

# American Thoracic Society

## Care of the Child with a Chronic Tracheostomy

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### CONTENTS

Tracheostomy Tube Selection  
Tracheostomy Tube Care  
Suctioning  
Humidification  
Speech Development  
Caregiver Education  
Medications  
Monitoring  
Decannulation Procedures  
Complications  
Areas of Suggested Research

Children with a chronic tracheostomy constitute an important subgroup of children who are at risk for potentially devastating airway compromise. There have been no standards published for their care and disappointingly little research. The Pediatric Assembly of the American Thoracic Society funded a working group with input from the disciplines of pediatric pulmonology, pediatric surgery, pediatric otolaryngology, respiratory therapy, speech pathology, and nursing to develop a consensus statement regarding their care. This statement has been reviewed and revised by the committee members, who concur with its recommendations. Many of the recommendations are by consensus in the absence of scientific data, and suggestions are made for areas of research.

### TRACHEOSTOMY TUBE SELECTION

Children require a tracheostomy for many different reasons. The size of the tracheostomy in relation to the airway, in some ways, is determined by the underlying problem. A child who has a tracheostomy to help prevent chronic aspiration might require a tracheostomy tube that is relatively large in relation to the diameter of the airway. A child who requires nocturnal ventilation but who plugs the tracheostomy during the day might do well with a much smaller diameter tracheostomy. In considering the diameter of a tracheostomy tube, the considerations should include tracheal size and shape, indications for the tracheostomy, lung mechanics, upper airway resistance, and the needs of the child for speech, ventilation, and airway clearance.

Several other factors should be considered when choosing a tracheostomy tube. These include the length, curvature, flexibility, and composition of the tube. Other decisions include the choice of a cuffed or a noncuffed tracheostomy tube, a fenestrated or a nonfenestrated tracheostomy tube, a tube with a straight or angled neck flange, and a standard tracheostomy tube or a specially manufactured tube. There are no research data available documenting optimal choices in tracheostomy tube selection. However, a tracheostomy tube whose distal position is not colinear with the trachea may cause complica-

tions such as esophageal obstruction (1) or partial occlusion of the tracheostomy tube tip by the tracheal wall (2). Other possible complications may include tracheal wall erosion, tracheo-innominate artery fistula, tracheoesophageal fistula, and stomal breakdown.

### Tracheostomy Tube Size and Curvature

*Background.* Tracheostomy tubes must fit the airway and the functional needs of the patient. They must have the appropriate shape and length to be secure in the airway and to fit without undue pressure on any portion of the neck or trachea.

### Consensus

- a. In most cases the selected tracheostomy tube should extend at least 2 cm beyond the stoma, and no closer than 1–2 cm to the carina.
- b. The diameter of the tracheostomy tube should be selected to avoid damage to the tracheal wall, to minimize work of breathing, and, when possible, to promote translaryngeal airflow. Some patients breathe well with a tracheostomy tube that is small in relationship to the diameter of the trachea. These patients often breathe both around and through the tracheostomy tube. Other patients require a tracheostomy tube with a much closer fit to the inner diameter of the trachea. These patients breathe only through the tracheostomy tube and will require a fenestrated tube for translaryngeal airflow.
- c. Curvature should be such that the distal portion of the *in situ* tracheostomy tube should be concentric and colinear with the trachea. Assessment of appropriate curvature requires neck/chest radiographs or flexible bronchoscopy.
- d. All tracheostomy tubes should have a 15-mm “universal” adapter to allow bag ventilation in an emergency; metal tracheostomy tubes are commonly made without this capacity.

### Tracheostomy Tube Composition

*Background.* The flexibility of a tracheostomy tube should be considered. Silicone tubes are quite flexible. Polyvinyl chloride tubes may be flexible or rigid. Metal tracheostomy tubes are rigid.

### Consensus

- a. Metal tubes are used in special circumstances such as with the Aboulker (3) stent after laryngeal reconstruction. Most metal tubes have an inner cannula that reduces the internal diameter of the tube. In small children this can lead to excessively high airway resistance.
- b. Tubes with an inner cannula may be useful in some patients with thick copious secretions, which rapidly build up on the walls of the tube. Cleaning the inner cannula avoids frequent tracheostomy changes.
- c. In patients for whom a standard polyvinyl chloride tube does not provide an optimal “fit,” a silicone tube will conform to the airway shape and may be a better option.

### Cuffed Tracheostomy Tubes

**Background.** Cuffed tubes may be used to minimize the risk of aspiration or for patients requiring mechanical ventilation. Patients requiring nocturnal ventilation may benefit from a cuffed tracheostomy tube. The cuff is inflated at night for ventilation and deflated during the day to facilitate speech. When a cuffed tracheostomy tube is employed, the distinction must be made between a high-volume/low-pressure cuff and a low-volume/high-pressure cuff. When a low-pressure/high-volume cuff is employed, pressure in the cuff is kept as low as possible. Generally, cuff pressures below 20 cm H<sub>2</sub>O are well tolerated. Perfusion of the airway epithelium is decreased when pressures above 20 cm H<sub>2</sub>O are employed (4). When the patient receives positive pressure mechanical ventilation, the minimal leak technique (5) or minimal occlusion technique (5) may be used. Cuff pressure and volume should still be monitored. When a low-volume/high-pressure cuff is employed, the cuff pressure will be much higher than the capillary perfusion pressure of the airway epithelium. In such cases, the maximum diameter of the tracheostomy tube with cuff inflated must be kept smaller than the minimum diameter of the trachea. These cuffs may place dangerous levels of pressure on the airway epithelium if not properly adjusted. Another potential complication of cuffed tubes is acquired tracheomegaly. Endoscopic or radiologic imaging may be needed to properly adjust the cuffs on these tubes. Different tubes may require either air or liquid instillation for cuff inflation. Manufacturer recommendations should be consulted.

#### Consensus

- a. The indications for cuffed tracheostomy tubes in pediatrics are limited.
- b. Uncuffed tracheostomy tubes are preferred over cuffed tracheostomy tubes in most circumstances. Cuffed tracheostomy tubes may be used in patients requiring ventilation with high pressures, patients requiring only nocturnal ventilation (i.e., patients who will speak and breathe around the tracheostomy tube during the day with the cuff deflated and are ventilated at night with the cuff inflated), and patients with chronic translaryngeal aspiration.

Areas where consensus was not reached:

The exact role for cuffed tracheostomy tubes in children was not defined.

### Fenestrated or Nonfenestrated Tracheostomy Tubes

**Background.** Experience indicates that fenestrated tracheostomy tubes aid speech by enhancing translaryngeal air flow. Fenestrated tubes may also enhance translaryngeal secretion clearance. The use of fenestrated pediatric tracheostomy tubes is the exception rather than the rule. The committee noted the European experience with multiple small fenestrations along the sides of the tracheostomy tube (6). Although the committee found no scientific data, there is a strong feeling from some experts that fenestrated tubes promote the development of granulation tissue in the area of the fenestration. In patients using speaking valves, fenestrations are especially important if the tracheostomy tube is large in relation to the airway. They also allow for secretion clearance from the tube while the speaking valve is in use.

#### Consensus

Some translaryngeal airflow is desirable either by using a tracheostomy tube that is small in relation to airway diameter, or

a fenestrated tracheostomy tube. The use of a speaking valve promotes translaryngeal air flow.

### Specially Manufactured Tracheostomy Tubes

**Background.** The vast majority of patients can achieve a satisfactorily fitting tracheostomy tube by using an off-the-shelf tube. At least one manufacturer offers a flexible silicone tracheostomy tube with an adjustable flange allowing the length of the inserted tracheostomy tube to be adjusted as needed. Specially manufactured tubes are necessary for a small minority of patients.

#### Physician Modification of Tracheostomy Tubes

Some practitioners modify tracheostomy tubes to temporarily serve a patient with an unusual airway. These modifications involve cutting a tracheostomy tube and smoothing the cut edges. It is difficult to achieve optimal smoothing and polishing of these cut edges. These modifications void the manufacturer warranty.

#### Consensus

Off-the-shelf tracheostomy tubes fit the majority of patients. Tracheostomy tubes modified by the physician should be used only in urgent situations until a specially ordered and manufactured tracheostomy tube is available from a manufacturer.

The committee is in agreement with the adoption of International Standards Organization (ISO) standards for tracheostomy tube sizing.

## TRACHEOSTOMY TUBE CARE

### Changing Tracheostomy Tubes

**Background.** The frequency of tracheostomy tube changes varies widely. Recommended tube change frequency ranges from daily to monthly (7, 8). No objective data are available to support particular practices. The advantages of frequent tube changes include keeping caregivers comfortable and well practiced in tube changing, the possibility of decreasing airway infection and/or airway granulomas, and the possibility of reducing the incidence of tube occlusion by inspissated secretions. The disadvantages of frequent tube changes include possible stretching of the tracheostomy stoma when cuffed tracheostomy tubes are employed, and patient discomfort.

#### Consensus

There is no consensus regarding the frequency of tracheostomy tube changes. The most common frequency of tracheostomy tube changes is weekly, according to those polled.

### Duration of Use of Individual Tracheostomy Tubes

**Background.** Flexible polyvinyl chloride (PVC) tracheostomy tubes are manufactured with a plasticizer that makes the PVC flexible. With use, the tracheostomy tube becomes progressively more rigid and may develop splits or cracks.

Clinical experience suggests that flexible PVC tubes may be used in a patient for 3 to 4 mo before they stiffen. Since most patients rotate the use of several individual tracheostomy tubes, an individual tracheostomy tube may be in intermittent use for 6 mo to 1 yr before stiffening. Silicone tracheostomy tubes do not stiffen after repeated use or after cleaning and disinfection. These tubes should be inspected before each use because cracks or tears may occasionally develop. Metal tracheostomy tubes may be reused indefinitely. Metal must also be inspected before use owing to occasional cracking of the soldered joint.

### Consensus

All tracheostomy tubes should be inspected before each use. Damaged tubes or flexible tubes that are becoming stiff should be discarded and replaced with new tubes.

### Cuff Deflation

*Background.* At some centers, tracheostomy tube cuffs are deflated on a regular schedule. Two rationales have been discussed to support this practice. First, deflation allows perfusion of the tracheal mucosa in the area of the cuff. However, even if the cuff is deflated on a regular schedule, the tracheal mucosa will be exposed to the cuff pressure the majority of the time. The committee was unable to find any data to support periodic cuff deflation.

The other rationale is to allow secretions to drain from around and above the tracheostomy cuff and be suctioned from the airway. There are no research data to support this contention.

### Consensus

No consensus exists on this issue. Given the absence of data regarding cuff deflation, this area merits further study, although the infrequent use of cuffed tubes may preclude meaningful research.

### Tracheostomy Ties

*Background.* At least three materials are used for tracheostomy ties: twill tape, specially manufactured Velcro ties, and stainless steel beaded metal chain. The committee found no data indicating the superiority of a particular type of tracheostomy tie. Many patients require several tracheostomy tie changes each day because the ties become soiled or wet. The potential problem with twill tape is unraveling of the ends of ties or accidental unraveling of the knots used to secure the twill tape. Twill tape may trap moisture and irritate the skin of the neck.

Velcro ties degrade over time, particularly when washed in hot water. One-person tie changes are easier with Velcro ties than with other tie materials. They are wider than many other ties and therefore have less tendency to abrade the skin than do narrower ties, such as twill tape. They are convenient and easily adjusted. There is concern that small children may pull the Velcro ties apart, leading to accidental decannulation. The authors are aware of one death from this mechanism.

Stainless steel beaded chain has the advantages of not trapping moisture and of being very durable. The frequency of tie changes may be less when using beaded chain ties. Beaded chains will also maintain a consistent tension; the tension will not vary depending on the caregiver's judgment. This can be an advantage when multiple caregivers are involved in changing or adjusting tracheostomy ties. It has the disadvantage of being threaded across the anterior neck between the flanges of the tracheostomy tube. This may be awkward or impossible with certain tracheostomy tubes.

The optimal tension of tracheostomy ties is not well defined. A common "rule of thumb" is "tight enough to slip one finger beneath the tie." Ties must be tight enough to secure the tube and loose enough to avoid skin breakdown and vascular obstruction. Tracheostomy tube ties should be kept clean and dry. The frequency of tie changes varies considerably from patient to patient. No objective data are available on this subject.

### Consensus

The most important aspect of choosing a tracheostomy tie is not the material from which the tie is manufactured but how well the tie is secured.

### Areas where consensus was not reached:

There is no consensus regarding the routine frequency of tracheostomy tie changes.

### SUCTIONING

Maintaining and ensuring a patent airway by suctioning is a vital component of management for a child with a tracheostomy. Techniques of suctioning are designed to efficiently clear the airway of mucus while avoiding the potential hazards of suctioning. The techniques described in nursing and respiratory care literature typically give recommendations for suctioning that assume the patient is critically ill and has an artificial airway (9–14). Those recommendations are not specific to a child with a chronic tracheostomy. Therefore, issues related to the suctioning procedure were reviewed and considered for appropriateness specific to a child with a tracheostomy. These recommendations would include care for a child at home, school, and in other community settings as well as hospital-based care.

The consensus recommendations that follow are made to provide the most effective and least traumatic suctioning to a child with a tracheostomy. They are distinctly different in some areas from traditional suctioning methods and should be considered in their entirety, since the recommendations are interrelated. These recommendations are not to be applied when suctioning a child with an orotracheal or nasotracheal tube.

#### Clean versus Sterile Technique

*Background.* "Sterile technique" is defined as the use of a sterile catheter and sterile gloves for each suctioning procedure. "Clean technique" is defined as the use of a clean catheter and nonsterile, disposable gloves or freshly washed, clean hands for the procedure. Care is taken not to allow the portion of the catheter that will be inserted in the tracheostomy tube to contact any unclean surface. Sterile technique has been the typical method of suctioning in the hospital setting (9, 12), although this practice is changing toward a "modified clean technique" (nonsterile gloves and sterile catheters). Clean technique is the usual method for suctioning in the home setting (15–17).

A typical cleaning procedure for suction catheters might include four steps: (1) washing and flushing the used catheters with hot, soapy water, (2) disinfecting the catheters by soaking them in a vinegar-and-water solution or a commercial disinfectant, (3) rinsing the catheters inside and out with clean water, and (4) air drying. Minimal research is available in this area. Secretions go through the interior of the catheter in one direction only; therefore, the cleanliness of the outside of the catheter is more important than the cleanliness of the internal surface of the catheter. However, dried secretions on the internal surface of the catheter will interfere with the ability of the catheter to suction optimally.

One study describing a home cleaning technique similar to the above demonstrated that 98% of the catheters had sterile exteriors and 91% had sterile interiors after cleaning (18). These catheters were then stored for 20 d and recultured and showed no new bacterial growth. The catheters tolerated repeated cleaning cycles without any change in integrity or appearance, except for a mild cloudiness of the plastic.

### Consensus

- Clean technique is recommended for home care. All caregivers should thoroughly wash their hands before and after each suctioning procedure. Alcohol or disinfectant foam is an acceptable substitute when soap and

water are unavailable for handwashing. Nonsterile, disposable gloves should be worn for the protection of any caregiver that is not a family member or by anyone who is concerned about infection.

- b. After suctioning is complete, the catheter is flushed with tap water until secretions are cleared from the lumen; the outside of the catheter is then wiped with alcohol and allowed to air dry. A hydrogen peroxide flush is useful when particularly adherent secretions are present. The catheter is then stored in a clean, dry area.
- c. Individual catheters can be used as long as the catheter remains intact and allows inspection of removed secretions.
- d. There are a number of methods available for more thorough cleaning including commercial products (Control III; Maril Products, Tustin, CA), alcohol, and a vinegar-and-water soak. There are no data to suggest the frequency of "more thorough" cleaning or that one method is better than another. Methods that do not unnecessarily burden an already busy family should be considered.

#### Suctioning Depth

*Background.* "Shallow suctioning" describes the insertion of a catheter just into the hub of the tracheostomy tube to remove secretions the child has coughed to the opening of the tracheostomy tube. The "premeasured technique" involves the use of a catheter with side holes close to the distal end (0.5 cm or less) of the catheter tube; the catheter is inserted to a premeasured depth, with the most distal side holes just exiting the tip of the tracheostomy tube. "Deep suctioning" describes the insertion of the catheter until resistance is met, withdrawing the catheter slightly before suction is applied.

Animal model studies clearly demonstrate denuded epithelium and inflammation where deep suctioning is routinely performed (19, 20). Abandoning the routine use of deep suctioning has been advocated in the literature for more than a decade, yet practice patterns continue to describe the frequent or exclusive use of deep suctioning by the majority of nurses (21). Injury to the airway can be minimized by using the premeasured technique.

Exact depth of insertion in the premeasured technique is critical to avoid epithelial damage (if inserted too deeply) or inadequate suctioning of the tip of the tracheostomy tube (if not inserted deeply enough). A tracheostomy tube, the same size as the one in the child, may be used to measure the exact depth to which the catheter should be inserted. The use of premarked catheters is also helpful in assuring accurate insertion depth. In children with standard fenestrated tracheostomy tubes, suction catheters may accidentally go through the fenestration. If this happens repeatedly, granulation tissue may develop at this site.

#### Consensus

- a. The premeasured technique is recommended for all routine suctioning.
- b. The technique should also include twirling or rotating the catheter between the fingers and thumb, not stirring the catheter with the entire hand. Twirling the catheter reduces friction, so that the catheter is more easily inserted, and moves the side holes of the catheter in a helix, thereby suctioning secretions off all areas of the tracheostomy tube wall.
- c. The use of premarked catheters is strongly recommended to ensure insertion to the proper depth.
- d. Special circumstances may necessitate the occasional use of deep suctioning, but this increases the risk of epithelial damage.

#### Frequency of Suctioning

*Background.* Routine suctioning is performed according to a set schedule, for example, every 2 h. "Suctioning as needed," or p.r.n., is based on assessment of the patient. Suctioning as needed is most frequently recommended. The frequency of suctioning will vary on the basis of individual characteristics including age, muscular and neurological status, activity level, ability to generate an effective cough, viscosity and quantity of mucus, and maturity of the stoma. In addition to removing secretions, suctioning allows the caregiver to assess tube patency. This is important because tubes can become obstructed without clinical symptoms (22).

#### Consensus

- a. Suctioning should be done on the basis of clinical assessment.
- b. In children with no evidence of secretions, a minimum of suctioning, at morning and bedtime, to check for patency of the tube is recommended.

#### Bag Ventilation

*Background.* Studies that evaluate the need for hyperoxygenation, hyperinflation, or hyperventilation during suctioning typically have been done in critical care settings with adult patients. Recommendations vary and are primarily adult focused. One Israeli study evaluated pediatric intensive care unit patients with a variety of pre- or postsuctioning treatments and found no clinically significant desaturations in the small group of patients with adequate saturations who were not given any pre- or posttreatment with hyperoxygenation, hyperinflation, or hyperventilation (23). One other study in seven children with tracheostomies and bronchopulmonary dysplasia compared oxygen saturations when using hyperinflation alone or in combination with hyperoxygenation and/or hyperventilation after chest physiotherapy. Chest physiotherapy affected saturations more than suctioning although this was not clinically significant. No technique was found superior to another (24).

Stable children with a tracheostomy and no additional respiratory support such as a ventilator, continuous positive airway pressure, or high levels of supplemental oxygen typically do not receive hyperoxygenation, hyperinflation, or hyperventilation before suctioning. The primary concern in the administration of an artificial breath before suctioning is that secretions may be forced down the trachea and the more distal airways. The use of postsuctioning breaths varies. Patients who are prone to atelectasis may need bag hyperinflation after the initial "cleaning" passes of the suction catheter. Children receiving a high level of support should be monitored carefully to evaluate their stability and need for additional support during the suctioning procedure.

#### Consensus

In patients with secretions, an initial pass of the catheter should be made first to quickly clear the tube of any visible or audible secretions before any hyperinflation or hyperoxygenation breaths are delivered. To deliver a manual breath when secretions are bubbling in the tube only serves to force these secretions into the more distal parts of the airway. Patients receiving supplemental oxygen should be evaluated for the need of hyperoxygenation when delivering artificial breaths. The patient's need for postsuctioning oxygenation or bag ventilation is best determined in the hospital before discharge. End tidal CO<sub>2</sub> measurement and oxygen saturations can guide decision making.

### Saline Instillation

**Background.** Normal saline instillation (NSI) has been considered useful to help stimulate a cough, loosen or thin secretions, lubricate the catheter, or serve as a vehicle for mucus to be removed from the airway. However, the routine use of NSI may be associated with undesirable outcomes such as a decrease in oxygen saturation, an inability to mix with (and therefore thin) mucus, and contamination of the lower airways with unsterile saline (25, 26). Studies do not demonstrate the efficacy of normal saline in thinning mucus (26). Proper attention to maintenance of adequate humidification will be more successful in maintaining thin mucus than NSI.

#### Consensus

The routine instillation of normal saline is not recommended.

### Suction Catheter Size

**Background.** The literature typically recommends use of a suction catheter size that is one-half the internal diameter of the tracheostomy tube (16, 27). This allows airflow around the catheter to avoid atelectasis during lengthy suctioning. Another consideration in choosing a catheter is the ability to remove secretions adequately and to detect partially obstructed tubes via tactile feedback. A larger, firmer catheter can be inserted easily and can quickly remove secretions. This is important because lengthy suctioning may result in atelectasis.

#### Consensus

The largest size catheter that will fit inside the tracheostomy tube is recommended, because a large-bore tube will remove secretions more efficiently than the previously recommended smaller size tube. Atelectasis is not as likely with the rapid, premeasured technique.

### Suction Pressure

**Background.** Concern about excessive vacuum pressure in deep suctioning, during which the airway epithelium has more exposure to the suction catheter, has led to recommendations to limit the pressure applied during suctioning (10, 16). Pressures of 80 to 100 mm Hg are typically used for pediatric patients. The vacuum delivered to the tip of the suction catheter is variable and based on multiple factors such as the viscosity of secretions, the length and diameter of tubing, and the size of the collection bottle. More important is the ability of the machine to generate adequate vacuum to efficiently suction the mucus in a few seconds. Secretions may thicken at times and increased pressure may be necessary. In children with particularly thick secretions, a stationary suction machine that can generate a greater vacuum may be beneficial in addition to the child's portable suction machine for home use.

#### Consensus

- Suction should be applied both while inserting and removing the catheter. The suction should be adequate to efficiently remove secretions with a rapid pass of the catheter.
- Before discharge, the home suction machine should be used to ensure that it is adequate to clear the patient's secretions.

### Duration of Suctioning

**Background.** The literature typically suggests limiting deep suctioning to 15 s or less (9–12) and the premeasured technique to 5 s or less (13, 16). With adequate and continuous suction pressure, the length of time required to perform the

premeasured technique should be on the order of a few seconds at most.

#### Consensus

A rapid technique that is completed in less than 5 s is recommended. This is vital when using a large suction catheter, relative to the tracheostomy tube size, to prevent atelectasis.

## HUMIDIFICATION

### Background

The upper airway (i.e., nose, oropharynx, and trachea) functions to filter, heat, and humidify inspired gas. In part it acts as a heat and moisture exchanger. During inspiration, air gains heat and moisture from the tissues of the respiratory tract, creating a mucosal temperature gradient extending from the nose (near room temperature) to a point within the lungs (called the isothermic saturation point) where the temperature is equal to core body temperature. During expiration, gas saturated with water at body temperature flows back along this temperature gradient, giving up both heat and water through condensation.

When the upper airway is bypassed, inspired air may have a significant humidity deficit that can lead to pathologic changes (28). These changes include loss of ciliary action, damage to mucous glands, disorganization of airway epithelium and basement membranes, cellular desquamation, and thickening of mucous secretions (28). The ultimate consequences include deterioration of pulmonary function and an increased risk of infection. To prevent these problems an attempt should be made to match the inspired gas conditions to the normal conditions at the point of entry into the respiratory system. Thus, gas delivered through a tracheostomy tube needs to be heated and humidified. The American Association for Respiratory Care Clinical Practice Guidelines for humidification during mechanical ventilation suggest that inspired gas contain a minimum of 30 mg of H<sub>2</sub>O per liter at 30° C (29).

There are three approaches to adding heat and humidity to inspired gas. The most efficient is the heated “pass-over” or “bubble-through” humidifier. A source of gas flow is directed through a heated water bath designed to have a large water surface-to-air ratio. If delivery tubes with heated wires are used, gas temperatures can be controlled at or even above body temperature with 100% relative humidity. This technology is most often used during mechanical ventilation in intensive care units. If the delivery tubing is not heated, much water is lost through condensation and the delivered temperature is difficult to control when room air temperature fluctuates.

Another common device is the large-volume jet nebulizer. With this device, a high-pressure gas flow is directed through a jet orifice, which creates a spray of small water droplets. Unheated nebulizers are commonly used to deliver oxygen to spontaneously breathing patients. Heaters are available, but they are usually not efficient and it is difficult to control the inspired gas temperature.

The third type of device is the passive humidifier, or “artificial nose.” These devices require no pneumatic or electrical power. They collect heat and moisture from the patient's exhaled gas and deliver some of it during inspiration. Speaking valves permit inspiration of room air through the valve but force expiratory gas to travel out through the upper airway. Passive humidifiers will not work with speaking valves because no heat or moisture is captured by the humidifier for the next inspiration. Passive humidifiers impose an added resistance to breathing as well as extra dead space. Dead space ranges from 19 to 94 ml, and resistance from 0.7 to 3.5

(cm H<sub>2</sub>O · s)/L. Neonatal- and pediatric-sized passive humidifiers are available.

There are four types of passive humidifiers: heat and moisture exchangers (HMEs), heat and moisture exchange filters (HMEFs), hygroscopic condenser humidifiers (HCHs), and hygroscopic condenser humidifier filters (HCHF). The HME is the simplest of the devices and consists of an aluminum insert with a fibrous element. The HMEF was originally marketed as a filter, but its hydrophobic, fibrous insert is a fairly efficient heat exchanger. The HCH has an insert treated with hygroscopic chemicals such as lithium chloride or calcium chloride that increase the efficiency of heat and moisture exchange. One study has shown that lithium can be absorbed into the body in toxic amounts. This may present a greater risk to small children (30). The HCHF adds a bacterial filter between the insert and the source of inspired gas. A study of 21 adult passive humidifiers showed that as a group, the moisture output ranged from 19.6 to 33.2 mg/L (31). As a group, HCHFs add more airway moisture than do HCHs and HMEFs.

There are three main issues relating to conditioning inspired gas for tracheostomy patients: the first concerns whether any supplemental heat and humidity are necessary. Although environmental conditions are a factor (breathing air on a cold winter day versus a hot summer day), even in warmer climates children can be exposed to room air conditioning leading to a significant humidity deficit. The scant data that exist in the literature suggest that use of passive humidifiers in adults with a chronic tracheostomy improves secretion viscosity, lung function, and sputum production compared with no humidification (32).

A second issue concerns the physiologic target values for heat and humidity. In the absence of relevant outcome data, physiologic data describing normal conditions in the upper air-

way may be used. These would suggest that the target for inspired gas temperature be 32° to 34° C and the target for inspired humidity be 36 to 40 mg/L (33).

The last issue concerns which technology is most appropriate to achieve the desired physiologic targets. There are no scientific data to guide the selection. An analysis of the relevant factors of efficacy, safety, cost, availability, and convenience leads to a crude ranking of the currently available technologies on the basis of these factors (Table 1). The complexity of technology decisions can be appreciated from the fact that Table 1 attempts to rank three different devices on the basis of four factors. The decision becomes even more difficult when the relative weights of the factors are included. For example, while efficacy and safety probably should be consistently weighted heavily, the relative weights of cost and convenience can depend on the particular application. Two broad categories of application are for active, traveling children versus inactive or sleeping children. Convenience may outweigh cost in some cases. For example, an HCH may be the most desirable device for an active child. During sleep the reduced cost and potentially better humidification provided by a nebulizer may outweigh the inconvenience of tubing and a gas flow generator. In addition, cost and equipment choice are affected by the duration of the tracheostomy. A tracheostomy of anticipated short duration would favor disposable equipment while an anticipated long duration might favor the depreciation of higher initial capital costs. In the final analysis, these factors must be balanced and applied to each situation by an informed caregiver.

Consensus

- a. From a theoretical point of view, it is desirable to heat and humidify inspired gas to match the normal physio-

TABLE 1  
FACTORS AFFECTING THE CHOICE OF APPROPRIATE HUMIDITY THERAPY  
FOR PATIENTS WITH CHRONIC TRACHEOSTOMIES

|             | Heated Humidifier   | Nebulizer  | HME-HCH   |
|-------------|---|--|---|
| Efficacy    | Good <ul style="list-style-type: none"> <li>• Efficient</li> <li>• Controllable temperature at high humidity levels</li> </ul>  | Fair <ul style="list-style-type: none"> <li>• May be too cool (heaters not very practical)</li> <li>• May deliver too much water</li> </ul>  | Fair <ul style="list-style-type: none"> <li>• Not appropriate for thick, copious secretions</li> <li>• Some brands may provide marginal humidity</li> <li>• Cannot be used with speaking valves</li> </ul>      |
| Safety      | Fair <ul style="list-style-type: none"> <li>• May cause burns</li> <li>• Electrical hazard</li> <li>• Inadvertent lavage from condensation</li> </ul>   | Fair <ul style="list-style-type: none"> <li>• Water droplets potential cause of bronchospasm</li> <li>• May deliver too much water</li> </ul>  | Fair <ul style="list-style-type: none"> <li>• No external power hazard</li> <li>• No condensation problem</li> <li>• May occlude with secretions</li> <li>• May be too much resistance or dead space</li> </ul> |
| Cost        | \$950/mo <ul style="list-style-type: none"> <li>• Heater with servo and alarm</li> <li>• Disposable water reservoir</li> <li>• Disposable tubing</li> <li>• Water at 3 L/d</li> <li>• Air compressor at 50 lb/in<sup>2</sup></li> <li>• IV pole to mount heater</li> <li>• Cleaning solution</li> </ul> | \$150/mo <ul style="list-style-type: none"> <li>• Nebulizer reservoirs (4/mo)</li> <li>• Tubing</li> <li>• Distilled water (2 gal/d)</li> <li>• Trach mask</li> <li>• Air compressor at 50 lb/in<sup>2</sup></li> <li>• Cleaning solution</li> </ul> | \$150/mo <ul style="list-style-type: none"> <li>• 1/d</li> </ul>  |
| Convenience | Poor <ul style="list-style-type: none"> <li>• Complex (with heated wire)</li> <li>• Condensation (without heated wire)</li> <li>• Water refill may last &gt; 8 h</li> </ul>   | Fair <ul style="list-style-type: none"> <li>• Simple</li> <li>• Water refill lasts &lt; 8 h</li> </ul>   | Good <ul style="list-style-type: none"> <li>• Simple</li> <li>• No need for additional equipment (e.g., compressor water)</li> </ul>  |

Definition of abbreviations: HCH = hygroscopic condenser humidifier; HME = heat and moisture exchange.

logic conditions at the level of the carina. These conditions are assumed to be 32 to 34° C, approximately 100% relative humidity, and absolute humidity of 33 to 37 mg of H<sub>2</sub>O/L.

- b. Factors such as efficacy, safety, cost, convenience, and the child's respiratory status should be considered for each individual application. An ideal device for every application is not currently available.

## SPEECH DEVELOPMENT

Communication and feeding are the most important aspects of care for the speech pathologist treating the child with a tracheostomy. The goals are to facilitate vocal communication and swallowing. These goals are dependent on medical status, patency of the airway, cognitive status, pulmonary status, size and type of tracheostomy, and type of mechanical ventilation being used. All patients with a tracheostomy should be referred to the speech department for services regardless of diagnosis, age, or expected length of time the patient is to have the tracheostomy. When possible, the speech pathologist should be contacted before to the tracheostomy surgery and a consultation with the child's family should be arranged.

### Communication

**Background.** There are many options for communication for children with tracheostomies. Those with severe medical complications who are not candidates for speaking valves can use sign language, augmentative communication devices, manual language boards/books, or an electrolarynx. Each of these is useful but is less desirable than normal speech. In order for any patient with a tracheostomy to speak clearly enough to be understood, the tracheal cannula must not exceed two-thirds the lumen of the anatomical trachea or must be fenestrated. This allows for exhaled air to leak around or through the cannula and up through the normal airway. Without occlusion of the tracheostomy tube most air will escape out the tube and speech will sound very breathy and be difficult to coordinate with respiration.

While finger or chin occlusion of the tracheostomy tube is possible, a more effective mode of occlusion is the use of a one-way speaking valve. The most widely used one-way speaking valves are the Passy-Muir (Passy & Passy, Inc., Irving, CA), Shiley speaking valve (Shiley Inc., Irving, CA), and the Montgomery valve (Boston Medical Products, Westboro, MA). Candidates for the use of speaking valves should be carefully chosen.

Criteria for selection are as follows:

- Tracheostomy tube size should not exceed two-thirds of the tracheal lumen (unless a fenestrated tube is used)
- Medical stability
- Ability to have the cuff deflated without aspiration\*
- Some ability to vocalize with the tracheostomy occluded
- Patency of the airway above the tracheostomy
- Secretions should not be thick

### Swallowing

**Background.** Initial evaluations of infants and older children can take place at the bedside with a nurse and/or respiratory therapist available to suction the patient when needed. Methylene blue dye mixed with the patient's food is useful in swallowing evaluations and its use should be considered. All feed-

ing evaluations should be preceded by a doctor's order and approval to use methylene blue dye. Depending on the child's oral motor ability and age, a variety of textures should be tried (i.e., liquid, thick liquid, puree, and soft solid when appropriate). Any trace of blue-tinged mucus over the next several hours is an indication that aspiration has taken place. The speech pathologist should also complete a full oral mechanism examination including cervical auscultation to assess if the swallow is complete or delayed and if multiple swallows are needed to clear the airway. If any of these components of the swallow appear disordered, videofluoroscopy will provide definitive clinical data regarding oropharyngeal coordination and function. If the child has a cuffed tracheostomy tube, the dysphagia evaluation and videofluoroscopy should be performed with the cuff inflated and deflated to note if there is any difference in the swallowing pattern. Any child using a one-way speaking valve should be evaluated with and without the valve in order to note if there are any changes. The videofluoroscopy should also be done with a speaking valve when the cuff is deflated.

### Consensus

A speech therapist experienced with patients with tracheostomies should be consulted before or as soon as possible after tracheostomy in all patients. Speaking valves offer significant advantages and should be strongly considered for all patients. Necessary components of the evaluation include both swallowing and communication.

## CAREGIVER EDUCATION

### Background

Successful transition from hospital to home-based care is dependent on family education and many other factors that are beyond the scope of the present discussion. Excellent reviews of the multiple factors to be considered are available (34, 35).

All children should receive skilled home nursing care during a transitional adjustment time after discharge. The duration and daily extent of this care must be prescribed by the physician on an individual basis, with periodic reassessment by members of the tertiary care center team. Many children will have an ongoing need for skilled nursing care and this reassessment will provide information as to the need to increase or decrease the level of skilled home nursing support. The family of the medically stable patient with complex care needs may benefit from the additional support of homemaker or home health aide services. Financial considerations make the duration and extent of in-home nursing a difficult and frequently contentious issue. The best interests of the patient are of primary importance, but perspectives may vary on how best to meet those needs.

Because a complication in a child with a tracheostomy represents a potentially life-threatening event, the preparation and education of home caregivers must be thorough and comprehensive.

### Consensus

- a. The home care teaching should begin even before the actual tracheostomy procedure. It should be individualized to the child and family, taking into account unique ethnic and language needs. Information should be conveyed in an unhurried, nonthreatening manner. Audiovisual aids may be of value, in addition to written materials.
- b. Education should include decision-making as well as technical skills. A doll or mannequin with a tracheo-

\* When deflated, some cuffed tubes do not deflate completely and may continue to block the airway making the use of a one-way speaking valve difficult. The Bivona high-pressure/low-volume cuffed tracheostomy tube (Bivona Medical Technology, Gary, IN), when deflated, adheres to the tracheostomy cannula more effectively.

stomy can be used for practice. The use of decision trees and role playing helps to reinforce skills and build confidence. When possible and appropriate, siblings should be included in the program. A rooming-in period before discharge, affording the family the opportunity to implement the care plan, should be encouraged. In addition, a day pass may be considered. All home care equipment, including portable equipment, should be used in the hospital before discharge.

- c. A child with a tracheostomy, whether in an institutional or home environment, should be cared for only by an individual who has been trained in the care and replacement of a tracheostomy tube. Patients should be hospitalized only in institutions where such caregivers—whether staff or home caregivers—are available around the clock. The physician who was responsible for the decision to place a tracheostomy is also responsible for ensuring that adequate training for the parents and/or other caregivers is available. Before discharge home, two adults who will be consistent caregivers should be trained by the multidisciplinary health care team. The length of training should not be arbitrarily delineated, for it is dependent on the demonstration of proficiency in skills and sound decision making. If at any time after discharge, the instance arises that there is no trained adult to provide care for the child in the home, the child should be readmitted to the hospital until provision can be made for return of trained personnel to the home.
- d. Each trained caregiver (parents, family, nurses) should properly demonstrate home care skills. Important elements of these skills and knowledge are listed in Table 2.

## MEDICATIONS

### Background

The administration of medications via the airway may be done for systemic or local effect.

### Systemic Effect

In a situation requiring emergency resuscitation, in which intravenous access is not immediately available, the airway has been found to be an acceptable route of delivery. Although there is no literature describing medication delivered through a tracheostomy, administration of emergency drugs via an endotracheal tube has been established as effective. Epinephrine, naloxone, atropine, and lidocaine may be administered endotracheally, with the general recommendations that the dose be two- to three-fold the usual intravenous dose, the medication be diluted to 3–5 cc with a 3- to 5-cc flush, administration be through a catheter beyond the tip of the tube, and administration be followed by bagging (36).

### Consensus

The recommendations for administration of emergency drugs via endotracheal tube appear to be reasonable to apply to tracheostomy tubes. Other than emergency drugs, there appear to be no indications for the endotracheal administration of medications meant for systemic effect.

### Local Effect

Medications for local effect usually administered through the mouth (aerosols) may be required in patients with a tracheostomy. There is no published experience in such patients, but extensive literature exists for patients with endotracheal tubes. In mechanically ventilated patients, factors that impact

medication delivery include the diameter of the endotracheal tube, diameter of the ventilator circuitry, ventilation mode, ventilator type, drug delivery device connection system, and drug type (37). For bronchodilator medications the recommendation has been to observe for therapeutic benefit and toxicity and adjust dosage on an individual basis.

Inhaled corticosteroids given orally are safe, in part, because of first-pass metabolism of the portion that enters the stomach. When these drugs are administered via a tracheostomy, all of the dose enters the respiratory tract. Drug absorption through the airway is not subject to the same degradative process, and there is subsequently more potential for systemic side effects.

### Consensus

- a. Some patients with a tracheostomy are given approved inhaled medications through the mouth while the tracheostomy is occluded. The presence of the tracheostomy tube in the trachea is likely to affect significantly the pulmonary deposition of the drug. The committee recommends administration of the drug through the tracheostomy as more likely to provide good pulmonary deposition. There needs to be careful attention to potential side effects secondary to increased systemic absorption.
- b. Because the distribution, deposition, systemic absorption, local toxic effects, and efficacy of other (nonapproved for aerosol use) medications given via aerosol through a tracheostomy are unknown, the committee recommends avoiding such administration unless appropriate studies are performed. Drugs that are safely nebulized in mouth-breathing patients may achieve toxic concentrations in situations other than those originally studied (38, B. W. Ramsey, personal communication).

## MONITORING

### Background

The role of continuous home monitoring for the child with a tracheostomy remains a controversial issue as there are no controlled studies on which to make objective recommendations. The use of monitoring is driven by the desire to reduce the significant morbidity and mortality associated with chronic tracheostomies in children, yet it is unclear whether this goal is achieved. Ideally, a monitor should provide an early, reliable warning signal of critical airway compromise so that emergency airway stabilization might be rapidly instituted. Unfortunately, most commercially available monitors provide only indirect evidence of airway occlusion, sometimes resulting in a delayed warning signal.

Clinical practice patterns vary widely with regard to home monitor use. Most experts prescribe monitoring for at least some of their children with a tracheostomy. However, some clinicians never prescribe monitors whereas others prescribe monitors for everyone.

### Consensus

- a. The best monitoring for the child with a chronic tracheostomy is the vigilant, well-trained, and properly equipped caregiver. When continuous, direct visualization by a competent caregiver is not practical, a monitoring device should be considered to alert caregivers of impending airway compromise.
- b. Children with chronic tracheostomies who are at high risk for airway complications should especially be considered for monitoring. Factors to consider when assessing risk include age, size of the tracheostomy, degree of



**TABLE 2**  
**TRACHEOSTOMY TRAINING: KNOWLEDGE, SKILLS, AND EQUIPMENT**

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|  |
|--|
| <p>Explain the basic anatomy of the trachea and its relationship to adjoining structures</p> <p>Explain the rationale for tracheostomy and the status of the airway in this child</p> <p>State elements of respiratory assessment and signs of illness; demonstrate counting of respiratory rate and apical heart rate. (Signs of illness may include change in amount, color, odor, or consistency of secretions; change in respiratory rate or rhythm; increased respiratory effort; diaphoresis; color change; hemoptysis; fever)</p> <p>State actions to be taken in the event of tube obstruction, accidental decannulation, and bleeding. Caregivers should be taught that tube obstruction is the most common cause of severe respiratory distress in the child with a tracheostomy and must be treated as an emergency: when in doubt, change the tracheostomy tube!</p> <p>An emergency/travel kit is available with the following supplies: manual resuscitation bag of appropriate size, suction source, suction catheter, DeLee suction traps, one tracheostomy tube of current size with ties in place, one tracheostomy tube that is one size smaller with ties in place, extra ties, shoulder roll, 15-mm adapter for children with metal tracheostomy tubes, suction catheter that can be used if necessary to guide new tube through stoma into tract, scissors, emergency phone numbers, brief description of medical history, description of airway status (i.e., does anatomy preclude oral or nasal intubation and/or ventilation through upper airway?). The contents of the bag should be checked at least annually by the healthcare team and updated as needed</p> <p>Demonstrate CPR. Instruction in CPR should include bag-to-tracheostomy ventilation, as well as mouth-to-mouth with stoma occlusion in a child with a patent upper airway</p> <p>Telephone services should be available in the home. The local emergency services should be notified and their ability to provide services to this child ascertained</p> <p>State the type and size of tracheostomy tube; name the parts of the tube and the purpose of each part; demonstrate use of the cuff and state guidelines for its use. If a fenestration is present, understand the emergency implications of this type of tube</p> <p>State the importance of humidification and method of delivery, and demonstrate care of the equipment</p> <p>Assess the need for suctioning. Demonstrate proper technique for suctioning, cleaning the inner cannula, and cleaning suction equipment. State indications for lavage and demonstrate lavage technique. The parents should be taught to use premarked catheters and to twirl catheter between fingertips during suctioning. The home care suction machine should also operate on a battery source</p> <p>Assemble supplies and demonstrate a tracheostomy tube change:</p> <ol style="list-style-type: none"> <li>1. Check tube integrity and flexibility; check cuff integrity (if present)</li> <li>2. Place obturator in a new tube (if used)</li> <li>3. Suction child's tracheostomy tube</li> <li>4. Position child with neck in slight extension, using a small roll under shoulders</li> <li>5. Deflate cuff (if present)</li> <li>6. Cut strings/detach ties</li> <li>7. Remove the tube in a upward and outward arc</li> <li>8. Insert a new tube in an downward, inward arc</li> <li>9. Immediately remove the obturator (if used)</li> <li>10. Reposition in neutral position by removing the shoulder roll</li> <li>11. Secure ties</li> <li>12. Inflate cuff (if used)</li> <li>13. Lock inner cannula in place</li> </ol> <p>Ideally, two trained adults should be present for the tube change; special circumstance may exist in a home with a single parent</p> <p>State the principles of skin care. Prevention is the key to skin care in the tracheostomy patient. Parents should be instructed that the primary principle of skin care is to keep the skin clean and dry and to avoid pressure necrosis. Regular daily cleansing is performed with soap and water. A solution, such as 1.5% hydrogen peroxide, can be used to removed encrusted secretions. After its use the skin should be cleansed with water and dried thoroughly. The peristomal area and neck skin should be carefully inspected daily. Children who are mechanically ventilated or infants with short, fat necks are at high risk for infection and pressure necrosis and require even more meticulous care. Products such as Duoderm can be used to cushion the skin beneath the tracheostomy ties. Soft tracheostomy ties may be less irritating than strings. The routine use of ointments and creams should be avoided. Petroleum-based products are contraindicated. Dressings, if used, should promote the movement of moisture away from the skin. In the early postoperative period, if dressings are used, they should be loose and nonocclusive</p> <p>Discuss and implement safety measures. Parents should be instructed to avoid all dust, smoke, lint, pet hair, powder, sprays, small toys, and objects. The child should not be in contact with fuzzy toys, clothes, or bedding. Contact sports and water sports are not permitted. The child may be bathed in 1–2 in. of water with a trained caretaker in attendance. Showers may be permissible in older children.</p> <p>Be aware of and participate in goals and plan for feeding program, occupational therapy, physical therapy, and speech therapy</p> <p>Be aware of and participate in the plan for return to school/classroom and any out-of-home arrangements, i.e., daycare. Children who are at most risk for a serious episode of tracheostomy obstruction are younger patients who do not yet attend school. However, in older, school-aged children who have a critical airway in which the risk of obstruction is high, a trained caregiver should be in attendance throughout transport to and from school and while in attendance at school</p> <p>Be aware of monitoring needs, if prescribed. Be able to operate the monitor correctly and act on the information</p> <p>Be aware of projected decannulation plan</p> <p>Discuss the plans for follow-up care</p> |
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airway obstruction, behavior of the child, the underlying airway pathology, the presence of other medical conditions, and the social environment.

- c. None of the commercially available monitoring devices are ideal. Cardiorespiratory monitors and oximeters (not approved for home monitoring) provide indirect evidence of airway compromise and sometimes delayed warnings. End tidal  $PCO_2$  monitoring may have some theoretical advantages, but these devices are prone to occlusion. False alarms from any monitors tend to condition the parents and cause stress and fatigue.
- d. For some high-risk tracheostomy patients who have a history of airway instability, 24-h home nursing may be necessary.
- e. Children with chronic tracheotomies should undergo routine evaluation including rigid or flexible bronchoscopy every 6 to 12 mo to assess the underlying airway pathology, detect and treat complications, assess tube size and position, and determine the readiness for decannulation. Patients with rapidly changing medical conditions or patients with rapid growth (such as patients in the first year of life) may require more frequent endoscopic evaluation. There are few published data on surveillance bronchoscopies.

## DECANNULATION PROCEDURES

### Background

There are two fundamental criteria for decannulation in a child with a chronic tracheostomy: (1) the original need for the tracheostomy tube is no longer present and (2) the patient is able to maintain a safe and adequate airway independent of the tracheostomy tube. In most cases, a tracheostomy tube is removed and the stoma is allowed to close spontaneously. In a small percentage of patients, the stoma will fail to close, and a formal closure of the resulting tracheocutaneous fistula will be required. On occasion there may be a need for surgical closure of the stoma at the time of decannulation.

The traditional decannulation technique involves sequential downsizing of the tube, often with partial or complete plugging of the tube, over a period of several days to several weeks. When the patient is able to tolerate the smallest tube, the tube is removed. The potential advantages of this technique are that it can be performed in the clinic, it involves no instrumentation or sedation, and it allows the patient to acclimate to breathing through the natural upper airway. The potential disadvantages of this technique include the fact that it often fails because of unexpected anatomic problems, and it risks progressively obstructing the patient's airway. In small children, progressive downsizing is more problematic because a step-down in tracheostomy size is a proportionately larger increase in airway resistance compared with a larger child, and because of an increased risk of a mucous plug in smaller tubes. If this technique fails, then it is important to evaluate the patient's airway endoscopically to ascertain the reason for failure.

An alternative method is the one-stage decannulation procedure. With this technique, the patient undergoes endoscopic examination of the airway. The airway is examined during spontaneous breathing, and the tube is removed during the evaluation. If the anatomic and functional patency of the airway is deemed adequate, the patient is decannulated without delay. In many patients, the tracheostomy tube may have been slightly downsized to facilitate the use of a speaking valve; this has the additional advantage of allowing the patient to experience a more natural voice and airflow through the natural (upper) airway before decannulation. The advantages of the one-

stage technique are that it allows the prompt recognition (and therefore, management) of anatomic factors such as airway granulation tissue, preventing successful decannulation, thus reducing the probability of a failed effort at decannulation.

Considerable experience may be required to predict accurately on the basis of endoscopic examination which patient will be successfully decannulated. An excessively conservative approach may lead to inappropriate delay in decannulation, while an overly aggressive approach will result in some decannulation failures.

### Consensus

The one-step method is generally preferred, although either method may be used. Patients are generally monitored in the hospital for 24–48 h after decannulation.

## COMPLICATIONS

### Background

Investigators have differed in the manner in which complications of pediatric tracheotomy have been categorized. The system of Myers and Stool (39) offers adequate stratification of the topic without being so rigid regarding the actual timing of the particular complication. Specifically, these authors allow separation of problems managed primarily by the surgeon (intraoperative) from those managed by the surgeon or intensive care unit staff (immediate postoperative) from those dealt with by the coordinator of the child's long-term care plan (late postoperative) (Table 3).

Globally, between 25 and 50% of pediatric patients with tracheostomies will develop complications. In general, young children have more problems than older children, young having been defined as either less than 1 or 3 yr of age, depending on the author. Similarly, premature infants have more problems than full-term babies (40, 41). Emergency tracheostomies are accompanied by more complications than elective procedures (75 versus 35%) (42). Some authors also find that patients who do not have an artificial airway preoperatively have a higher complication rate (55 versus 35%) and that children under either 3,000 g (44 versus 35%) or 2,000 g (55% versus 34%) have higher rates of complications when compared with larger infants (42). However, this may be a reflection of the severity of illness of the child and not a reflection of the specific operative procedure.

Wetmore and coworkers (43) looked at the primary diagnosis of patients with complications and found that complications were most common in children with upper airway obstruction (33%), followed by central nervous system disorders (22%), miscellaneous disorders (18%), respiratory distress syndrome (18%), congenital heart disease (9%), and craniofacial disorders (1%).

Gianoli and colleagues (44) reported a direct relationship between length of cannulation and late postoperative complications (11% with tracheostomy < 100 d, 55% for 101–500 d,

TABLE 3  
LATE POSTOPERATIVE COMPLICATIONS  
OF PEDIATRIC TRACHEOSTOMY

|                             |                                    |
|-----------------------------|------------------------------------|
| • Suprastomal collapse      | • Catastrophic hemorrhage          |
| • Tracheal wall granuloma   | • Tracheomalacia                   |
| • Tracheoesophageal fistula | • Tube obstruction or displacement |
| • Depressed scar            | • Decannulation failure            |
| • Laryngotracheal stenosis  | • Recurrent tracheitis/bronchitis  |
| • Tracheal wall erosion     | • Death                            |

and 80% > 500 d). These authors also noticed an inverse relationship between morbidity score and the number of early and late complications, thus indicating that the healthier children survived. In addition, they confirmed the higher incidence of complications in emergency tracheostomies done without a controlled airway.

The management of most complications does not seem particularly controversial. Although authors may differ in their approach, most treat the problems in a relatively standard and straightforward manner that is well described in the book chapters by Myers and Stool (39) and Shott (45). The most disagreement seems to exist regarding the removal of tracheostomy suprastomal granulomas on a routine basis, regardless of size, realizing they will eventually recur since they are, in all likelihood, a foreign body reaction. Recurrent infection (tracheitis and/or bronchitis) is a common complication. Since tracheostomies rapidly become colonized, cultures of tracheostomy secretions are not always helpful. A survey of pulmonologists indicates that the empiric use of antibiotics is common (46).

The possibility of catastrophic bleeding from tracheal erosion into a major artery exists with a tracheostomy. Bleeding from suctioning must be differentiated from the sentinel bleeding that occurs from arterial erosion. If the latter is suspected, immediate evaluation in the operating room by personnel capable of performing a sternotomy is essential. When bleeding is felt to be secondary to suction trauma, flexible endoscopic evaluation through the tracheostomy tube may allow the assessment of trauma that may have been caused by suctioning and allow appropriate counseling of the family and caregivers to take place.

#### Complications of Decannulation

If decannulation is performed without endoscopic evaluation of the airway, decannulation may fail because of anatomic or functional obstruction (i.e., granulation tissue above the stoma, unresolved subglottic narrowing, tracheomalacia, etc.). Even with endoscopic evaluation and surgical repair of anatomic lesions encountered, patients may fail decannulation because of upper airway obstruction or other factors that were not adequately appreciated at the time of evaluation, or because of failure to respond adequately to surgical or medical management. The vast majority of decannulation failures occur within 12–36 h after decannulation and, because of rapid anatomic closure of the stoma, it may be difficult to achieve recannulation in an emergency.

In most patients, the stoma closes spontaneously within hours or days. However, if the stoma persists, formal closure is necessary.

In a small number of patients, decannulation will apparently proceed well, but the patient will later require an artificial airway because of anatomic or functional airway obstruction, or for mechanical ventilation. This may be more frequent in patients who have undergone decannulation without endoscopic evaluation, since high degrees of relatively fixed airway obstruction at a point above the stoma (i.e., granulation tissue at the internal stoma) may cause relatively few clinical signs of obstruction until the degree of obstruction becomes critical, such as with increased secretions or mucosal edema associated with an infection. One may minimize this risk by performing an endoscopic evaluation immediately before decannulation, a few weeks after decannulation (if done by sequential downsizing of the tube), or by obtaining a lateral neck film. In patients with minimal respiratory reserve who are at relatively high risk for requiring mechanical ventilation with a respiratory infec-

tion, consideration should be given to not decannulating until after the high-risk respiratory infection season has passed.

#### Consensus

- a. The selection of a tracheostomy tube of the proper diameter, length, and curvature for the individual patient will minimize the incidence of potential complications. These include suprastomal collapse, distal tracheal wall granuloma secondary to impingement and erosion, and dysphagia from esophageal compression.
- b. The availability of a tracheostomy tube one size smaller than usual is appropriate for emergency use if one is unable to insert a same-size tracheostomy tube after accidental decannulation. A tube that is one size smaller should accompany the patient at all times in case this event occurs away from home.
- c. In the child with a tracheostomy who requires mechanical ventilation, suprastomal collapse can be minimized by several factors, including the use of a tracheostomy with flexible flanges, an appropriate connector, and by securing the ventilator tubing to the child's clothing. The latter also serves to minimize the chances of accidental decannulation.
- d. Although there are no data to support the concept, flexion of the neck to cover the tracheostomy with the chin in order to facilitate vocalization may increase the amount of suprastomal collapse. Utilization of a speaking valve should reduce this possibility.
- e. If accidental decannulation occurs in the late postoperative period, the primary caregivers or emergency response personnel should attempt to replace the tracheostomy with a tube of the same size or one size smaller. In an emergency situation, if the child is capable of being intubated, then this should be considered should one not be able to replace the tracheostomy tube. If the patient is stable, no intervention should be attempted and the child should be transported to a tertiary care facility.
- f. Blood in the tracheal secretions may precede a catastrophic hemorrhage and should trigger an appropriate evaluation.

#### AREAS OF SUGGESTED RESEARCH

There are surprisingly few scientifically valid data to support many of the recommendations made by this consensus panel. Areas that were identified as particularly in need of or amenable to research include the following:

- a. The relationship of the frequency of tracheostomy tube change to the incidence of airway infection or granulation tissue, and to the ability of caregivers to deal with emergencies such as accidental decannulation.
- b. The factors involved in the development of increasing stiffness in PVC tubes, and in the development of cracks, leaks (in cuffed tubes), and tears
- c. The comfort, convenience, safety, and complications of tracheostomy ties, and the optimal frequency of tie changes
- d. The cleaning and reuse of suction catheters
- e. The optimal use of humidification, the complications associated with inadequate humidification, and the best technology to use in particular situations
- f. The pharmacokinetics of medications inhaled through a tracheostomy, particularly in spontaneously breathing patients
- g. The utility and timing of surveillance endoscopies
- h. The role of home monitoring devices

This statement was prepared by an ad hoc committee including representation from the Scientific Assembly on Pediatrics of the ATS<sup>1</sup> and representatives from the disciplines of ENT Surgery,<sup>2</sup> Pediatric Surgery,<sup>3</sup> Respiratory Therapy,<sup>4</sup> Nursing,<sup>5</sup> and Speech Pathology.<sup>6</sup>

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