emergency)
Number of patients with presenting symptoms:	30
Mediastinal emphysema	23
Subcutaneous emphysema	20
Cough	13
Haemoptysis	9
Cervical pain	5
Respiratory failure	2
Bronchospasm	2
Pneumothorax	1
Number of tracheal rings affected, mean ± SD [range]	5.0 ± 1.9 [2–10]
Length of PITL, mean ± SD [range], cm	3.2 ± 1.1 [1.5–6.0]
Location of PITL (in each patient)	
Upper	5
Mid	7
Mid-Lower	7
Lower	11
Grading of PITL (in each patient)	
Level I	3
Level II	24
Level IIIA	2
Level IIIB	1

PITL: postintubation tracheobronchial laceration; SD: standard deviation.

complications of elective surgery. Patients presented with the usual range of symptoms characteristic of this form of injury, with mediastinal or subcutaneous emphysema being the most common presenting symptom. The mean number of tracheal rings affected was 5.0 (±1.9, range 2–10). One patient (No. 15) had a Level IIIB PITL, whereas the other 29 patients had less severe injuries – Level I (n = 3), II (n = 24) or IIIA (n = 2). Single lumen intubation was used in 26/30 patients (87%); 26/30 patients sustained linear tears.

As shown in Table 2, the 29 patients with Level I, II or IIIA PITL underwent bronchoscopic repair with Tissucol. In 23 patients, this procedure was managed with spontaneous ventilation under local anaesthesia. The other six patients received treatment under mechanical ventilation and were extubated immediately after the procedure or after 2, 3, 4, 5 or 6 days (one case each). These six patients had also undergone mechanical ventilation at the time of sustaining the PITL. The patient with Level IIIB PITL had tracheal limb injury with rapid progression of mediastinal and subcutaneous emphysema, necessitating tracheal repair through right posterolateral thoracotomy. All patients received antibiotic prophylaxis as per hospital policy, with most stopping treatment after day 7 bronchoscopy assessment.

No patient died while in hospital (30-day hospital mortality). Morbidity included atrial fibrillation in two patients and renal failure in one. Mean hospital stay was 12.9 (±10.2) days. None of the 29 patients who received conservative treatment developed mediastinitis after application of Tissucol. The patient who underwent surgical repair through posterolateral thoracotomy had an uneventful recovery; chest drains were removed on postoperative day

Table 2
Patient characteristics, bronchoscopic findings, grading of PITL, and management.

Patient no.	Sex	Age (year)	Height (cm)	BMI (kg m^{-2})	Reason for intubation	Lumen type	Mechanical ventilation	Presenting symptoms[a]	Endoscopic finding (cm)	No. of rings (cm)	Tracheal location	PITL Level	Antibiotic Rx (days)
1	F	73	166	25.3	Elective	Single	No	1,2,3	Tracheal limb	5 (3)	Upper	II	7
2	F	79	162	24.6	Elective	Single	No	1,2,8	Linear tear	10 (6)	Mid-Lower	II	12
3	F	29	161	28.4	Elective	Single	No	2,3,8	Linear tear	8 (5)	Lower	II	7
4	F	56	163	30.1	Emergency (cardiac arrest)	Single	Yes	1,2	Linear tear	7 (4.5)	Mid	II	8
5	M	63	173	23.9	Elective	Single	No	3,8	Linear tear	3 (2)	Upper	IIIA	7
6	F	76	158	25.8	Emergency (cardiac arrest)	Single	Yes	1,2	Linear tear	4 (2.5)	Mid-Lower	II	7
7	F	12	163	24.1	Elective	Single	No	2	Linear tear	4 (2.5)	Upper	II	7
8	F	48	156	27.3	Emergency (cardiac arrest)	Single	Yes	1,2	Linear tear	3 (2)	Mid	II	7
9	F	53	159	26.2	Elective	Single	No	1,5	Linear tear	3 (2)	Lower	I	9
10	M	18	176	25.3	Emergency (cardiac arrest)	Single	Yes	1	Linear tear	4 (3)	Lower	II	10
11	F	43	167	23.8	Elective	Double	No	1,2,3	Linear tear	4 (3)	Lower	II	11
12	F	81	164	26.1	Elective	Single	No	1,7,8	Linear tear	4 (2.5)	Mid	II	7
13	F	45	160	25.2	Emergency (cardiac arrest)	Single	No	1,8	Linear tear	4 (2.5)	Upper	I	7
14	F	39	157	27.3	Elective	Double	No	1	Linear tear	5 (3)	Mid	II	7
15	F	29	155	24.1	Emergency (cardiac arrest)	Single	Yes	1,2,4	Tracheal limb	6 (3.5)	Lower	IIIB	9
16	F	30	154	23.9	Elective	Double	No	6,8	Linear tear	6 (3.5)	Lower	II	7
17	F	67	157	24.6	Elective	Double	No	2,3,8	Linear tear	2 (1.5)	Mid	II	8
18	F	41	163	26.1	Elective	Single	No	1.2	Linear tear	5 (3)	Lower	II	10
19	F	60	159	25.6	Emergency (resp. failure)	Single	Yes	1,2,5	Linear tear	8 (4.5)	Mid-Lower	II	7
20	F	82	161	23.7	Elective	Single	No	1,2,6	Substance loss	3 (2)	Mid	II	7
21	F	45	159	24.2	Elective	Single	No	1,7,8	Linear tear	6 (3.5)	Lower	II	7
22	F	62	169	23.8	Elective	Single	No	1,2,3	Substance loss	6 (4)	Upper	II	7
23	F	39	168	24.3	Elective	Single	No	3,6,8	Linear tear	5 (3.5)	Mid-Lower	I	10
24	F	65	170	26.5	Elective	Single	No	1.2	Linear tear	5 (3.5)	Lower	II	7
25	F	58	159	22.8	Elective	Single	No	1.6	Linear tear	6 (3.5)	Lower	II	7
26	F	66	165	27.4	Elective	Single	No	2,3,8	Linear tear	7 (4.5)	Mid-Lower	II	8
27	F	27	160	26.8	Emergency (cardiac arrest)	Single	Yes	1,2,6,8	Linear tear	2 (1.5)	Mid-Lower	II	7
28	F	61	158	23.3	Elective	Single	No	1,2,8	Linear tear	7 (4.5)	Mid-Lower	II	8
29	F	79	157	26.6	Elective	Single	No	1,2,3	Linear tear	4 (2.5)	Lower	IIIA	8
30	F	49	160	23.4	Elective	Single	No	1,2,8	Linear tear	5 (3)	Mid	II	8

PITL: postintubation tracheobronchial lacerations; F: female; M: male; BMI: body mass index.
[a] 1: mediastinal emphysema, 2: subcutaneous emphysema, 3: haemoptysis, 4: pneumothorax, 5: respiratory failure, 6: cervical pain, 7: bronchospasm, 8: cough.

5 and the patient was discharged on day 7. In all 30 patients, day 7 bronchoscopy and subsequent outpatient follow-up assessments (including bronchoscopy) showed no tracheal abnormalities. Tracheal lesions healed within 28 days, without complications.

4. Discussion

As yet, there is no clear consensus on the management of PITL. Surgery represents the cornerstone of current treatment, with conservative treatment reserved for the minority of patients and only taking place in selected institutions. Selection criteria for conservative management are a matter of debate: some authors stress the fact that there should be no evidence of respiratory or haemodynamic instability, others consider the length or depth of the laceration as important criteria.

The purpose of surgery, provided that any pneumothorax or subcutaneous emphysema is properly treated, is to obtain closure of the defect in order to restore effective ventilation; to prevent mediastinitis secondary to contamination from the airways and to reduce the risk of subsequent healing complications or long-term tracheal stenosis. As regards ventilation, two different scenarios are possible: spontaneous or mechanical ventilation. In patients with spontaneous ventilation, a non-invasive positive pressure ventilatory support can be helpful in some cases. When mechanical ventilation is needed, the tip of the endotracheal tube should be placed distal to the rupture (bridging the lesion); if the lesion is too close to the carina, separate endobronchial intubation may be necessary [10].

Preventing mediastinitis is a key goal of the physician dealing with PITL. In our opinion, in the presence of mediastinal collection, a prompt referral to a thoracic surgeon should be mandatory, notwithstanding a low reported incidence of mediastinitis following PITL without oesophageal involvement. In a series of 42 patients with iatrogenic tracheal injuries, Leinung et al. noted three significant risk factors for dehiscence of the tracheobronchial suture – the presence of mediastinitis ($p = 0.005$), prior surgery in the mediastinum ($p < 0.001$) and a long interval between injury and diagnosis (114 h vs 12 h; $p = 0.004$) [11]. In PITL without evidence of mediastinitis, endoscopic treatment in accordance with our guidelines prevents the development of mediastinitis.

The incidence of long-term tracheal stenosis following PITL is very low: tracheal stenosis is caused by a retraction phenomenon during recovery as a result of a circumferential necrosis following a prolonged intubation; this rarely happens after PITL [12,13].

Several authors have published the results of their recent experiences in managing PITL conservatively, and put forward various recommendations regarding indications for conservative management based on these experiences (Table 3) [7,10,14–21]. These recommendations share many similarities and highlight some differences. Most point out that the patient needs to be in a stable physical condition to be eligible for conservative treatment. In contrast, others point out that a poor general condition represents a high operative risk, and that such patients should default to conservative management [19,20]. This comparison not only highlights the absence of clear guidelines to help in making the choice between conservative or surgical management for PITL, but also serves to underscore the value of an individualised approach.

In our view, provided that (1) pneumothorax is promptly resolved; (2) the patient has stable vital signs; and (3) an adequate respiratory status has been achieved (spontaneous or mechanical), the bronchoscopic findings in primis should determine further treatment, with greater attention given to the depth of the tracheal injury than to its length. It is our opinion that the depth of tracheal injury represents the most important determinant in achieving the goals of surgical repair – closure of the defect, prevention of mediastinitis and complications that impede healing. In contrast, the length of tracheal injury has a very limited role in the genesis of complications, for example, Level II injuries up to 10 rings in length have been successfully treated with medical management. Lacerations located in close proximity to carina in patients requiring mechanical ventilation are very often surgically treated because separate endobronchial intubation may not be successful. A persistent pneumothorax associated with PITL may be an additional indication for surgery.

Our proposed staging system provides surgeons with a tool to help standardise the treatment of PITL. Level I and Level II injuries should be safely managed conservatively. The incidence of Level I injuries is almost certainly underestimated because clinical signs can be minor and difficult to detect. Level IIIA injuries represent high-risk PITL and can be treated non-surgically provided that the hospital has extensive experience in tracheal management. Level IIIB PITL must be treated surgically. In our series, we had 27 patients with Level I or II injuries, who were managed conservatively, with healing noted on bronchoscopy at day 28 follow-up in all 27 patients. We also had two patients with a Level IIIA injury, who were successfully treated conservatively.

As regards risk factors for experiencing PITL, female sex appeared to be an important factor, with 28 of the 30 patients in our consecutive series being female (93%). This is consistent with other reports [10,22]. Half of our patients were overweight (BMI >24.9 kg m^{-2}), and one was obese (BMI >30 kg m^{-2}), leading us to speculate that greater BMI may predispose to PITL. The mean height of our 28 female patients was 161.1 ($\pm$4.3) cm, which is significantly shorter than the mean height of the general female population in Italy (164.4 cm; 18–40-year age group; $p = 0.003$ [Student's t-test]) [23]. However, little can be inferred from this study as our population is so small and somewhat older than this comparator cohort. Intuitively, a shorter and narrower trachea will predispose to a risk of placing the endotracheal tube too deeply or selecting a too-large tube size.

A question this study does not attempt to answer is to determine the role of fibrin glue as an aid to medical management of PITL. In most institutions, medical management consists of spontaneous healing supplemented by intravenous (IV) antibiotics and enteral (post-pyloric) or parenteral nutrition. Broad-spectrum antiobiotic therapy for PITL is indicated to treat infection of the mediastinum, which is typically polymicrobial in nature, arising from a disruption of normal mucosal and tissue barriers. In our institution, the

Table 3
Recommendations for conservative versus surgical management of iatrogenic PITL[a], as suggested by various authors (recent publications only).

Authors	Indications for conservative management	Data on PITL cases managed conservatively
Schneider et al. [16]	• Spontaneous or uncomplicated mechanical ventilation • Laceration sufficiently covered by the oesophagus • Mild or no emphysema	11/11 cases with iatrogenic tracheal injuries (not all PITL) treated successfully
Conti et al. [10]	• Presence of stable vital signs • Easy achievement of adequate respiratory function (spontaneous or mechanical) • Minimal mediastinal fluid collection • Absence of oesophageal injury • Nonprogressive pneumomediastinum • Short ruptures • Absence of stenosis	15/15 cases with spontaneous ventilation treated successfully 9/13 cases with mechanical ventilation treated successfully
Sippel et al. [18]	• Small ruptures in the upper third of the trachea • No respiratory distress or mediastinitis	2/2 cases treated successfully
Gómez-Caro Andrés et al. [17]	• No associated oesophageal injuries • No rapidly progressive subcutaneous or mediastinal emphysema • No mediastinitis	14/17 cases treated successfully
Lampl. [19]	• A delay in diagnosis of more than 3 days • Refusal of surgery by the patient • Unstable condition in severely ill patients	14/15 cases treated successfully
Carbognani et al. [14]	• Small (length <2 cm) uncomplicated lesions • Presence of stable vital signs • No progression of clinical symptoms throughout hospital stay	3/3 cases treated successfully
Hofman et al. [15]	• Small tears • Stable condition • Minimal and asymptomatic pneumomediastinum and/or cutaneous emphysema	1/1 case treated successfully
Gabor et al. [20]	• Tear localised to upper two-thirds of trachea • Laceration small (<2 cm) and not involving all tracheal wall layers • Patients in poor general condition with a high operative risk	1/2 cases treated successfully
Jougon et al. [7]	• Delay in onset of symptoms • Short tear (<4 cm) • Stable clinical signs	7/7 cases treated successfully
Mussi et al. [21]	• Short, superficial tears • Minimal and nonprogressive symptoms and signs	2/2 cases treated successfully

PITL: postintubation tracheobronchial lacerations.
[a] This excludes patients with tracheobronchial lacerations arising from chest trauma, tracheostomy or thoracic surgery.

bronchoscopic instillation of fibrin glue to supplement medical management of PITL is the routine standard of care. Tissucol® fibrin glue promotes tissue sealing and regeneration [24], which may play an important role in augmenting PITL management, especially in patients with Level II or Level III lesions. This may have contributed to the high level of success observed with conservative management in our study. Clearly, a randomised controlled trial comparing conventional versus fibrin glue-supplemented medical management would be a worthwhile study.

In conclusion, any suspicious PITL should be promptly referred to a thoracic surgeon or the thoracic endoscopist for a thorough bronchoscopic evaluation to assess the full extent of the injury.

Level I or II PITL should be managed non-surgically provided that pneumothorax is promptly resolved, the patient has stable vital signs and an adequate respiratory status has been achieved (through either mechanical or spontaneous ventilation). Level IIIA PITL with adequate respiratory status can be managed conservatively in selected institutions only, because these represent high-risk tracheal lesions. Any PITL associated with injury involving the oesophagus or with mediastinitis (Level IIIB) should be treated as soon as possible by open surgery. Our morphological classification of PITL represents an original tool to guide the management of PITL, and further studies are needed to refine this classification and to determine the contributory role of fibrin glue in promoting healing.

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References

[1] Maxeiner H. Weichteilverletzungen an kehlkopf bei notfallmaessiger intubation. Anaesth Intensivmed 1988;29:42—9 [in German].

[2] Borasio P, Ardissone F, Chiampo G. Post-intubation tracheal rupture. A report on ten cases. Eur J Cardiothorac Surg 1997;12:98—100.

[3] Personne C, Kleinmann P, Bisson A, Toty L. Tracheobronchial tears caused by Carlens' tube. Ann Chir 1987;41:494—7 [in French].

[4] Spaggiari L, Rusca M, Carbognani P, Solli P. Tracheobronchial laceration after double-lumen intubation for thoracic procedures. Ann Thorac Surg 1998;65:1837—9.

[5] Massard G, Rougé C, Dabbagh A, Kessler R, Hentz JG, Roeslin N, Wihlm JM, Morand G. Tracheobronchial lacerations after intubation and tracheostomy. Ann Thorac Surg 1996;61:1483—7.

[6] Marty-Ané CH, Picard E, Jonquet O, Mary H. Membranous tracheal rupture after endotracheal intubation. Ann Thorac Surg 1995;60:1367—71.

[7] Jougon J, Ballester M, Choukroun E, Dubrez J, Reboul G, Velly J-F. Conservative treatment for postintubation tracheobronchial rupture. Ann Thorac Surg 2000;69:216—20.

[8] Angelillo-Mackinlay T. Transcervical repair of distal membranous tracheal laceration. Ann Thorac Surg 1995;59:531—2.

[9] Mussi A, Ambrogi MC, Ribechini A, Lucchi M, Menoni F, Angeletti CA. Acute major airway injuries: clinical features and management. Eur J Cardiothorac Surg 2001;20:46—51.

[10] Conti M, Pougeoise M, Wurtz A, Porte H, Fourrier F, Ramon P, Marquette C-H. Management of postintubation tracheobronchial ruptures. Chest 2006;130:412—8.

[11] Leinung S, Möbius C, Hofmann H-S, Ott R, Rüffert H, Schuster E, Eichfeld U. Iatrogenic tracheobronchial ruptures — treatment and outcomes. Interact Cardiovasc Thorac Surg 2006;5:303—6.

[12] Couraud L, Jougon JB, Velly JF. Surgical treatment of nontumoral stenoses of the upper airway. Ann Thorac Surg 1995;60:250—9.

[13] Massard G, Hentz J-G, Wihlm J-M. Reply. Ann Thorac Surg 1998;65:1838.

[14] Carbognani P, Bobbio A, Cattelani L, Internullo E, Caporale D, Rusca M. Management of postintubation membranous tracheal rupture. Ann Thorac Surg 2004;77:406—9.

[15] Hofmann HS, Rettig G, Radke J, Neef H, Silber RE. Iatrogenic ruptures of the tracheobronchial tree. Eur J Cardiothorac Surg 2002;21:649—52.

[16] Schneider T, Storz K, Dienemann H, Hoffman H. Management of iatrogenic tracheobronchial injuries: a retrospective analysis of 29 cases. Ann Thorac Surg 2007;83:1960—4.

[17] Gómez-Caro Andrés A, Moradiellos Díez FJ, Ausín Herrero P, Díaz-Hellín Gude V, Larrú Cabrero E, de Miguel Porch E, Martín De Nicolás JL. Successful conservative management in iatrogenic tracheo-bronchial injury. Ann Thorac Surg 2005;79:1872—8.

[18] Sippel M, Putensen C, Hirer A, Wolff M. Tracheal rupture after endotracheal intubation: experience with management in 13 cases. Thorac Cardiovasc Surg 2006;54:51—6.

[19] Lampl L. Tracheobronchial injuries. Conservative treatment. Interact Cardiovasc Thorac Surg 2004;3:401—5.

[20] Gabor S, Renner H, Pinter H, Sankin O, Maier A, Tomaselli F, Smolle Jüttner FM. Indications for surgery in tracheobronchial ruptures. Eur J Cardiothorac Surg 2001;20:399—404.

[21] Mussi A, Ambrogi M, Menconi G, Ribechini A, Angeletti CA. Surgical approaches to membranous tracheal wall lacerations. J Thoracic Cardiovasc Surg 2000;120:115—8.

[22] Chen EH, Logman ZM, Glass PSA, Bilfinger TV. A case of tracheal injury after emergent endotracheal intubation: a review of the literature and causalities. Anesth Analg 2001;93:1270—1.

[23] Instituto Nationale di Statistica (ISTAT). La vita quotidiana nel 2006 ''Aspetti della Vita Quotidiana. ISTAT Editions; 2006, Rome. Unpublished data derived from the ISTAT Annual Report ''Aspetti della Vita Quotidiana 2006'' [In Italian].

[24] Sierra DH. Fibrin sealant adhesive systems: a review of their chemistry, material properties and clinical applications. J Biomater Appl 1993;7:309—52.