The tracheas of 12 patients who had undergone autopsies after percutaneous dilatational tracheotomy (PDT) were analyzed macroscopically and microscopically. The puncture site of the trachea varied from just below the cricoid cartilage (two patients) to below the third ring (three patients). A fracture of one or more tracheal rings was present in 11 patients, of whom 2 had a fractured cricoid. Destruction of one or more tracheal rings was present in all eight patients cannulated for more than 10 days and was related to duration of cannulation (p<0.005). Protrusion of the anterior wall into the tracheal lumen with tracheal stenosis was seen in two patients. Improvements to the PDT technique are discussed to avoid complications.

Key words: cricoid cartilage; histology; pathology; percutaneous tracheotomy; percutaneous tracheotomy; tracheal stenosis; tracheotomy

Abbreviations: PDT—percutaneous dilatational tracheotomy

Injury of the trachea is a well-known late complication of both translaryngeal intubation and tracheotomy. After tracheotomy, lesions of the trachea are found distally, at the site of the tip of the cannula or at the cuff site and more proximally at the level of the stoma itself. The incidence of distal lesions due to pressure necrosis has been greatly reduced by the use of low-pressure cuffs. Tracheal damage at the stoma site is related to a large stoma with a mobile cannula and to infection.

Percutaneous dilatational tracheotomy (PDT) is a relatively new technique to introduce a cannula into the trachea. No surgical wound is made and the cannula is snugged between the surrounding tissue reducing movements of the cannula. An incision into the tracheal rings is not necessary and the rings remain theoretically intact. The parastomal infection rate is considerably lower than after conventional open tracheotomy. A preliminary study of the effects of percutaneous tracheotomy on the trachea in dogs showed only minor microscopic changes of the trachea, and animals with tracheal stenosis were not found 3 months after tracheotomy.

We examined macroscopic and histopathologic changes of the trachea in patients who underwent PDT to assess the effects of PDT on the trachea.

**Materials and Methods**

PDT was performed by four surgeons and surgical residents with a commercially available kit (Cook; Som, the Netherlands). The technique described by Ciaglia et al was followed. After hyperextension of the neck and a small incision through the skin, the first tracheal interspace was identified. The trachea was punctured with a cannulated needle on a syringe. The intraluminal position of the needle was checked, the syringe and the needle removed, and through the sheath a guidewire was introduced into the lumen. Over the guidewire, the tract was progressively dilated with tapered dilators so that a Shiley size 8 tracheal cannula with an outside diameter of 12 mm (Laméris; Utrecht, the Netherlands) could be introduced mounted on an appropriately sized dilator.

In the 15-month period between November 1, 1993, and February 1, 1995, the tracheas of 12 consecutive patients who died after PDT were removed at autopsy. The cause of death was the tracheotomy related. The specimens were removed en bloc and were opened along the membranous portion. The location of the tracheotomy and macroscopic damage were noted. The tracheas were photographed. The specimens were fixed in 10% formalin and embedded in paraffin. Hematoxylin-eosin-stained transverse sections were microscopically analyzed.

The patient characteristics, the duration of cannulation, and the duration of previous orotracheal intubation are listed in Table 1. Nine patients were orotracheally intubated and received their cannula for prolonged ventilation. The other three received a cannula for bronchial toilet. Operative complications of the procedure and complications during cannulation, assessed by retrospective chart review, included bleeding in two patients. Suture ligation was necessary in one. In one patient cannulated for 122 days, granulation tissue at the stoma site was removed by laser therapy.

Comparison of group characteristics was performed by the
Fisher's Exact Test for categorical measures. A p value of 0.05 or less was considered evidence of a significant difference between groups.

RESULTS

The tracheostomy site in this group of patients varied greatly: twice between the cricoid cartilage and the first ring, six times between the first and second ring, once through the thyroid isthmus between the second and third ring, and three times between the third and fourth ring.

Broken cartilaginous rings, the cricoid cartilage included, were registered in 11 patients, of whom 6 had more than one broken ring (Table 2). In all eight patients with a tracheostomy for more than 10 days, destruction and necrosis of one or more rings was found. This was significant compared with the group with a shorter duration of cannulation, in whom no destruction of rings was found (p<0.005). In one patient cannulated for 122 days, two tracheal rings next to the cannula were almost completely devoid of cartilage with extensive ossification next to the rings. Necrosis of the cartilaginous rings with ossification at the outer side of the rings was always present if a patient had been cannulated for more than 3 weeks (Fig 1). It was found only in one patient with a shorter duration of cannulation (p<0.01). There was no relation between damage of the cartilaginous rings and the position of the tracheal cannula.

Both patients with their cannula just below the cricoid cartilage had a fracture of their cricoid. At the time of death, they had been cannulated for 2 and 5 days. Necrosis of the cricoid was seen once at the outer side of the cartilage caused by a cannula that was inserted very obliquely into the tracheal lumen.

Tracheal stenosis of 20% and 30% was registered in two patients cannulated for 20 and 12 days, respectively. In both there was a broken tracheal ring just proximal to the tracheotomy site causing protrusion into the tracheal lumen. It was the result of a cannula tract that very obliquely entered the tracheal lumen.

Deep ulceration of the mucosa with exposure of the cartilaginous rings was present at the stomal site in 11 patients. In one patient cannulated for 2 days, there was no mucosal ulceration. Only in those with a duration of cannulation of more than 3 weeks did it exceed more than two segments or more than half of the circumference of the trachea. In all others, ulcers were smaller. As on the inner side, there was damage on the outer side of the trachea. In six patients, one or more rings proximal to the cannula were bared on the outer side by continuous pressure from the cannula.

Ulceration of the distal trachea was usually shallow, although there was deeper ulceration with exposure of tracheal rings in four patients. It was located anteriorly and never exceeded more than three segments. Fractures or necrosis of the cartilage were never found. In one of three patients with a cannula for sputum retention, a deep anterior ulcer was found despite a deflated cuff. Ulceration of the compliant membranous portion of the trachea was never seen.

Damage to the mucosa varied from incomplete to complete erosion, acute inflammatory reaction with submucosal edema, and hemorrhage, which was especially present in both patients with operative bleeding. Metaplasia with flattening of the epithelium was identified in most patients. One had a cannula tract that was completely covered with stratified squamous epithelium.

DISCUSSION

PDT is a relatively easy technique for the insertion of a tracheal cannula. The operative complications are low and in a prospective randomized study, this technique was superior to the conventional open procedure.7 However, few studies assess the late complications of this technique and involve only limited numbers of patients.10 To our knowledge, pathologic studies have never been done. Although the number of tracheas in this study is relatively small and there is no comparison to tracheas after orotracheal intubation or conventional open tracheotomy, the results of the study may improve the percutaneous dilatational technique and prevent complications.

PDT is carried out by direct needle puncture of the trachea after a small skin incision. There are surgeons who dissect bluntly the pretracheal tissue with a mosquito clamp before they puncture the trachea. This

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Table 1—The Patient Characteristics of 12 Autopsies

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>7</td>
</tr>
<tr>
<td>Age, yr, median (range)</td>
<td>73.5 (69-84)</td>
</tr>
<tr>
<td>Duration of cannulation, d, median (range)</td>
<td>16 (2-122)</td>
</tr>
<tr>
<td>Prior oral intubation, d, median (range)</td>
<td>6 (0-13)</td>
</tr>
</tbody>
</table>

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Table 2—Damage of the Trachea After PDT in 12 Patients at Autopsy

<table>
<thead>
<tr>
<th>Damage</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartilaginous ring fracture</td>
<td>11</td>
</tr>
<tr>
<td>Destruction of one of more rings</td>
<td>8</td>
</tr>
<tr>
<td>Deep mucosal ulceration</td>
<td>11</td>
</tr>
<tr>
<td>Damage of the cricoid cartilage</td>
<td>3</td>
</tr>
<tr>
<td>Protrusion of the tracheal wall into the lumen</td>
<td>2</td>
</tr>
</tbody>
</table>

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enables clear palpation of the cricoid cartilage and the tracheal rings. Because we believed that this enlarged the risk of procedural bleeding, we have not generally used this technique. Others show good results of endoscopic guided PDT, which may be helpful to confirm the exact puncture site. The puncture sites in this small group of patients show a large variation and show cricoid damage with the risk of laryngotracheal stenosis.

PDT is generally used at the subcricoid level or between the first and second tracheal rings. Many surgeons are reluctant to use lower levels because of fear of hemorrhage from the isthmus of the thyroid. We found a fractured cricoid ring in both patients who underwent tracheotomy at the subcricoid level. Necrosis and destruction of cartilage were present in all patients with a duration of cannulation of more than 10 days. To prevent destruction of the cricoid cartilage and subglottic stenosis, we prefer insertion of the cannula below the first or preferably below the second tracheal ring.

Fractured rings were seen after both short and long duration of cannulation. Since the cannula used does not always fit tightly on the appropriate dilator, it requires firm pressure to push the dilator-cannula complex into the tracheal lumen. This can fracture the cartilaginous rings. After prolonged cannulation, necrosis and softening of the rings make them vulnerable for fragmentation and damage from the cannula. Similar to cartilaginous changes due to high-pressure cuffs, necrosis and destruction of cartilaginous rings
are present after 10 days to 2 weeks of cannulation. It is caused by high pressure from the cannula. Destruction of rings can lead to loss of rigidity of the tracheal wall and to tracheal collapse. Reactive ossification, which was always present after 3 weeks of cannulation, may be able to prevent tracheal collapse.

Tracheal stenosis at the stomal site is generally seen anteriorly. It is caused by fibrosis of the trachea, granulation tissue next to the stoma, and a posterior displaced anterior tracheal wall. A tracheal cannula that is inserted obliquely may fracture its proximal ring and result in protrusion of the tracheal wall into the lumen (Fig 2). Extreme hypertension of the neck for adequate exposure pulls the trachea upward. If in this position a skin incision is made over the first tracheal ring, the trachea is punctured, and a cannula inserted, the tract of the cannula becomes oblique when the head is brought forward to its normal position at the end of the procedure. Also, the trachea recedes from the surface as it passes down from the level of the cricoid cartilage to the carina. Puncture at a right angle to the skin means an oblique puncture of the trachea. Installation of the cannula may fracture the ring above the site of the entry and indentation of the anterior tracheal wall.

Since 1990, we have performed more than 200 PDTs at De Wever Hospital with excellent early results. Since details are of importance to avoid long-term complications, this pathologic study may be helpful in improving the technique used. After clear identification of the tracheal rings, the trachea is punctured below the first or preferably the second tracheal ring. An oblique position of the cannula to the trachea should be avoided.

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