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Review

Tracheal rupture after endotracheal intubation: a literature systematic review☆

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Summary

We aim to perform a systematic review and meta-analysis of the cases of postintubation tracheal rupture (PiTR) published in the literature, with the aim of determining the risk factors that contribute to tracheal rupture during endotracheal intubation. A further objective has been to determine the ideal treatment for this condition (surgical repair or conservative management). A MEDLINE review of cases of tracheal rupture after intubation published in the English language and a review of the references in the articles found. The articles included were those that reported at least the demographic data (age and sex), the treatment performed, and the outcome. Those papers that did not detail the above variables were excluded. The search found 50 studies that satisfied the inclusion criteria. These studies included 182 cases of postintubation tracheal rupture. The overall mortality was 22% (40 patients). A statistical analysis was performed determining the relative risk (RR), 95% confidence intervals (95% CI) and/or statistical significance. The analysis was performed on the overall group and after dividing into 2 subgroups: patients in whom the lesion was detected intraoperatively, and other patients. Patient age ($p = 0.015$) and emergency intubation (RR = 3.11; 95% CI, 1.81—5.33; $p = 0.001$) were variables associated with an increased mortality. In those patients in whom the PiTR was detected outside the operating theatre (delayed diagnosis), emergency intubation (RR = 3.05; 95% CI, 1.69—5.51; $p < 0.0001$), the absence of subcutaneous emphysema (RR = 2.17; 95% CI, 1.25—4; $p = 0.001$), and surgical treatment (RR = 2.09; 95% CI, 1.08—4.07; $p = 0.02$) were associated with an increased mortality. In addition, age ($p = 0.1$) and male gender (RR = 1.89; 95% CI, 0.98—3.63; $p = 0.13$) showed a clear trend towards an increased mortality. PiTR is an uncommon condition but carries a high morbidity and mortality. Emergency intubation is the principal risk factor, increasing the risk of death threefold compared to elective intubation. Conservative treatment is associated with a better outcome. However, the group of patients who would benefit from surgical treatment has not been fully defined. Further studies are required to evaluate the best treatment options.

Keywords: Meta-analysis; Tracheal rupture; Intubation

1. Introduction

Tracheal rupture is a rare condition, and its most common cause is head and neck injury. Iatrogenic rupture is extremely rare and has many causes (intubation, tracheostomy, bronchoscopy, placement of stents, esophagectomy, and others), though orotracheal intubation is the most common [1]. Its importance derives from the high associated morbidity and mortality. The majority of publications on this condition are of isolated cases or small series with few patients. A multifactorial origin of rupture has been proposed, with important roles both for mechanical, such as anatomical, and individual factors, many of them still undefined [2]. Diagnosis is based on a high clinical suspicion, thanks to the appearance of clinical signs and symptoms that, although not specific, are highly suggestive—subcutaneous emphysema, respiratory insufficiency, pneumothorax, and hemoptysis. Diagnostic confirmation is made by bronchoscopy, which will reveal the size and site of the lesion. The treatment of choice has traditionally been urgent surgical repair, though the authors of the largest series now tend to advocate conservative treatment whenever permitted by the lesion and state of the patient. However, the group of patients who would benefit from surgical treatment has not been fully defined.

The aim of this study was to perform a systematic review and meta-analysis of the cases of postintubation tracheal

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rupture (PiTR) published in the literature in order to determine the risk factors that favor tracheal rupture during orotracheal intubation. In addition, we have aimed to determine which approach (surgical repair or conservative management) is associated with the best outcome.

2. Material and methods

An online systematic literature review was performed on MEDLINE (PubMed Advanced MEDLINE Search) for scientific articles describing cases or case series of tracheal rupture. The period chosen for the study was from 1966 to March, 2007, and included four of our own cases. The search was defined using the terms 'tracheal rupture intubation', 'tracheobronchial rupture intubation', 'tracheal laceration intubation', 'tracheobronchial laceration intubation', 'tracheal rupture postintubation', 'tracheobronchial rupture postintubation', 'tracheal laceration postintubation', and 'tracheobronchial laceration postintubation' in the title of the article. In order to increase the number of papers selected, a review was then performed of the references of the articles found. The articles included were those published in English, excluding the study of patients under 14 years of age and those articles in which the following patient characteristics were not reported: age, sex, management (surgical or conservative), and outcome. In addition, the cases of tracheal rupture which occurred during a tracheotomy procedure or in patients with pre-existing tracheostomy (stoma = chronic opening after previous tracheotomy) were excluded. A total of 50 articles [1—50] with 182 cases, including four of our own cases, were found for the study.

The data collected for the analysis included the demographic characteristics of the patients (age and sex), presence of a history of cancer, characteristics of the procedure that caused the rupture, characteristics of the orotracheal intubation (emergency or elective), difficulty of intubation evaluated by the responsible physician (easy or difficult), type of orotracheal tube (single or double lumen), interval between intubation and diagnosis of the rupture, presence of subcutaneous emphysema or other symptoms suggestive of tracheal rupture, length of the rupture, whether or not the rupture was detected intraoperatively, management (surgical or conservative), and outcome (death or survival).

The results were analyzed for the overall group and after division into two subgroups: intraoperative (immediate diagnosis) and delayed diagnosis group. Intraoperative ruptures were considered to be those caused by orotracheal intubation in the operating theatre in patients undergoing thoracic surgery, that were detected during the course of the operation, and that were treated by surgical repair. In these cases, there was considered to be no time interval between intubation and diagnosis of the PiTR. Those patients undergoing thoracic surgery and in whom the diagnosis was made after completion of the operation, after the patient had left the operating theatre, were considered as delayed diagnosis cases. Patients intubated in the operating theatre for non-thoracic surgery were considered extraoperative cases. All patients intubated outside the operating theatre, whatever the motive, were considered extraoperative cases. Independent prognosis variables were identified using logistic regression analysis. The variables included in the model of regression were those that met the criteria for confounders.

3. Statistical analysis

Analyses were performed with the crude data obtained from the revised papers. A descriptive analysis was performed based on age, sex, management, and mortality observed. Fisher's exact test was used to analyze categorical variables and unpaired *t*-test and Mann—Whitney *U* test to analyze quantitative variables. The relative risk was calculated together with the 95% confidence interval as a measure of association. The statistical analysis was performed using the SPSS for Windows, version 15, statistical package (SPSS Inc, Chicago, IL, USA).

4. Results

Fifty articles were selected that reported cases or case series of PiTR [1—50], describing a total of 178 patients, to which we added four of our own cases published previously [51], giving a study group of 182 patients. There was a clear female predominance: 156 women (85.7%) with a mean age of 60.7 ± 15.8 years. The men (14.3% of all patients) presented a mean age of 63.1 ± 13.3 years. An oncologic history was detected in only 40 cases, of which 62.5% (25 cases) were confirmed.

Orotracheal intubation was performed for an elective procedure in 120 patients (65.9%) and as an emergency procedure in 50 cases (27.4%); this information was unavailable in 12 patients. A single lumen orotracheal tube was used in 97 cases (53.3%) and a double-lumen tube in 85 cases (46.7%). The procedure was described as difficult in 26 patients (14.2%). The PiTR was diagnosed intraoperatively in 31 patients (17%) and delayed in 150 cases (82.4%); this data was unavailable in one patient. The time interval until the diagnosis of tracheal rupture was made was variable. Diagnosis was immediate in the intraoperative cases but the intervals in the extraoperative cases reached a maximum of 240 h. The length of the rupture varied from a minimum of 5 mm up to 130 mm in the most severe cases. Subcutaneous emphysema was the most common clinical manifestation and was detected in 118 cases (64.8%); this was followed by pneumomediastinum, pneumothorax, dyspnea/respiratory distress, and hemoptysis. Less common symptoms included pneumomediastinum, pneumopericardium, angina, hypotension, and shock.

Management was surgical in 111 patients (61%) and conservative in 71 (39%). All the patients diagnosed intraoperatively underwent surgical treatment, using the fact that the patient was already in theatre in order to perform surgical repair. The overall mortality was 22% (40 patients).

PiTR is characterized by an insidious onset, a difficult diagnosis requiring a high index of suspicion, and a high mortality. For this reason, possible risk factors for mortality were studied. There is no effect of duration to diagnostic or

Table 1
Population characteristics.

Age (years)	Mean: 61.04; SD: 465 Full range (15–92)
Interval diagnosis (h)	P 25th: 0; P 50th: 5; P 75th 24 Full range (15–92)
Length of rupture	P 25th: 30; P 50th: 40; P 75th: 50 Full range (15–92)
Intraoperative	*n* = 31 (17.1%)
Elective intubation	*n* = 120 (65.9%)
Easy intubation	*n* = 55 (30.2%)
Simple tube	*n* = 97 (53.3%)
Subcutaneous emphysema	*n* = 118 (64.8%)
Surgical treatment	*n* = 111 (61%)
Rate mortality	*n* = 40 (22%)

P: percentile; SD: standard deviation.

the length of rupture on survival. The other results of the analysis are presented in Tables 1–5.

In the multivariate analysis, male sex (odds ratio: 3.6; 95% IC: 1–12.9, $p = 0.049$), emergency intubation (odds ratio: 6; 95% IC: 1.9–18.4; $p = 0.002$) and patients with delayed diagnosis (odds ratio: 5.3; 95% IC: 1.1–22.4; $p = 0.067$) were the independent factors adversely influencing mortality. In addition, the presence of subcutaneous emphysema (odds ratio: 0.3; 95% IC: 0.1–1.2; $p = 0.226$) showed a clear trend towards an increased mortality.

5. Discussion

Orotracheal intubation is a routine procedure that has potential complications. Despite the large number of intubations performed every day, these complications are rare. They include from throat pain, laryngitis, glottic edema, and mucosal ulceration, to laryngeal or tracheal stenosis, necrosis of the tracheal wall, fistulas, aspiration, esophageal intubation, bronchial intubation, atelectasis, and tracheal rupture [3].

PiTR is a very rare condition and we therefore do not have adequate prospective studies to evaluate its incidence. To illustrate this, the first case series of PiTR was not published until 1995 [24]. Despite these limitations, it was estimated that the incidence of PiTR is of 1/20,000 intubations [6], although this figure varies depending on the publication. However, the incidence estimation in the last decade ranged from 0.05% to 0.37% of all orotracheal intubations performed [52–54]. Another characteristic of this condition is that all the information available is based on case reports and small case series; the largest series published to date includes 30 patients [49].

The exact mechanism underlying the lesion is uncertain. There is a series of risk factors that contribute to PiTR; these factors may be divided into mechanical and anatomical. Mechanical factors include multiple forced attempts at

Table 2
Study of age as a prognostic variable.

	Dead	Alive	*p*-value[a]
Overall group	66.2 (SD: 14) years (*n* = 40)	59.5 (SD: 15.4) years (*n* = 142)	0.015
Delayed diagnosis group	65.5 (SD: 14.8) years (*n* = 36)	60.3 (SD: 15.2) years (*n* = 114)	0.07
Intraoperative group	73 (SD: 10.2) years (*n* = 4)	55.8 (SD: 16.3) years (*n* = 27)	0.052

The results are expressed as mean with standard deviation (SD).
[a] Unpaired *t*-test for equality of means.

Table 3
Prognostic variables, in the overall population, associated with mortality.

Factor	No. deaths; percentages of death within each group	RR (95% CI)	*p*-value[a]
Sex	Men (*n* = 9; 36%) vs *women (*n* = 31; 19.7%)	1.82 (0.99–3.63)	0.15
Intubation	E (*n* = 22; 44%) vs *EL (*n* = 9; 14.2%)	3.11 (1.81–5.33)	0.001
Orotracheal tube	SL (*n* = 22; 22.7%) vs *DL (*n* = 9; 22.5%)	0.99 (0.50–21.9)	0.98
Type of rupture	DDG (*n* = 36: 24%) vs *Intra (*n* = 4; 12.9%)	1.86 (0.71–4.85)	0.23
Subcutaneous emphysema	Yes (*n* = 22, 18.6%) vs *No (*n* = 18; 28.1%)	0.66 (0.38–1.14)	0.19

E = emergency; EL = elective; SL = single lumen; DL = double lumen; DDG: delayed diagnosis group; Intra: intraoperative. RR = relative risk; CI = confidence interval.
[a] Fisher's exact test.
[*] Reference category.

Table 4
Prognostic variables, in the subpopulation with intraoperative rupture, associated with mortality.

Factor	No. deaths; percentages of death within each group	Crude RR (95% CI)	*p*-value[a]
Sex	Men (*n* = 2; 25%) vs *women (*n* = 2; 8.7%)	2.94 (CI: 0.27–1.72)	0.24
Orotracheal tube	DL (*n* = 4; 14.8%) vs *SL (*n* = 0; 0%) [b]	1.61 (0.10–25.2)	0.41
Emphysema	Yes (*n* = 1; 25%) vs *No (*n* = 3; 11.1%)	2.25 (0.30–16.7)	0.41

SL = single lumen; DL = double lumen; RR = relative risk; CI = confidence interval.
[a] Fisher's exact test.
[b] RR is computed with a constant continuity correction ($k = 0.5$).
[*] Reference category.

Table 5
Prognostic variables, in the subpopulation with delayed diagnosis rupture, associated with mortality.

Factor	No. deaths; percentages of death within each group	Crude RR (95%CI)	*p*-value[a]
Sex	Men (*n* = 7; 41.2%) vs *women (*n* = 29; 21.8%)	1.89 (0.98–3.63)	0.13
Type of intubation	E (*n* = 22; 44%) vs *EL (*n* = 13; 14.4%)	3.05 (1.69–5.51)	0.001
Orotracheal tube	SL (*n* = 22; 23.9%) vs *DL (*n* = 5; 38. 5%)	0.99 (0.50–21.9)	0.31
Type of rupture	DDG (*n* = 36; 24%) vs *Intra (*n* = 4; 12.9%)	1.86 (0.71–4.85);	0.17
Emphysema	Yes (*n* = 21; 17.1%) vs *No (*n* = 15; 44.8%)	0.46 (0.25–0.80)	0.013
Management	S (*n* = 24; 30.4%) vs *C (*n* = 10; 14.5%)	2.09 (1.08–4.07)	0.02

E = emergency; EL = elective; SL = single lumen; DL = double lumen; DDG: delayed diagnosis group; Intra: intraoperative; S = surgical; C = conservative. RR = relative risk; CI = confidence interval.
[a] Fisher's exact test.
* Reference category.

intubation, inexperience of the health professional, endotracheal tube introducers that protrude beyond the tip of the tube, overinflation of the cuff (diffusion of nitric oxide into the cuff), incorrect position of the tip of the tube, repositioning the tube without deflation of the cuff, inappropriate size of the tube, significant cough, and movements of the head and neck while the patient is intubated [24,33,40]. The anatomical factors include congenital tracheal abnormalities, weakness of the pars membranosa of the trachea, chronic obstructive pulmonary disease and other inflammatory lesions of the tracheobronchial tree, diseases that alter the position of the trachea (mediastinal collections, lymph nodes, or tumors), chronic use of steroids [15,25], advanced age, and female sex. This latter aspect was detected in our analysis, in which 86.2% of cases were women. In addition, age also appears to play a role because, in the series published, there was not only evidence of a female predominance, but the mean age of these women was over 50 years in the majority of series published (Table 6). Our meta-analysis supports this finding. Furthermore, the study by Chen et al. [40], who performed a literature review, defined an at-risk population that included women over 50 years of age who required intubation with double-lumen tubes and/or excessive pressure of the tube cuff. However, although the present meta-analysis found women to be the population most affected, men presented a higher risk of death, with a difference that bordered on statistical significance. We have not been able to determine the reason why men with PiTR present a higher mortality, although it could be due to different types of disease that required orotracheal intubation.

Some authors have suggested that PiTR may present more frequently in women because the pars membranosa is weaker in women than in men [25], due to the use of endotracheal tubes of a larger size than appropriate for women [27], or that women are not as tall and, as a consequence, the endotracheal tube is positioned significantly more distantly in a trachea that is already smaller [27]. Other authors have also suggested that a short stature could be a predisposing factor for PiTR; in the studies by Marty-Ané et al. [24] and by Massard et al. [26], all the patients had a height under 165 cm. Hoffman et al. [55] also reported that 50% of their patients had a height under 160 cm. More authors have drawn attention to this finding in their articles, though without specifying the height of their patients [18]. We have been unable to evaluate this data in the present study, as the height was not published in the majority of articles analyzed.

This meta-analysis has confirmed that the circumstances under which orotracheal intubation is performed play a determining role in the outcome of PiTR. There was a threefold increase in the risk of death among patients in whom orotracheal intubation was performed as an emergency procedure. We therefore deduce that if the procedure is performed by experienced staff following specific action guidelines, the risk of rupture may be greatly reduced, even accepting that there are certain factors on which it is very difficult or impossible to act.

The most common clinical manifestations of PiTR are subcutaneous emphysema, mediastinal emphysema, and pneumothorax. Other signs include dyspnea, dysphonia, cough, hemoptysis, and pneumoperitoneum [2,18,19,26–28]. These signs often develop immediately or soon after extubation, though they can take several days to appear. This time course can lead to delays in diagnosis that vary from a maximum of 5 h in the series by Carbonagni et al. [2] to over 100 h [3,14,26,27,37]. It is interesting to note that the onset of subcutaneous emphysema is not only the most common symptom, it is also a protective factor, as reflected in the

Table 6
Principal series in the literature (this includes only those cases accepted for this meta-analysis).

Series	Number of cases (% women)	Age of the women median (range)
Carbonagni et al. [2]	13 (100%)	60 (52–69)
Jougon et al. [37]	13 (84.6%)	69 (25–80)
Kaloud et al. [27]	11 (90.9%)	44 (22–72)
Massard et al. [26]	10 (90%)	54 (15–80)
Meyer [41]	12 (91.6%)	67 (45–86)
Mussi et al. [38]	11 (90.9%)	67 (35–92)
Sippel et al. [50]	11 (100%)	61 (30–83)
Gómez-Caro et al. [48]	15 (86.7%)	65 (26–86)
Conti et al. [49]	30 (86.7%)	65 (31–79)

findings of this meta-analysis, as its presence alerts to the possible existence of tracheal rupture, accelerating the procedures for its definitive diagnosis and the initiation of the correct treatment. Herniation of the cuff may sometimes be observed on chest radiograph and may contribute to an increase in the size of the laceration [25].

Clinical suspicion must be followed by diagnostic confirmation, which is achieved by direct visualization of the tracheal rupture by bronchoscopy. This procedure provides data on the exact site and extension of the lesion, helps to plan the therapeutic approach, and can be used to reposition the tube or reintubate the patient if this is necessary [19]. Tracheal rupture is usually longitudinal and is most frequently located in the pars membranosa, the posterior part of the trachea that lacks cartilaginous support [28].

Very often the clinical manifestations of the lesion are not immediately obvious, and presentation can mimic that of other clinical conditions. It would appear logical to think that an early diagnosis and, if this is not possible, a high clinical suspicion would be associated with a lower mortality as they would lead to earlier therapeutic maneuvers. A delay in diagnosis could favor the onset of mediastinitis, with deterioration in the clinical situation [50]. However, in the present study we did not find that a delay in the diagnosis had any influence on mortality. One explanation is that death was mainly associated with the cause that required intubation rather than with the PiTR itself [26,41,50].

Consensus has not yet been reached on the management of PiTR. Early surgical repair has traditionally been the mainstay of treatment [24,26,27,38,52]. Its supporters consider that it offers good results and that the prognosis will generally depend on the underlying disease rather than on the tracheal damage itself [5]. However, there are ever more authors who opt for conservative treatment in patients with small ruptures, less than 2 cm [2,18,53], and in selected patients with minimal, non-progressive symptoms and with no air leakage on spontaneous breathing [18,24,34,37,48,49,56,57]. In the case of ruptures longer than 2 cm, there are currently greater differences of opinion. Some authors propose surgical treatment in the majority of ruptures over 2 cm in length [2,50,9], while other authors recommend surgery only in those ruptures caused by intubation prior to thoracic surgery and in ruptures that give rise to immediate symptoms [37].

Analysis of the two types of treatment has been one of the objectives of this meta-analysis, as all recommendations published to date are based on personal experience with small groups of patients. The present study found that surgical repair led to a twofold rise in the risk of death in those patients in whom the PiTR was detected outside theatre (delayed diagnosis group). In this respect, it is important to differentiate between the intraoperative and delayed diagnosis patients. When rupture occurs during thoracic surgery (open chest surgery), there is greater agreement among different authors that surgical repair is possibly the best therapeutic option [37,49]. However, our results support the proposals of the authors of more recent publications, who consider conservative management to be the treatment of choice [37,48,49]. According to the most recent studies, patients who are clinically stable, in spontaneous respiration, with no respiratory difficulty or air leakage, no esophageal damage, minimal mediastinal collections, no signs of clinical progression (emphysema or pneumomediastinum), and no symptoms of infection, and patients in whom extubation is likely to occur within the following 24 h or who require mechanical ventilation to treat an underlying respiratory problem, should be managed conservatively [49,57]. This management includes intubation with the cuff distal to the area of rupture, continuous tracheal aspiration, use of a pleural drain if required, and appropriate empirical antibiotic therapy [24]. The options for surgical repair are multiple. The surgical technique will depend on the type and extension of the lesion. End-to-end anastomosis is usually the option in tracheal section, but there are a larger number of possibilities in the case of lacerations of the pars membranosa. Segmental dissection of the trachea followed by simple suture, or anterior transverse tracheotomy [6], longitudinal tracheotomy [8] or a combination of the two, are examples of the techniques used to treat these lacerations. The surgical approach will depend on the site and extension of the lesion. Cervicotomy is used in lesions of the upper two thirds of the trachea, while juxtacarinal lesions are managed via a right thoracotomy, particularly if a mainstem bronchus is affected [38]. In the future, minimally invasive techniques such as videothoracoscopy may also be used [4]. When planning the best therapeutic option, there are authors who consider that the length of the lesion should also be taken into account, and not only the site of the lesion or the clinical situation of the patient.

The results of this study and of the larger case series published (Table 6) agree that there is ever more evidence to support conservative management, allowing the possible closure of the tracheal tear by adopting an expectant (conservative) approach. Moreover, some series have demonstrated that surgical repair in critically ill patients is a high-risk procedure with a mortality that can reach 71% [41]. The treatment guidelines up to a few years ago were based on a heterogeneous series of case reports involving different etiologies. Evidence now available allows us to suggest that the time may have arrived to reconsider the therapeutic options and, in the future, perform studies that will establish the indications for each type of treatment. The present meta-analysis was unable to answer some of the issues causing greatest debate among authors, such as the real incidence of PiTR, the influence of the length or size of the rupture on the patient's prognosis. This was because these data, as others, have not been reported in many of the cases included in this meta-analysis.

In summary, PiTR is a rare condition but it carries a high morbidity and mortality. Diagnostic suspicion is essential, with subsequent confirmation by bronchoscopy. The condition is most common in elderly women, although the risk of death is higher in men. Emergency intubation is a risk factor that leads to a threefold increase in the risk of death in comparison with elective intubation. The appearance of subcutaneous emphysema is a protective factor as it favors early diagnosis and the rapid initiation of the appropriate treatment. Treatment is controversial, although it appears that conservative management is associated with a better

outcome. However, it is not clear which group of patients will benefit from surgical treatment. Greater training of the staff who manage the airway or who are likely to do so in the future could reduce the incidence of iatrogenic tracheal rupture. Further studies are necessary to evaluate the best treatment options.

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