patients from the study which resulted in an estimate of 78.6% prevalence. All radiographs were reviewed from patients treated at University of New Mexico Health Sciences Center and found evidence of pleural fluid, even if of minimal amount, in 22 of 23 (95.6%) patients during the course of their illness. In an autopsy review of HPS, thus representing the sickest of patients, all subjects had large bilateral serous pleural effusions ranging between a total of 210 to 8,420 mL. Histologically, all lungs had varying amounts of intraalveolar and septal edema, and all but one had slight to moderate interstitial infiltrates of mononuclear cells. The respiratory epithelia were intact, capillary endothelial cells were enlarged without evidence of necrosis, and no evidence of vasculitis or thrombosis was detected.

The pleural fluid characteristics have not been previously described but were thought to be exudative on the basis of capillary leak. In this communication, samples A and D were obtained within 1 day of admission. Sample D clearly was a transudate, while sample A had borderline criteria for an exudate, with an absolute LDH level of 403 IU/L (exudate criteria, two thirds the upper serum limit, 400 IU/L) and is classified a transudate. The presence of a transudate in these two samples could be explained by volume resuscitation and depressed cardiac function. A pulmonary artery catheter was placed in 1 of these subjects (patient D) which revealed a nadir cardiac index of 3.8 L/min/m². Hemodynamic data from other patients have documented very low cardiac output during the acute phase of HPS. With recovery of acute cardiopulmonary dysfunction and diuresis, the effusion may begin to take on characteristics of an exudate. Two patients (B and C) had profound cardiopulmonary dysfunction with a predicted mortality of 100% (lactate level, greater than 4 mmol/L), yet they survived because ECMO was instituted. Sample B, obtained 7 days after admission and successful treatment with ECMO, was exudative, with pleural fluid protein to serum protein ratio greater than 0.5. The initial thoracentesis done on day 7 for patient C narrowly met criteria for an exudate by the protein ratio and LDH level while on day 12 the only criterion for exudate was LDH.

Pleural fluid quantity did not appear to impair respiratory dynamics except for patient B who required insertion of bilateral chest tubes to facilitate weaning from mechanical ventilation.

In conclusion, the vast majority of patients with HPS have evidence of pleural effusion on chest radiographs. The pleural fluid characteristics appear to be transudative during the initial phase of the illness, coincident with the period of maximal cardiopulmonary dysfunction. As cardiac function normalizes during recovery, the pleural fluid characteristics may change to those of an exudate but may remain transudative. It is important to note that ECMO therapy could have influenced the pleural fluid characteristics and could have contributed to the transformation of the transudate into an exudate. On a cautionary note, it is possible that the small number of patient samples obtained may not reflect the true nature of the effusions in HPS, and clearly, as new cases occur, acquisition of more pleural fluid samples will be important to describe better the pleural fluid characteristic.

References

**Bronchoscopic Balloon Dilatation in the Combined Management of Postintubation Stenosis of the Trachea in Adults**

Marc Noppen, MD, PhD, FCCP; Marc Schlesser, MD; Marc Meyssman, MD; Jan D’Haese, MD; Rudi Peche, MD; and Walter Vincken, MD, PhD, FCCP

Bronchoscopic balloon dilatation (BBD) using angioplasty balloon catheters has been employed successfully in the treatment of tracheobronchial stenoses in children and has worked with variable success in adults with bronchial stenosis. In adults with tracheal stenosis, BBD only has been reported anecdotally. In this study, experience with BBD using a valvuloplasty balloon catheter in the combined treatment (with Nd-YAG laser photoablation and stenting) of severe benign postintubation tracheal stenoses in

*From the Respiratory Division (Drs. Noppen, Schlesser, Meyssman, and Vincken) and Anaesthesiology Department (Dr. D’Haese), Academic Hospital AZ-VUB, Brussels, Belgium; and the Respiratory Division (Dr. Peche), Hôpital Vésale, Montgoy-le-Tilleul, Belgium. Manuscript received September 24, 1996; revision accepted February 14, 1997. Reprint requests: Marc Noppen, MD, PhD, FCCP, Respiratory Division, Academic Hospital, University of Brussels (AZ-VUB), Laarbeeklaan 191, 1000 Brussels, Belgium*
three adults is delineated. BBD was particularly successful in establishing tracheal patency when laser photoablation was contraindicated or was too dangerous; BBD allowed easy insertion of tracheal stents and the “opening” of folded silicone stents. BBD is a simple, inexpensive, safe, and efficient adjunct in the combined treatment of severe postintubation rigid tracheal stenosis in selected adults.

(CHEST 1997; 112:1136-40)

Key words: airway stents; bronchoscopy; Nd-YAG laser; tracheal stenosis; valvuloplasty balloon catheter

Abbreviation: BBD=bronchoscopic balloon dilatation

Bronchoscopic balloon dilatation (BBD) has been used successfully in the treatment of congenital and acquired tracheal and bronchial stenoses in children since 19841-14 although discouraging results from dilatation of low or long tracheal strictures also have been reported.15,16 In adults, mainly bronchial (and not tracheal) stenoses have been treated with BBD: in the majority of the reports, bronchial stenoses were secondary to restenomosis after sleeve lobectomy or lung transplantation.17-25 Other causes of bronchial stenosis in adults successfully treated with BBD include bronchial artery embolization,26 granuloma formation after inhalation of a foreign body,27 bronchial cancer, and tuberculosis.28 Heretofore, there have been, as best as can be determined, only anecdotal reports on the use of BBD in the management of tracheal postintubation and neoplastic stenosis in adults. This study details experience with BBD in the combined treatment of tracheal postintubation stenosis in adult patients.

Case Reports

Three patients were treated with BBD from June to August 1996.

Case 1

A 36-year-old man had been ventilated via a tracheostomy cannula for 6 months after cardiopulmonary resuscitation for cardiac arrest secondary to a myocardial infarction.

After two sessions of Nd-YAG laser phototherapy for granulomatous lesions in the vicinity of the cannula, the latter could be removed. Six weeks later, a severe concentric cicatricial tracheal stenosis developed, which was complicated by retro-obstructive infection. Because of the uncertain and distorted tracheal anatomy distal to the stenosis (due to the long-standing tracheostomy and former laser treatments), only a limited laser resection of the stenosis was considered safe. In the same session, the residual stenosis, however, could easily be dilated using gentle BBD. A 14×40-mm Dumon silicone stent was inserted for maintenance. Later, displacement and migration necessitated reininsertion procedures on two occasions.

Case 2

A 40-year-old man had developed severe tracheal stenosis and tracheomalacia after prolonged mechanical ventilation for post-traumatic coma. After Nd-YAG laser photoablation of the concentric cicatricial tracheal stenosis, a 16×50-mm Dumon silicone stent tracheal prosthesis was inserted into the stenotic-malacic region, completely restoring airway patency. Six months later, Nd-YAG laser photoablation of a granuloma distal to the tracheal stenosis was performed. The same procedure had to be repeated twice, 18 and 21 months after stenting. At 24 months, the patient was readmitted for severe stridor and retro-obstructive pneumonia. At bronchoscopy, the stent had moved distally, and a severe combined endotracheal-trachomalacic stenosis had recurred. The stenosis was dilated with 2 BBD attempts. Thereafter, the stent could successfully be grasped with an alligator forceps and withdrawn after folding through the stenosis. Unfolding, however, was impossible with the forceps. Instead of replacing the prosthesis with a smaller sized model, the folded stent easily could be opened using BBD. Thereafter, airway patency was completely restored.

Methods

BBD is performed with the patient under general anesthesia (intravenous propofol, alfentanil hydrochloride, atracurium besylate) and after intubation with a rigid bronchoscope (Efer; La Ciotat; France; or Storz; Karl Storz GMBH; Tuttingen, Germany) with its distal end proximal to the tracheal stenosis. Ventilation and oxygenation are ensured using high-frequency jet ventilation (Acutronic; Acutronic Medical Systems; Jona, Switzerland) delivered through a side port of the bronchoscope. FIO2 varies between 0.21 and 1.0.

Dilatation of Postintubation/Post-tracheostomy Stenosis

If possible, radial “incisions” using Nd-YAG laser photoablation are made in the stenotic web. BBD, however, is also possible and successful without previous photoablation. A deflated mitral valve valvuloplasty balloon (Mansfield Scientific; Mansfield, Mass) with a maximal diameter of 15 mm and a length of 30 mm, mounted at the tip of a 9F, 1,200-mm long catheter is inserted through the stenosis (Fig 5). Preoxygenation with 100% oxygen is performed for 2 min. Thereafter, the balloon is gently inflated with saline via a three-way valve, under close balloon pressure monitoring. During this procedure, mechanical ventilation is interrupted. A balloon pressure of 2 atmospheres is produced during the first dilation attempt for 1 min. Then the balloon is deflated and withdrawn, and mechanical ventilation is resumed. If necessary, a second and further attempts are made using up to 3 atmospheres balloon pressure for 1 min.
**Figure 1.** Bronchoscopic view of recurrent severe concentric cicatricial postintubation stenosis of the trachea. The stent is invisible distal to the stenosis.

**Figure 2.** The stent is withdrawn through the stenosis but cannot be opened by forceps manipulation.

**Figure 3.** The balloon catheter is passed through the unfolded stent and inflated.

**Figure 4.** After the procedure, the tracheal lumen is restored and the stent is completely reopened.

**Opening of a Folded Dumon Stent**

The alligator forceps is passed through the rigid bronchoscope and is used to “open” the proximal end of the folded stent. The lubricated tip of the (deflated) balloon catheter then is introduced into the stent and gently pushed until the deflated balloon completely “enters” the stent. After discontinuation of mechanical ventilation, the balloon is gently inflated to 1 atmosphere. Unfolding of the stent can be monitored through the telescope.

Most often, pressures up to 1 atmosphere suffice for complete stent unfolding. This technique follows the principle of the balloon-expandable Palmaz Stent, which was originally designed for the treatment of vascular obstructions but has been used successfully in tracheal stenosis in children.7

**DISCUSSION**

In this study, experience with BBD of postintubation tracheal stenotic lesions in adults is presented. The BBD
enabled us to create tracheal patency in three patients with severe postintubation stenoses in whom Nd-YAG laser photoresection was considered too dangerous because of the presence of (dislocated and migrated) silicone stents (patients 1 and 2) or because of an uncertain tracheal anatomy (patients 2 and 3), or both. In this manner, the migrated stents easily could be retrieved using an alligator forceps through the dilated stenosis, and replacement or insertion of the stent became much easier. A second interesting feature of BBD consisted of its ability to "reopen" a folded silicone prosthesis completely in a few seconds, obviating the often difficult and sometimes unsuccessful "twisting and turning" with the forceps.

Migration of the Dumon-type tracheal stents is not uncommon, occurring in 16 to 22% of cases, because of an imperfect fit and adherence to the tracheal wall, especially in the case of short and conical stenoses as was the case in our patients. Theoretically, tracheal stent immigration can be limited or even avoided using stent fixation techniques for the Dumon stent or by using alternative stent types (eg, the bifurcated Rüsch stent, the screw-thread stent, or the Montgomery stent in case of a present tracheostomy). Percutaneous balloon dilatation catheters, originally designed for transluminal angioplasty, also have been used for the dilatation of other structures, eg, biliary strictures, ureteral strictures, and gastroenterostomy strictures. Because of their stiffness and capability of exerting and withstandinpressures of several atmospheres, there have also been used in the treatment of tracheobronchial stenoses in children. In adults, curiously, there have been very few reports on BBD of tracheal stenoses. However, gentle mechanical dilatation of the trachea using the rigid bronchoscope (usually following previous laser photoresection) has been performed successfully in the past without ventilatory or oxygenation problems, and in this study there were no problems using BBD for tracheal stenosis.

In this study, a contrast medium was not used to inflate the balloon, and insufflation procedures were performed without fluoroscopic control because balloon positioning easily could be controlled visually with the bronchoscope and there was no risk for inappropriate placement of the distal catheter tip in a small (sub)segmental bronchus, as is the case for bronchial BBD. However, should the technique given herein be used for distal tracheal lesions, fluoroscopic control seems advisable for safety reasons.

Other potential complications of this technique may be bleeding, rupture (partial or complete) of tracheal rings with resulting pneumomediastinum, pneumothorax and mediastinitis, and balloon rupture. No preoperative or postoperative procedure-related complications were encountered in this study.

BBD dilates the stenotic region, probably by stretching and expanding the tracheal wall, perhaps up to creating a longitudinal posterior tracheal wall split, somewhat comparable to the mechanism of balloon angioplasty. Although this method, therefore, may be considered appropriate for the treatment of cicatrical annular strictures, its long-term effects are unknown. In children, BBD of congenital or acquired tracheobronchial lesions has yielded persistent airway patency for periods varying from 2 months to 3 years, whereas in adults mechanical dilatation of bronchial stenosis using mechanical bougie dilatation may be successful for up to 9 years. However, if dilatation is performed for stenoses secondary to "active" disorders (eg, sarcoidosis, bronchial posttransplant anastomotic stenosis), subsequent procedures (eg, monthly) usually are necessary to maintain airway patency, or stents should be inserted in order to maintain airway patency.

The systematic use of corticosteroids or antibiotics as suggested by some authors probably is not necessary, although no definitive data are available. In this series, antibiotics were given to patients 2 and 3 but only because there was a documented retro-obstructive infection.

CONCLUSION
A variety of endoscopic techniques are available for the treatment of rigid tracheal stenosis in adults in whom surgical resection and end-to-end anastomosis are contraindicated, not feasible, or refused by the patient. Of these, Nd-YAG laser photoresection and stenting probably are used most often. BBD may represent an inexpensive, simple, safe, and efficient adjunct to laser and stent therapy in the following situations: distally migrated silicone stents with recurrent proximal tracheal stenosis (when laser therapy is too dangerous); "pre-stenting" dilatation; uncertain tracheal anatomy; and stents that are difficult or impossible to "unfold" by forceps manipulation.

ACKNOWLEDGMENTS: The authors would like to thank Carine Michiels, Brigitte Terrijn, and Bea Van Elewijk for their assistance during the endoscopic procedures and Hilde De Smelt for secretarial assistance.

REFERENCES

CHEST / 112 / 4 / OCTOBER, 1997 1139
41 Iles PB. Multiple bronchial stenoses: treatment by mechanical dilatation. Thorax 1981; 36:784-86

Bilateral Sequential Lung Transplantation for Pulmonary Alveolar Microlithiasis*

Jeffrey D. Edelman, MD; Joseph Bacaria, MD; Larry R. Kaiser, MD, FCCP; Leslie A. Litzky, MD; Harold I. Paley, MD, FCCP; and Robert M. Koloff, MD, FCCP

Pulmonary alveolar microlithiasis (PAM) is characterized by deposition of calcium phosphate within the alveolar spaces. There is currently no effective medical therapy and affected individuals may