“Corkscrew stenosis”: Defining and preventing a complication of percutaneous dilatational tracheostomy

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Objective: The short-term safety of percutaneous dilatational tracheostomy has been widely demonstrated. However, less is known about their long-term complications. Through an illustrative case series, we present and define “corkscrew stenosis,” a type of tracheal stenosis uniquely associated with percutaneous dilatational tracheostomy.

Methods: Patients treated at our institution for tracheal stenosis after percutaneous dilatational tracheostomy were reviewed. Demographic data including gender, age, history of presentation, lesion morphology, imaging, and management was collected and evaluated. The pathology of the stenosis and the strategies for prevention are presented.

Results: From January, 2008 through December 2011, 11 patients had tracheal stenosis after percutaneous dilatational tracheostomy. The mean age was 54 ± 17 years and 55% were male. The stenotic lesions were characterized by a corkscrew morphology at the stoma site with a mean distance of 2.3 ± 0.8 cm from the vocal cords. Images of these lesions demonstrated disruption and fracture of the proximal tracheal cartilages and displacement of the anterior tracheal wall into the tracheal lumen. The majority of our patients required tracheal resection for definitive repair.

Conclusions: We suggest that a unique form of tracheal stenosis can result from percutaneous dilatational tracheostomy. We observed corkscrew stenosis to be located proximally, associated with fractured tracheal rings, and morphologically appearing as interdigitation of these fractured rings. Recognizing corkscrew stenosis, its unique mechanism of formation, and technical means of prevention may be important in advancing the long-term safety of this procedure for critically ill patients who require prolonged ventilatory support. (J Thorac Cardiovasc Surg 2013;145:716-20)

The open tracheostomy as commonly performed today was first described by Chevalier Jackson¹ in 1909 and later popularized by his report of this procedure in 1923.² This procedure has since become the standard of care for patients in need of prolonged ventilator support. The first bedside percutaneous tracheostomy was reported by Sheldon and associates³ in 1955. Initiated by a procedure description and report of his first 24 cases in 1985, Ciaglia, Firsching, and Syniec⁴ popularized the percutaneous dilatational tracheostomy (PDT). The convenience and cost effectiveness of this procedure led to a rapid increase in its popularity, and the short-term safety of PDT has been demonstrated in multiple

settings.⁵⁻⁸ Some argue that PDT should be considered the procedure of choice for establishing a long-term airway for ventilatory support.⁸

Although its short-term safety has been widely documented, less is known about the long-term complications related to PDT.⁹ Follow-up of critically ill patients has proven difficult. For instance, a survey of practitioners found that only 12% of those who used PDT maintain long-term follow-up with their PDT patients.¹⁰ Additionally, the studies that evaluate the long-term outcomes of PDT are limited by high patient mortality rates and poor follow-up. In short, the critical evaluation of the potential long-term complications of PDT is, at best, a work in progress.

In 1994, tracheal stenosis after PDT was described in a report of 4 patients by McFarlane and colleagues¹¹ after it had been surmised that PDT would lead to a decreased frequency of tracheal stenosis because the cartilaginous rings remain intact.¹² This report was followed by a handful of case reports that have demonstrated tracheal stenosis to be a serious long-term complication of PDT.¹³⁻¹⁶ Moreover, some of these early findings of tracheal stenosis after PDT suggest that this condition is actually quite different from stenosis seen after traditional open tracheostomy. If

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Abbreviation and Acronym

PDT = percutaneous dilatational tracheostomy

this form of tracheal stenosis is in fact unique to PDT, a thorough understanding of its etiology is critical to facilitating its prevention. With a concern that PDT may potentially lead to a new type of tracheal stenosis, we reviewed our experience in treating PDT-associated tracheal stenosis. Here we define corkscrew stenosis and suggest its unique characteristics, mechanism of formation, and means of prevention.

METHODS

We performed a retrospective review of all cases of tracheal stenosis occurring after PDT at St Joseph's Hospital and Medical Center, Phoenix, Arizona, between January 2008 and December 2011. An operative case log database at our institution was used to identify patients with tracheal stenosis after PDT. All cases of either a diagnosis coded as tracheal stenosis or a procedure coded as tracheal resection, rigid bronchoscopy, or flexible bronchoscopy were reviewed. Subjects identified as having tracheal stenosis after PDT underwent a comprehensive review including their electronic medical record, paper chart, operative images, and radiology studies. Demographic data included gender, age, history of presentation, lesion morphology, and management strategies. The study was approved by our institutional review board.

RESULTS

Over a 4-year period, 14 tracheal resections, 218 bronchoscopic procedures, and 32 other airway procedures were performed in the operating room at our institution. Eleven patients were found to have tracheal stenosis associated with a prior PDT. The mean age of our patients was 54 ± 17 years old (range, 28-75 years), and 54.5% were male.

A review of the patients' history demonstrated that the most common etiology of their initial respiratory failure and need for PDT was severe sepsis (5 patients). Other causes of respiratory failure included heart failure (3 patients) and hanging injury (1 patient). Seven patients were referred from an outside institution. All patients presented decannulated. The mean time between PDT and presentation for tracheal stenosis was 13 months (range, 1.5-24 months). Data were unavailable for size of tracheostomy tube used and duration of cannulation (Table 1).

Evaluation of each lesion morphology demonstrated stenosis occurring in the proximal trachea, at or just above the stoma site. The mean distance from the vocal cords was 2.3 ± 0.8 cm (range, 0.8-3 cm). The mean length of stenosis was 1.6 ± 0.5 cm (range, 1-2.6 cm). Intraoperative images most commonly demonstrated a turning or corkscrew appearance to these lesions. This corkscrew pattern was seen to involve tracheal rings just proximal to the stoma

site that were fractured, posteriorly displaced, and interdigitated (Figure 1).

Management of these stenoses primarily involved tracheal resection (7 patients). The decision for operative management was based on the degree of symptoms and disability experienced by the patients. Each of these operative patients underwent circumferential tracheal resection and primary reconstruction with end-to-end anastomosis via the cervical approach. In all cases the stenotic trachea with stoma was resected. A new tracheostomy was placed at the time of tracheal resection in 1 case. Four patients had previously undergone failed dilatation. There were no deaths among those treated with tracheal resection. Postoperative morbidity was present in 3 patients. This included restenosis requiring further intervention in 1 patient, transient oropharyngeal dysphagia in another, and vocal cord paresis in a third patient. A minority was managed with tracheal dilatation and stent placement (3 patients) or observation (1 patient).

CONCLUSIONS

We have described a stenotic tracheal lesion in 11 patients after PDT. The pattern of this stenosis, "corkscrew stenosis," had several characteristic features. First of all, the stenotic lesion was proximal, occurring 2.3 cm from the vocal cords, either at or just above the stoma site. This proximal location has also been demonstrated by other authors. Norwood and associates,¹⁷ Walz and Schmidt,¹⁸ and Dollner and colleagues¹⁹ have separately published 3 series evaluating the safety of PDT; all found tracheal stenosis to occur exclusively at or immediately above the level of the stoma.¹⁷⁻¹⁹ Further, Koitschev and coworkers⁹ endoscopically evaluated 146 patients after tracheostomy assessing for the presence of proximal stenosis. One hundred five patients had undergone PDT and 41 had received a traditional open tracheostomy. Twenty-four percent of the PDT group were found to have greater than 50% proximal stenosis whereas only 7% of the open surgical group were affected in this way. Finally, Raghuraman and colleagues²⁰ evaluated 29 patients with tracheal stenosis requiring tracheal resection. Fifteen patients had previously undergone PDT and 14 had traditional open tracheostomy. The nature of each patient's stenotic lesion was characterized using preoperative bronchoscopic evaluation with a rigid scope and pathologic evaluation of resected surgical specimens. Proximal stenotic lesions were found in 58% of the PDT group and only 17% of the traditional surgical group. Further, stenosis after PDT was located a mean distance of 1.6 cm from the vocal chords and 3.4 cm after open tracheostomy. The location of stenosis observed in our series and the above studies appears more proximal than stenoses seen after traditional open tracheostomy.

Our experience suggests that corkscrew stenosis is associated with tracheal ring fractures. This concept is not new

TABLE 1. Patient demographics and features of corkscrew stenosis

Patient demographics and corkscrew stenosis features						
Patient no.	Age, y	Sex	History	Symptoms	Distance to cords, cm	Length, cm
1	41	F	S/P hanging	Dyspnea, stridor	1.5	1.5
2	28	M	Severe sepsis	Dyspnea	2.5	2
3	71	M	Heart failure	Stridor	2	2
4	62	F	Severe sepsis	Dyspnea, hoarseness	2.5	1
5	60	M	Heart failure	Dyspnea with phonation	2.8	1.3
6	29	M	Stroke	Dyspnea	3.5	2.6
7	43	F	Severe sepsis	Dyspnea	0.75	1.5
8	75	F	Severe sepsis	Dyspnea, cough	3	1
9	59	M	Heart failure	Dyspnea, cough	3	1.5
10	72	F	Unknown	Dyspnea	1.5	1.7
11	55	M	Severe sepsis	Dyspnea, wheeze	2.4	1.15
Mean	54 ± 17				2.3 ± 0.8	1.6 ± 0.5

S/P, Status post; F, female; M, male.

and was first introduced by Jackson¹ in 1909, who suggested that an injury to the cricoid cartilage could produce a stenotic lesion. In 2005, Ho and associates²¹ reported the first case of tracheal stenosis after a known tracheal ring fracture occurring in association with PDT. In the previously mentioned study by Raghuraman's group,²⁰ it was noted that the PDT group requiring tracheal resection for stenosis commonly had tracheal ring fractures whereas the open tracheostomy group did not. Raghuraman and associates²⁰ commented that the tracheal ring injury appeared to result in a "caving in" of the anterior tracheal wall. Finally, Dollner and coworkers¹⁹ provided important data when they performed laryngotracheoscopy to evaluate 38 patients for the presence of tracheal stenosis after PDT. In

their subgroup analysis, they found those without tracheal ring fracture had an average stenosis of 3.7% whereas those with near-midline tracheal fractures had an average stenosis of 18.8%. Our experience is concordant with the above data. Bronchoscopic imaging of our cases most consistently demonstrated tracheal ring fractures at the site of stenosis.

Our experience suggests that it is the fractures associated with severe posterior displacement that lead to an increased risk of corkscrew stenosis. Nondisplaced fractures are quite common after PDT as demonstrated by autopsy studies.^{18,22} However, severe disruption of the proximal tracheal cartilages during PDT leads to posterior displacement of the anterior tracheal wall into the tracheal lumen (Figure 2). This mechanism is quite different from open tracheostomy, where the anterior tracheal wall flap is displaced away from the tracheal lumen. We suggest that if this posterior displacement during PDT is severe enough, the

FIGURE 1. Bronchoscopic view of tracheal stenosis involving ring fracture with interdigitation of the posteriorly displaced, deformed tracheal rings.

FIGURE 2. Anterior-proximal tracheal ring fracture associated percutaneous dilatational tracheostomy. Arrow depicts the force that creates torque about the axis of the tracheostomy site and may increase the risk of these tracheal ring fractures.

broken ends of the tracheal rings have a tendency to interdigitate because the circumference of the trachea at that location has shortened. Images from our series show this interdigitation leads to the severely narrowed corkscrew formation of the tracheal lumen, especially when more than 1 ring is fractured (Figure 1). Lengthy cannulation may serve to hold the deformed rings in this unfavorable position while the tracheal ring fracture and mucosal injury incites the local inflammatory process followed by scar formation, which fixes the tracheal rings in this unfavorable position (Figure 3). Even with short-term cannulation, scar contracture may pull fractured ends of the tracheal rings into this interdigitated corkscrew position. Other patterns of tracheal stenosis after PDT and ring fracture have been described, such as Dollner's "gothic arch" pattern.¹⁹ Certainly other patterns of stenosis are possible and depend on the precise pattern of ring fracture and subsequent scar formation. However, the corkscrew pattern described here represents the pattern most commonly seen in our experience. We suspect that it corresponds with the most severe pattern of stenosis and will often require resection. Finally, our experience demonstrates corkscrew stenosis developing after use of a single-step curved dilator. Whether or not this can happen with the use of serial dilators or the Griggs technique is unknown.

We believe that strategies to avoid PDT-associated corkscrew stenosis depend on avoidance of tracheal cartilage fracture with posteriorly displaced tracheal ring segments. Table 2 contains a list of suggested techniques that may help prevent tracheal ring fracture. Optimal placement between the second and third rings is critical, because placement through a tracheal ring will certainly result in a displaced fracture. Use of bronchoscopic guidance should be considered the standard of care. Consistent proper placement has proven to be technically difficult even with bronchoscopic visualization¹⁹ and it is nearly impossible without it.^{23,24} Second, rotational torque about the axes of the tracheostomy insertion site can cause posterior displacement of the proximal rings and should be avoided (Figure 2). There is a tendency to apply torque in this

FIGURE 3. Cross-section showing anterior tracheal ring fractures, leading to corkscrew stenosis.

TABLE 2. Prevention of displaced tracheal ring fracture

- Ensure optimal placement between the second and third tracheal rings with bronchoscopic guidance.
- Avoid rotational torque about the axes of the insertion site.
- Complete perpendicular rather than oblique insertion into the trachea.
- Provide a counterforce to the anterior tracheal wall with the endotracheal tube/bronchoscope.
- Complete adequate skin incision and blunt soft tissue dissection preventing the tendency to supply excessive insertion force or torque.
- Ensure a perfect fit between the tracheostomy and obturator.
- Use tapered tracheostomies.
- Use the smallest tracheostomy that will provide satisfactory function.

manner during insertion of tight-fitting tracheostomy tubes. Adequate skin incision, soft tissue dissection, and fitting of the appropriate-sized dilator within the tracheostomy at the time of placement will help relieve excessive tightness and resistance during insertion. While inserting the tracheostomy, one should be mindful of applying force in an inferior direction along the axis of the tracheostomy/obturator complex to avoid this torque and tracheal ring injury. Third, insertion of the tracheostomy at a right, rather than oblique, angle to the trachea helps prevent ring fracture. The importance of this technique has been well described by van Heurn and coworkers²² and better allows for the superior-inferior spreading of tracheal rings rather than posterior collapse of the proximal rings under an obliquely inserted tube. Finally, during insertion of the tracheostomy tube, the bronchoscopist can provide a counterforce against the anterior wall of the trachea with the endotracheal tube/bronchoscope complex. This limits the displacement of the tracheal wall and helps prevent fracture. Although this has not been previously described, we use this technique routinely and find it very helpful in reducing tracheal collapse and the risk of ring fracture.

Our study has several limitations. This is a retrospective review of a series of cases at a single institution describing our experience. Studies with a more comprehensive design are needed to confirm whether our observations truly represent the suggested phenomenon. Retrospective studies comparing groups of open and PDT for differences in stenosis patterns would be helpful. Further, prospectively observing PDT patients with tracheal ring fractures for the development of tracheal stenosis would provide valuable information. Additionally, a center with long-term follow-up of tracheal resections could compare the nature of tracheal stenosis from the pre-PDT and post-PDT era. Finally, our suggested techniques for prevention of corkscrew stenosis have not been tested in a methodical way but are strategies developed after retrospective review of this problem. Further study is also needed to validate these recommendations.

PDT has several advantages over open tracheostomy. It has dramatically increased in popularity since its early description in 1985, and some argue that it should now be

considered the gold standard. The introduction and widespread application of all new procedures involves critically evaluating their complications and identifying means of their prevention. Corkscrew stenosis can be a serious long-term complication of PDT. We suggest that the mechanism by which this complication occurs is unique to PDT and is associated with posteriorly displaced tracheal ring fractures. In its most severe form, the fractured ends of the tracheal rings interdigitate and scar into a corkscrew-shaped pattern. We further suggest that several technical approaches such as optimal bronchoscopic guided placement, avoidance of rotational torque, perpendicular insertion, and use of an intraluminal counterforce may help prevent this complication.

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