Objective: Analysis of laryngotracheoscopic findings of the upper airway tract following percutaneous tracheostomy using the technique according to Griggs.

Design: Retrospective cohort study

Patients: Nineteen of 32 long-term surviving patients (mean follow-up duration, 17 months; range, 11 to 23 months) underwent a modified Griggs tracheostomy during their stay in the ICU following cardiothoracic surgery.

Interventions: Nineteen patients gave their informed consent for laryngotracheoscopy to localize and assess the percutaneous dilatational tracheostomy (PDT) puncture site, to evaluate the laryngotracheal morphology, and to quantify tracheal stenosis if present. In addition, specific symptoms of the upper airway tract were evaluated.

Results: At the time of examination, no clinically relevant cases of stenoses were found, although one patient had undergone surgical revision of the PDT for extensive granulation prior to our examination. The endoscopic examination revealed that 12 of 19 patients (63%) had tracheal stenoses >10%, and 2 patients had tracheal stenoses >25%. In 7 of 19 patients (32%), the cricoid cartilage was affected by the PDT site. Despite endoscopic guidance during PDT, the location of the puncture site was found to vary greatly.

Conclusion: In contrast to recent reports on the long-term outcome after Griggs PDT, we found tracheal stenoses >10% in 63% of our patients. The grade of stenosis depended mainly on the puncture site of the PDT. Based on these results, we would emphasize the importance of adequate endoscopic guidance during PDT. Further studies are required in order to clarify the risk of long-term complications arising after PDT using the technique of Griggs.

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Key words: flexible laryngotracheoscopy; Griggs tracheostomy; percutaneous dilatational tracheostomy; tracheal pathology; tracheal stenosis; tracheostomy

Abbreviations: BMI = body mass index; PDT = percutaneous dilatational tracheostomy; TLS = tracheal luminal stenosis

Tracheostomy is one of the most commonly performed elective operations in critically ill patients. Different methods of percutaneous dilatational tracheostomy (PDT) have been developed over the last decades as alternatives to the standard surgical tracheostomy. As experience in this field has grown, PDT has been increasingly implemented in the long-term management of critically ill patients. The most commonly used PDT techniques are those according to Ciaglia et al., and less frequently according to Griggs et al. Both methods have been modified during the last years, and the most crucial modification is tracheoscopic guidance during PDT. Despite the increased use of PDT, long-term follow-ups are only provided by 12% of the departments using these techniques. Most studies on this follow-up data regarding long-term findings have focused on the Ciaglia method, whereas comparatively little research has covered the Griggs method.

The most crucial long-term complication, besides puncture of the tracheal wall during PDT, is tracheal stenosis. Leonard and coworkers reported no
significant (> 10%) tracheal stenosis in their long-term follow-up of 10 patients who were examined endoscopically. Steele and coworkers used spiral CT scans and found dilatations rather than stenosis of the trachea after PDT. These findings were somewhat surprising because investigations of the Ciaglia method regularly report varying degrees of tracheal stenosis in long-term outcome.

This study was initiated to investigate the particular pathology after PDT using the technique of Griggs, focusing on laryngotracheoscopic findings in long-term follow-up. It describes the functional and morphologic findings that were directly assessed by flexible laryngotracheoscopy in patients who underwent Griggs PDT during their postoperative stay on the Cardiac Surgery ICU, University of Heidelberg. In addition, this study relates the findings of the endoscopic assessment to specific clinical symptoms for laryngotracheal stenosis.

Materials and Methods

Patients

Percutaneous tracheostomy according to Griggs et al was introduced in the ICU of the Cardiac Surgery Department, University of Heidelberg, in 1996. In the beginning, the method was performed in approximately 20 to 30 selected patients per year and the procedure were done by two cardiac surgeons and one anesthetist. To ensure that the study was not affected by operations performed during the initial learning process, we evaluated patients who underwent PDT in 1999. In 1999, approximately 1,200 operations were performed using cardiopulmonary bypass. During the postoperative ICU stay, 93 patients required mechanical ventilation for > 5 days. Using the Portex-kit (SIMS Portex; Kent, UK), 60 of these patients received tracheostomies according to the Griggs method, modified by endoscopic guidance of the whole procedure. Twenty patients died during their postoperative ICU stay due to non-PDT-related reasons. A routine 6-month postoperative follow-up revealed that 8 of the surviving 40 patients had died for various reasons, also unrelated to PDT. The remaining 32 patients were contacted and asked to participate in this follow-up study. One patient had moved to a foreign country, and three other patients had moved to unknown destinations and could therefore not participate in the study. Four patients were in the hospital due to their cardiac diseases and could not be interviewed or examined. Telephone interviews with the attending doctors of the hospitalized patients revealed no clinical problems relating to PDT. Four patients were not willing to participate due to personal reasons. For these four patients, clinical problems relating to PDT could be excluded by telephone interviews. Twenty patients participated in an initial examination, and specific histories were taken for tracheal or laryngeal effects, ie, voice change, hoarseness, stridor, cough, and dyspnea. Nineteen of these 20 patients gave their informed consent for further laryngotracheoscopic examination, and these form the basis of this study. PDT had been performed in these patients after an average postoperative intubation time of 9.5 days (range, 2 to 18 days).

Laryngotracheoscopy

Flexible laryngotracheoscopy (Olympus ENF Type T3; Olympus; Tokyo, Japan) was performed with local anesthesia (nebulized 1% oxybuprocaine-HCl), monitored by ECG and pulse oxymetry. The examination took place in the ICU to provide a maximum medical backup. A cardiac surgeon, an anesthetist, and an end, nose, and throat surgeon were present throughout the examinations. No complications occurred during the examinations or within the obligatory 1-h observation period after the examinations. Each individual laryngotracheoscopic examination was documented on video so that they could be analyzed afterwards.

For each patient, we localized the PDT puncture site, evaluated the laryngotracheal morphology, and assessed tracheal stenosis planimetrically. To quantify tracheal luminal stenosis (TLS), representative video sequences were digitized. Single digital pictures of the stenotic site and the free tracheal lumen in close proximity (control) were taken. Using these pictures, the cross-sectional area was determined planimetrically. TLS was determined by comparing the cross-sectional area from control and stenotic sites. TLS values were expressed as a percentage as follows:

\[
\text{TLS}(\%) = \frac{\text{CSAs} \times 100}{\text{CSAc}}
\]

where CSA = cross-sectional area; CSAs = cross-sectional area from stenotic sites, and C Sac = cross-sectional area from control.

TLS values were graded in four categories: (1) TLS < 10%, (2) TLS 10 to 25%, (3) TLS 25 to 50%, and (4) TLS > 50%. The data are presented as mean values ± SD, unless indicated differently. In addition, we compared our laryngotracheoscopic findings with the specific histories taken for symptoms affecting the upper airway tract, such as: voice change, dyspnea, stridor, cough, and hoarseness.

Results

This study includes 19 patients (age range, 20 to 82 years; mean age, 64 years), who underwent modified PDT according to the Griggs method on postoperative day 2 to postoperative day 18 (mean, 9.5 days). Thirteen of the 19 patients were male (68%). The cardiac diagnosis and operations performed are shown in Table 1. Definitive decannulation occurred in a mean of 24 days after PDT (range, 4 to 90 days). Overall follow-up time was 325 months; mean follow-up time was 17 months (range, 11 to 23 months). Calculating the body mass index (BMI) of each patient revealed a mean BMI of 27.1 ± 5.7 (range, 17.1 to 38.1). A BMI > 25 was found for 11 of 19 patients (58%), and a BMI > 30 was found for 7 patients.

PDT Puncture Site

In six patients, the puncture site of the PDT could be localized between the first and second tracheal ring (31.6%). In three patients, the trachea was punctured straight through the first tracheal ring, including extended tracheostomies from the cricoid.
to the second tracheal ring in two patients. Five patients had punctures between the cricoid and the first tracheal ring (26.3%). In one patient, the PDT was performed between the second and the third tracheal ring, and in three patients between the third and fourth tracheal ring. In the remaining patient, the PDT site was localized through the third tracheal ring.

Tracheal Stenoses

We found a TLS of < 10% (grade I TLS, 7.4 ± 3.6%) in 7 patients; TLS of 10 to 25% (grade II TLS, 17.0 ± 3.2%) in 10 patients, and TLS of 25 to 50% (grade III TLS, 39.6 ± 6.0%) in 2 patients. In most cases, the stenoses were located above the PDT puncture site. Dilatations of the anterior aspects of the trachea were found below the puncture sites in 4 of 19 patients (21%). These dilatations seemed to be residues of the tracheostoma. All findings are summarized in Table 2.

As mentioned above, we found the puncture and later cannulation site involving the cricoid cartilage in seven patients. All these lesions included fractures of the first tracheal ring. Mean TLS of these patients was quantified as 22.7 ± 12.6%. Further investigation of the morphology of the stenoses revealed “triangulation” of the cricoid without additional pathologic changes in two cases, and isolated impression/malacia of the cricoid in two other cases. In two patients, fracture of the cricoid occurred with cricoidal granulation and cricoidal web formation. The worst case of stenosis in our patient group (TLS of 43.9%) included triangulation of the cricoid, cricoidal and subcricoidal granulation, and near-midline fracture of the first tracheal ring, which resulted in a “gothic arch” deformation (see below). The PDT of this patient had been converted surgically into a permanent tracheostoma 4 months after PDT for clinically relevant tracheal obstruction. Therefore, it is important to note that the morphology described here does not reflect the original post-PDT situation. In addition to the PDT conversion, extensive subglottic granulation was resected. Primary closure of the tracheostoma was performed 1 month after surgical intervention and 11 months prior to the reexamination reported here.

The morphology of the tracheal stenoses resulting from PDT punctures below the cricoid was mainly due to fractures of tracheal rings and varied according to the fracture site. If the fracture was localized more toward the middle of the tracheal ring, the resulting deformation gave the impression of a gothic arch (Fig 1). Stenoses resulting from fractures localized more laterally were due to dislocated cartilaginous fragments in the tracheal lumen, and in one case, granulation at the fracture site. Stenoses without any signs of fractured tracheal rings were due either to malacia and subsequent impression of a tracheal ring (2 of 19 patients) or to isolated granulation (1 of 19 patients).

Additional Findings

In addition to these morphologic findings, we found three vocal cord palsies in our patients. Two of them were on the left side, and one was on the right side. One left-sided palsy could be traced back to cardiac surgery performed in the patient’s history (left-sided Blalock-Taussing shunt). The remaining two vocal cord palsies were not related to surgery (coronary artery bypass graft surgery and valve-replacement operations). A malignancy-related palsy could be excluded by additional CT scans of the neck and upper chest. However, the patients denied clinical symptoms like voice change, hoarseness,
Table 2—Laryngotracheoscopic Findings After PDT According to the Griggs Method

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>PDT Localization, Horizontal/Vertical</th>
<th>Comment</th>
<th>Laryngotracheal Stenosis</th>
<th>Tracheal Dilatation, Localization/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>TLS, %</td>
<td>Grade</td>
</tr>
<tr>
<td>1</td>
<td>RAQ1–2 TR</td>
<td>No fracture</td>
<td>0.6</td>
<td>I</td>
</tr>
<tr>
<td>2</td>
<td>LAQ1–2 TR</td>
<td>Fracture first TR</td>
<td>4.3</td>
<td>I</td>
</tr>
<tr>
<td>3</td>
<td>RAQ1–2 TR</td>
<td>Fracture first TR</td>
<td>9.1</td>
<td>I</td>
</tr>
<tr>
<td>4</td>
<td>RAQCR-1 TR</td>
<td>Fracture first TR</td>
<td>9.1</td>
<td>I</td>
</tr>
<tr>
<td>5</td>
<td>LAQ/1 TR</td>
<td>Fracture first TR</td>
<td>9.2</td>
<td>I</td>
</tr>
<tr>
<td>6</td>
<td>RAQ3–4 TR</td>
<td>No fracture</td>
<td>9.8</td>
<td>I</td>
</tr>
<tr>
<td>7</td>
<td>RAQ2–3 TR</td>
<td>Fracture second TR</td>
<td>9.9</td>
<td>I</td>
</tr>
<tr>
<td>8</td>
<td>RAQ1–2 TR</td>
<td>Fracture first TR</td>
<td>13.5</td>
<td>II</td>
</tr>
<tr>
<td>9</td>
<td>LAQ/1–2 TR</td>
<td>Fracture first TR</td>
<td>13.8</td>
<td>II</td>
</tr>
<tr>
<td>10</td>
<td>RAQCR-2 TR</td>
<td>Fracture first TR</td>
<td>14.0</td>
<td>II</td>
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<td>Fracture first TR</td>
<td>14.8</td>
<td>II</td>
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<tr>
<td>12</td>
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<td>Fracture first TR</td>
<td>16.1</td>
<td>II</td>
</tr>
<tr>
<td>13</td>
<td>RAQ3–4 TR</td>
<td>No fracture</td>
<td>17.4</td>
<td>II</td>
</tr>
<tr>
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<td>RAQ3n TR</td>
<td>Fracture third TR</td>
<td>17.5</td>
<td>II</td>
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<td>15</td>
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<td>Fracture first TR</td>
<td>18.9</td>
<td>II</td>
</tr>
<tr>
<td>16</td>
<td>LAQ/3 TR</td>
<td>Fracture third TR</td>
<td>21.6</td>
<td>II</td>
</tr>
<tr>
<td>17</td>
<td>ML/CR-2nd TR</td>
<td>Fracture first TR</td>
<td>22.6</td>
<td>II</td>
</tr>
<tr>
<td>18</td>
<td>RAQCR-1st TR</td>
<td>Fracture first TR</td>
<td>35.4</td>
<td>III</td>
</tr>
<tr>
<td>19</td>
<td>RAQCR-1st TR</td>
<td>Fracture first TR</td>
<td>43.9</td>
<td>III</td>
</tr>
</tbody>
</table>

*RAQ = right anterior quadrant; LAQ = left anterior quadrant; ML = midline; CR = cricoidal cartilage; TR = tracheal ring.

†Dilatation at this site is due to surgical conversion of the PDT into a permanent tracheostoma and its closure using a skin flap.
cough, and stridor. The respective TLS results were quantified as 9.8% and 13.5% (patient 6 and patient 8, respectively; Table 2).

**Specific Clinical Symptoms**

During the consultation before the laryngotracheoscopic examination, we asked the patients if they had noticed any symptoms of voice change, dyspnea, cough, hoarseness, and stridor, which could indicate laryngotracheal affection. Thirteen patients reported experiencing none of these symptoms after PDT. Laryngotracheoscopy revealed a mean TLS of 13.6 ± 8.7% (range, 0.6 to 35.4%). TLS grading revealed five grade I lesions, six grade II lesions, and one grade III lesion. Four of these asymptomatic patients had PDT lesions involving the cricoid cartilage. Two of these patients had additionally vocal cord palsies without specific symptoms.

Four patients reported voice change as a symptom, and a mean TLS of 14.6 ± 3.2% (range, 10 to 17.5%) was quantified. Vocal cord palsy related to cardiac surgery was diagnosed in one of these patients, and his voice change is more probably due to cardiac surgery than to PDT (TLS of 17.5%). Another patient reported stridor and dyspnea, although stridor could not be confirmed during the examination. Laryngotracheoscopy revealed a gothic arch deformation of the first tracheal ring (TLS of 16.1%) without any additional laryngotracheal pathology in this patient.

Two patients reported isolated dyspnea: one of these patients (TLS of 22.6%) underwent double-lung transplantation (for COPD), and dyspnea was clearly related to poor lung function. This patient died from chronic rejection 4 months after the examination. In the second of these two patients, isolated dyspnea was not clearly related to the laryngotracheal pathology, because although we calculated a TLS of 43.9%, indicating that dyspnea could be related to the laryngotracheal stenosis, the patient reported preexisting (prior to PDT) dyspnea as a cardiopulmonary symptom. In our patient group, dyspnea alone does not seem to be a sensitive parameter for indicating laryngotracheal effects after PDT.

**Discussion**

There is ongoing discussion about the most appropriate method for the follow-up of percutaneous tracheostomy. Spiral CT scans,14 plain tracheal radiography,8 and MRI17 are the methods most frequently used, and they are reported as being more acceptable for patients due to their noninvasive nature.14 Steele and coworkers14 ranked laryngotracheoscopic follow-up as uncomfortable and cited studies9,11,12 with high refusal rates. However, in our experience, laryngotracheoscopy was well accepted by our patients. The high acceptance rate of the examination in our study (95%; 19 of 20 patients) was probably due to adequate information about the

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**Figure 1.** Examples of specific laryngotracheoscopic findings after PDT. Due to near-midline fractures, the specific pathologic findings for a tracheal ring (gothic arch formation) and for the cricoid cartilage (triangulation) are shown.
procedure. Comparable acceptance rates have been reported by Law and coworkers.\textsuperscript{11}

However, more important than the acceptance rate of a follow-up method, is its reliability to identify pathologies. We chose the laryngotracheoscopy technique because it ensures that the morphology can be examined as well as the function of the upper airway tract.

For example, in those patients with vocal cord palsies (3 of 19 patients), clinical symptoms like voice change would most probably have been misinterpreted if indirect radiomorphologic techniques had been used. It appears that if CT scans, plain tracheal radiography, MRI, or functional lung testing are used alone, then they may not be sufficient to identify impairments of the upper airway tract and establish a diagnosis. Therefore, we recommend that any follow-up study designed to identify long-term outcomes after PDT should at least include a laryngoscopic examination. Moreover, we would point out that the findings of indirect assessments of the trachea (eg, by spiral CT scans) have to be interpreted in mind the limitations of their methodologic approach. To classify intratracheal abnormalities as "trivial scars"\textsuperscript{14} should be based on more direct assessment methods like tracheoscopy and histology.

The main interest of our study was the identification, localization, and quantification of tracheal stenoses after PDT according to the Griggs method. The degrees of the stenoses have been quantified planimetrically. At the time of examination, none of the patients showed clinically relevant symptoms clearly related to the PDT procedure they underwent. However, one of these patients had been operated on for clinically relevant tracheal stenosis after PDT and prior to our examination. Two of 19 patients had stenoses affecting >25\% of the free tracheal lumen. We recommended further control examinations for these two patients.

An unexpected result of the study was the high incidence of cricoidal lesions (7 of 19 patients), which may lead to complex and severe problems due to the anatomic characteristics and the important function the cricoid cartilage.\textsuperscript{18,19} As discussed by McFarlane and coworkers,\textsuperscript{15} cricoidal lesions are crucial complications of percutaneous tracheostomy techniques. Despite the endoscopic guidance throughout the PDT procedures reported here, only 32\% of the puncture sites were found to be in the desired place, between the first and the second tracheal ring. Since the mean BMI of the patients was 27.1 ± 5.7, one could argue that the PDT sites that were located too high may be due to the fact that patients were overweight. It is known that in obese patients with short thick necks, it is more difficult to access the trachea below the first ring. When we compared the BMIs of the patients with PDT located above the first and second ring (8 of 19 patients; average BMI, 27.6 ± 5.2) with those patients in whom PDT was performed below the first and second ring (5 of 19 patients; mean BMI, 25.8 ± 7.0), it was revealed that the average BMIs were almost the same. Nevertheless, we think that PDT performed in young trauma or neurosurgical patients of normal weight may result in a lower variability of the puncture site. Therefore, our findings regarding the PDT location in cardio-surgical patients may only apply to this patient group.

Due to the limited number of patients examined, we did not carry out a statistical analysis for the relationship between TLS grades and puncture sites. However, one trend does appear in our findings: in TLS grades I, II, and III, 1 of 7 patients, 4 of 10 patients, and 2 of 2 patients, respectively, had cricoidal lesions. Although these findings are based on a small number of patients, we would emphasize the importance of performing a tracheostomy between the first and second tracheal ring in order to prevent later laryngotracheal stenosis.

Based on this unexpected variability in the endoscopically guided punctures, together with the high incidence of cricoidal lesions in our patient group (7 of 19 patients), we would stress the importance of adequate and experienced endoscopic guidance throughout the PDT procedure. To ensure that the puncture is made at the desired site between the first and second tracheal ring,\textsuperscript{20} endoscopic identification of the cricoid cartilage is crucial. Videomonitoring of the endoscopic examination may provide better feedback on the procedure and may help to ensure the quality of this method.

In addition to stenoses, we found in four patients dilatations of the anterior tracheal wall. These dilatations were located at or below the stenotic site but always below the PDT puncture site. Three of these dilatations were caused by fractured tracheal rings and seemed to be residues of the tracheostoma. One tracheal dilatation was due to cutaneous flap closure of the formerly converted PDT into a permanent tracheostoma (patient 19). No dilatation has been found at the posterior tracheal aspect as described by Steele at al.\textsuperscript{14}

In conclusion, 1 of the 19 patients examined developed clinically relevant tracheal stenosis, requiring surgical revision after PDT. Despite endoscopic guidance during PDT, only 32\% of the patients were found to have the puncture site in the preferred place between the first and second tracheal ring, and we found a surprisingly high incidence of cricoidal lesions. Using laryngotracheoscopy, we found 12 of 19 patients (63\%) had tracheal
stenosis of between 10% and 50%. None of these patients had clinically relevant stenosis at the time of our examination. Considering the level of tracheal stenosis after PDT, our findings clearly contrast to previously published studies regarding the Griggs technique, but are comparable to those results published for the Ciaglia method.

Since only few studies have been published concerning the long-term follow-up of the Griggs technique, further research is necessary to ensure the quality of this method. In addition, we would emphasize the use of the flexible laryngotracheoscopy in long-term follow-up studies. This technique enables direct morphologic and functional examinations, and is therefore a highly accurate and reliable method to describe laryngotracheal pathologies.

REFERENCES

7 Marx WH, Ciaglia P, Graniero KD. Some important details in the technique of percutaneous dilatational tracheostomy via the modified Seldinger technique. Chest 1996; 110:762–766