Superficial tears may heal spontaneously, deeper and longer lacerations, especially if the patient has symptoms, require prompt surgical repair.1,4,5 We review 11 cases of membranous tracheal laceration consequent to endotracheal intubation that we have treated during the past 7 years. 

Patients and methods 
From March 1993 to March 1999, 11 patients received our attention because of suspicion of membranous tracheal wall rupture related to endotracheal intubation. Ten patients were female and 1 was male, with a mean age of 68 years (range, 35-92 years). The orotracheal intubation related to the tear was carried out under general anesthesia for elective surgery in 10 patients and as an emergency procedure as a result of anaphylactic shock in 1 patient. Intubation was with a double-lumen selective tube. In 4 cases the tracheal tear was promptly repaired, by way of a thoracotomy in 4 and by way of a cervicotomy and longitudinal tracheotomy in 5. In 2 cases the tear was small and was consequently managed conservatively.

Results: All surgical procedures proved effective in repairing the laceration, and there was no mortality or morbidity in the perioperative period. Early and late endoscopic follow-up showed no signs of tracheobronchial stenosis.

Conclusions: When repair of membranous tracheal laceration is required, the surgical approach should be through a thoracotomy if the tear involves the distal trachea, a main stem, or both, and through a cervicotomy when the laceration is located in the proximal two thirds of the trachea. Performing a longitudinal tracheotomy to reach and suture the posterior tracheal wall is a reliable, quick, and safe procedure, and it avoids lateral and posterior dissection of the trachea. (J Thorac Cardiovasc Surg 2000;120:115-8)
rior mediastinal goiter in the another, both operations being performed through a right thoracotomy. In these patients the anesthesiologist reported recurrent episodes of desaturation and bleeding from the tracheal tube. Meanwhile, during the operation, the surgeon observed the appearance of mediastinal emphysema. A bronchoscope was immediately inserted through the double-lumen tube, and it revealed a juxtacarinal membranous tracheal tear involving the right main bronchus in 1 patient and the left main-stem bronchus in the other. In both cases surgical repair was directly performed through the same right thoracic incision.

In the other 9 patients the most common signs and symptoms were hemoptysis, dyspnea, and subcutaneous emphysema (Table I). These symptoms usually developed just after extubation and always within 12 hours of extubation. Chest radiography revealed a pneumomediastinum in 7 patients. Bronchoscopy confirmed the clinical suspicion in 8 patients. In 1 patient the diagnosis was made during bronchial aspiration. Two patients, both of whom had small mucosal tears (ie, not gaping during respiratory air flow) and no signs or symptoms of full-thickness involvement of the tracheal wall (eg, subcutaneous emphysema and pneumomediastinum), were treated conservatively.

The other 7 patients, who had deeper and longer lacerations, the edges of which gaped during respiratory air flow, and who had important clinical manifestations, underwent surgical repair within 12 hours (mean, 6 hours) of the intubation. In 2 patients the tear involved the distal trachea and the right main-stem bronchus posteriorly for a length of 40 and 45 mm, respectively. In the other 5 patients the lacerations were in the proximal two thirds of the trachea, and the mean length was 36 mm (range, 30-50 mm). All patients underwent general anesthesia and were again intubated with bronchoscopic guidance. The first 2 were intubated with a double-lumen tube (Bronco-Cath; Mallinckrodt Medical, Cornamaddy, Athlone, County Westmeath, Ireland) for a right posterolateral thoracotomy, and the other 5 patients, who underwent cervicotomies, were intubated with a 5.5-mm inner diameter single low-pressure cuffed orotracheal tube (Bivona Aire-cuf, Gary, Ind). In the patients treated through the thoracic incision, the distal trachea and the involved main-stem bronchus were isolated posteriorly, and the tear was repaired by means of interrupted absorbable 4-0 Maxon sutures (Davis & Geck, Wayne, NJ). In the other 5 patients we used an approach recently reported by Angelillo-Mackinley.4 A small collar incision was performed 2 cm above the sternum with the neck hyperextended, as is done for mediastinoscopy. A minimal dissection allowed us to reach the pretracheal space, and the thyroid isthmus was sectioned in all but 1 case. The anterior tracheal wall was then incised longitudinally along the midline, for the length of 4 to 7 rings, in exact correspondence to the injury, with a fiberoptic bronchoscope used as a guiding tool. Tracheotomy edges were retracted laterally, and while the orotracheal tube was withdrawn, a second 4.5-mm inner diameter sterile low-pressure cuffed flexible armored endotracheal tube was inserted into the distal airway through the tracheal incision across the field of operation. No jet ventilation was used. During the suture, the endotracheal tube was withdrawn several times to adequately expose the tracheal tear. The laceration was

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Intubation</th>
<th>Location</th>
<th>Length (mm)</th>
<th>Signs-symptoms</th>
<th>Treatment</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (35, F)</td>
<td>Orotracheal</td>
<td>4 cm above carina</td>
<td>30</td>
<td>Hemoptysis, subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Cervicotomy</td>
</tr>
<tr>
<td>2 (74, F)</td>
<td>Orotracheal</td>
<td>5 cm above carina</td>
<td>30</td>
<td>Dyspnea, subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Cervicotomy</td>
</tr>
<tr>
<td>3 (65, F)</td>
<td>Orotracheal</td>
<td>4.5 cm above carina</td>
<td>30</td>
<td>Dyspnea, subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Cervicotomy</td>
</tr>
<tr>
<td>4 (92, F)</td>
<td>Orotracheal</td>
<td>3.5 cm above carina</td>
<td>50</td>
<td>Hemoptysis, subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Cervicotomy</td>
</tr>
<tr>
<td>5 (69, F)</td>
<td>Orotracheal</td>
<td>3.5 cm above carina</td>
<td>40</td>
<td>Subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Cervicotomy</td>
</tr>
<tr>
<td>6 (83, F)</td>
<td>Orotracheal</td>
<td>Trachea and right main bronchus</td>
<td>45</td>
<td>Subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Right thoracotomy</td>
</tr>
<tr>
<td>7 (65, F)</td>
<td>Orotracheal</td>
<td>Trachea and right main bronchus</td>
<td>40</td>
<td>Hemoptysis, subcutaneous emphysema, pneumomediastinum</td>
<td>Surgical</td>
<td>Right thoracotomy</td>
</tr>
<tr>
<td>8 (65, F)</td>
<td>Selective double lumen</td>
<td>Trachea and left main bronchus</td>
<td>50</td>
<td>Pneumomediastinum, desaturation bleeding</td>
<td>Surgical</td>
<td>Right thoracotomy</td>
</tr>
<tr>
<td>9 (55, F)</td>
<td>Selective double lumen</td>
<td>Trachea and right main bronchus</td>
<td>55</td>
<td>Pneumomediastinum, desaturation bleeding</td>
<td>Surgical</td>
<td>Right thoracotomy</td>
</tr>
<tr>
<td>10 (72, M)</td>
<td>Selective double lumen</td>
<td>2 cm above carina</td>
<td>20</td>
<td>Hemoptysis</td>
<td>Conservative</td>
<td>—</td>
</tr>
<tr>
<td>11 (77, F)</td>
<td>Selective double lumen</td>
<td>4 cm above carina</td>
<td>25</td>
<td>Dyspnea</td>
<td>Conservative</td>
<td>—</td>
</tr>
</tbody>
</table>
repaired with a 4-0 Dexon II running suture (Davis & Geck), generally starting from the distal end of the tear. While the patients were in an apneic state, the anesthesiologist monitored their vital signs to decide when to ventilate again. Once the laceration was repaired, the endotracheal tube was withdrawn from the field of operation, and the original orotracheal tube was advanced by the anesthesiologist beyond the suture. The longitudinal tracheotomy was closed by using 3-0 Dexon II interrupted crossed stitches.

Results
All surgical procedures proved effective. There was no mortality or morbidity involved. In the 2 patients in whom the tracheobronchial tear was discovered after the initial operation, the average duration of the surgical procedure through an elective right thoracotomy was 110 minutes. On the other hand, the mean time required for the cervicotomy procedure was less than 1 hour. All patients were immediately extubated at the end of the surgical procedure.

The postoperative course was uneventful in all cases, and the patients were discharged on average after 5.7 days (range, 3-8 days). The mean postoperative hospital stay was 4.6 days in the 5 patients who underwent the cervical approach (range, 3-6 days). Endoscopic follow-up after 10, 30, and 60 days showed a perfect healing process of the laceration in all cases, with no symptoms or signs of tracheal or bronchial stenosis.

Discussion
Tracheal laceration is a rare complication of general anesthesia, which generally involves the posterior membranous wall. The relatively high incidence in our series (11 cases in 7 years) may be explained by the fact that ours is a tertiary referral center for tracheal surgery in our country. Similar to our experience, in the literature tracheal lesions have been reported to be associated with both double-lumen selective and single-lumen intubations, and women seem to be more prone to the complication than men. Many factors may be responsible for producing the lesion: repeated attempts at a difficult intubation, as in one of our cases; the presence of tracheal abnormalities; and overdistention or rupture of the tube cuff. However, many times a tracheal laceration occurs after an intubation carried out with no apparent difficulty, as in the other cases of our report.

The diagnosis is not a difficult one if the physician keeps in mind such a possibility. The first signs often appear immediately after the extubation or within the first 12 hours. These symptoms are hemoptysis; subcutaneous emphysema of the head, neck, and upper chest; and, in severe cases, dyspnea and cyanosis. Chest x-ray films usually show a pneumomediatinum, as in 7 of our patients, and in some cases, especially when the laceration is in the lower part of the trachea or has extended to one main bronchus, a pneumothorax.

Tracheobronchoscopy can confirm the diagnosis and establish the location and the extent of the tear, thus allowing the surgeon to plan the correct surgical approach. When a tracheoesophageal fistula is suspected, an esophagoscopy is also required.

In the literature several isolated cases of postintubation tracheal tears managed successfully by means of conservative therapy have been reported. They were mainly small tears in patients in stable condition with at most minimal and nonprogressive manifestations, such as subcutaneous emphysema, pneumomediastinum, and pneumothorax. We likewise treated 2 patients in our series with these same features. In these cases endoscopic findings, rather than clinical manifestations, have influenced our strategy of treatment. We believe that only short and superficial tears may spontaneously heal without a significant risk of early and late complications.

Still, definitive single-stage surgical repair remains the preferred choice of treatment in most cases of tracheobronchial laceration. It should be performed as soon as possible to avoid both early complications, such as descendent mediastinitis, and belated sequelae, such as tracheal stenosis.

Juxtacarinal membranous tracheal lacerations are generally managed through a right thoracotomy, especially if they involve a main bronchus. This was our approach in 4 patients with a tracheobronchial lesion. On the other hand, when the tear involves the proximal two thirds of the posterior tracheal wall, a cervical approach would be more fitting, as in the case of the remaining 5 patients in our report. Traditional technique would provide for a left cervicotomy, sometimes extended to a sternal split, followed by a lateral and then posterior paratracheal dissection to isolate the trachea and to reach the membranous wall for suturing. In contrast, in all our patients who underwent the cervical approach, we used the technique reported by Jacobs in 1978 and recently revised and modified by Angelillo-Mackinley, with a slight twist on the airway management. Jacobs and colleagues first reported 2 cases of posterior tracheal laceration as a complication of tracheostomy that were promptly repaired with a single-layer closure through the same tracheotomy. In a case report, Angelillo-Mackinlay described suturing a tear through a cervical mediastinoscopy–like approach and making a vertical incision in the anterior wall of the trachea. His patient was intubated with a small single-
lumen tube retracted laterally to allow the suturing of the tear. Our approach was almost the same, but we substituted the orotracheal tube with a smaller one inserted into the distal trachea across the field of operation, as is usually done for tracheal resection and reconstruction. This allowed us to easily alternate suturing with ventilation and afforded us optimal maneuverability in repairing the distal end of the laceration when the tube was removed and the patient was in an apneic state. Moreover, during this procedure, we realized that it may be possible to repair tears extending all the way to the carina without the necessity of a sternal split.

In conclusion, we concur with those authors who opt for conservative management in patients with minimal and nonprogressive symptoms and signs and with small tears that do not gape during respiration. However, these cases are the exception and not the rule. Early surgical repair is the mainstay of treatment; it offers good results, and prognosis generally depends on the underlying disease and not on the injury itself. When surgical repair is required and the tear is above the carina, we suggest the transcervical-transtracheal approach. This minimally invasive technique, although very quick and easy to perform, provides excellent results and avoids lateral and then posterior dissection of the trachea (necessary to reach the membranous tracheal wall) and consequent exposure of the recurrent laryngeal nerve to injury.

REFERENCES