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REVIEW ARTICLE

Neonatal Tracheostomy

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ABSTRACT

Tracheostomy is an established and widely practiced surgical technique. Neonates and young children represent a special population with unique tracheostomy-related concerns. A tracheostomy may be of substantial benefit to the child but is associated with significant morbidity and potential mortality risk. We describe surgical techniques, review pediatric tracheostomy tubes, and discuss relevant care issues.

Keywords: Neonatal, Pediatric, Tracheostomy, Tracheotomy.

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INTRODUCTION

The practice of tracheostomy dates back hundreds of years. It is thought that widespread use of tracheostomy in children developed in the 19th century in cases of airway obstruction relating to diphtheria. Indications for tracheostomy in the infant have since changed significantly and care practices evolved.

Neonates requiring a tracheostomy represent a special population. A tracheostomy in infancy may be of great benefit to the patient; however, it may also be associated with significant morbidity and mortality. This diverse patient group has specific care needs and consideration should be given to the significant impact that a tracheostomy may have on the family, both practical and psychosocial.

The term tracheostomy describes creation of a stable opening within the neck skin leading to the tracheal lumen. A tracheotomy is strictly an incision and opening into the trachea. These terms are often used interchangeably and usage may vary according to region.

INDICATIONS

Numerous large case series of pediatric tracheostomies may be found in the literature and reflect changing indications alongside development of new techniques.

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Table 1: Examples of indications for pediatric tracheostomy

Upper airway obstruction	*Long-term ventilation/ prolonged intubation*	*Pulmonary toilet*
Craniofacial malformations	Central sleep apnea	Chronic aspiration
Lymphovascular malformations	Tracheobronchomalacia	
Bilateral vocal cord palsy	Lung parenchymal disease	
Subglottic stenosis	Neuromuscular disease	
High tracheal stenosis		
Tracheomalacia		

Indications for tracheostomy in the neonatal period may be grouped into several categories: the prevention of complications of long-term intubation, the management of upper airway obstruction, and the assistance of lower airway function through reduction of dead space and suction clearance of secretions. Table 1 includes examples of indications for neonatal tracheostomy.

Hadfield et al[1] described a changing trend in tracheostomy indication from 1993 to 2001; pediatric tracheostomies performed for subglottic hemangioma and laryngeal clefts became less common due to new management approaches, while the commonest indication was prolonged ventilation due to neuromuscular or respiratory concerns. Upper airway obstruction remains a major indication, representing 64% of patients in a recent UK series.[2] Variations in practice between different centers may, however, limit detailed interpretation of both indications and outcomes.

The "EXIT" (*ex-utero* intrapartum treatment) is a relatively recent and highly specialized technique. An anticipated critically threatened upper airway may be secured (by a variety of methods, including by tracheostomy) during a modified cesarian section, while maternofetal gas exchange continues via the placental circulation.

PREOPERATIVE PLANNING

When a tracheostomy is recommended, it is ideal for the carers of the patient to be able to see and handle tracheostomy tubes, and where possible see other children with a tracheostomy. The consent process includes not only the surgical procedure but also the aftercare of a tracheostomy, both short and long term. When circumstances permit, the family and carers of

the patient should be given ample time for consideration and adjustment.

ALTERNATIVES

In circumstances of failed extubation and early subglottic stenosis, a cricoid split may be performed. "Decompression" of the area of the cricoid cartilage may be achieved by endoscopic and open approaches and is typically followed by a period of laryngeal rest before a further trial of extubation.

Single-stage laryngotracheal reconstructive surgery may also avoid a tracheostomy. Following surgery, the patient typically remains intubated in the short term, while the endotracheal tube acts a stent. Use of this surgical technique is, however, limited in the neonatal period.

Noninvasive ventilation may be delivered to the neonate by either a nasal mask or by a "pediatric helmet," which covers the entire head and upper torso of the infant. Few choices of nasal masks are available for the neonate and specific concerns include cutaneous complications and development of facial deformity related to mask pressure. Significant expertise is required in the titration and monitoring of ventilation. Use of ventilation in a home setting in the longer term requires lengthy preparation and a tailored healthcare infrastructure.

Advances in anesthetic techniques, such as videolaryngoscopes and use of the fiberoptic bronchoscope may also aid in cases of difficult intubation, avoiding the need for a tracheostomy.

TECHNIQUE

Preparation

An elective tracheostomy in a neonate is performed under general anesthesia. The airway should be secured for the procedure by endotracheal intubation. This may not be possible in some cases of upper airway obstruction or abnormal anatomy. Alternative options include use of a laryngeal mask airway or in rare cases it may be necessary to bag-mask ventilate the neonate until the tracheostomy has been performed.

Careful supine positioning of the child is essential prior to commencement of the tracheostomy. The neck of the neonate should be extended and the head supported in a central position. A gel pad or rolled towel may be placed under the shoulders and a ring-shaped pillow maintains central position of the head. Symmetry of both the shoulders and the body should be checked to ensure that the child is not in a rotated position. Care, as always, must be taken to ensure protection of the skin from pressure and the infant kept warm. It is important not to hyperextend the very flexible neonatal neck; this risks placement of the tracheostomy in too low a position.

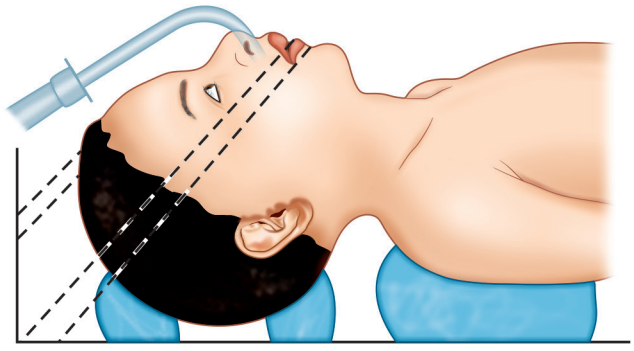


Fig. 1: Positioning of the neonate for tracheostomy using head support and shoulder roll. Dotted lines indicate elasticated tape from chin to operating table

A bridge of elasticated adhesive tape from the operating table to the chin of the neonate may be used to optimize neck extension (Fig. 1).

Palpation of the laryngeal framework then identifies the key landmarks for tracheostomy. The cricoid cartilage is felt as the most prominent midline ridge and may be followed in a cephalad direction to the palpable depression of the cricothyroid membrane and the thyroid cartilage with its upper prominence. These soft and pliable landmarks may be difficult to palpate in a young child; use of gentle pressure by a small finger or blunt instrument such as small hemostat may permit better assessment. Key landmarks such as the sternal notch and cricoid cartilage may be marked.

Dissection

The skin incision may be made either vertically or transversely, according to the preference of the surgeon. A transverse skin incision is recognized to typically give a better cosmetic result. However, in the context of a neonatal tracheostomy, this incision into very elastic tissues rapidly becomes square in nature with retraction of the skin edges. A significant amount of subcutaneous fat is often present in the infantile neck and a small core of fat may be excised to facilitate both deeper dissection and tracheostomy tube placement.

The midline should be identified and is represented by a white fascial strip between the strap muscles. Meticulous hemostasis in each layer of dissection is essential, ensuring optimal identification of deeper structures; bipolar diathermy is recommended. The thyroid isthmus may or may not be encountered. This may be displaced if it does not directly overlay the tracheotomy site, or may be divided by bipolar diathermy in the neonate. Repeated palpation, again by either a finger or by a small blunt-tipped instrument, should be undertaken to ensure the dissection is proceeding in the midline and onto the anterior wall of the trachea. Lateral dissection risks

esophageal or great vessel injury. Care should be taken to ensure that overenthusiastic retraction by a surgical assistant does not displace the elastic neonatal trachea. The domes of the pleura may also rise above the clavicle, particularly in a neonate. Careful midline dissection, in a blunt fashion where possible, will minimize the risk of pleural damage.

Tracheotomy

In the neonate, the authors recommend a vertical tracheotomy, typically through the third and/or fourth tracheal rings. Again, the cricoid should be identified before the tracheotomy is performed to ensure that the incision is not sited too high. It is critical that incision through the cricoid cartilage and first tracheal ring is avoided. We do not recommend excision of a tracheal window or creation of a Bjork flap in the neonate; this may reduce the circumference and/or stability of the trachea and increase the risk of tracheomalacia.[3] Several alternative incisions have been described and include horizontal tracheotomy and a cruciate incision (the "starplasty" technique).[4,5]

Once the airway has been opened, further diathermy use is inadvisable as it may risk an airway fire in a high-oxygen environment. A ventilatory leak will also be present. Should this be problematic, the tracheotomy may be intermittently occluded using digital pressure and a small swab. "Stay sutures" using a nonabsorbable suture material (e.g., 4/0 Prolene®) may be placed either side of the tracheotomy either before or after it is performed. It is advantageous to secure these to the chest of the infant using tapes marked "do not remove."

Many surgeons favor a "maturation" technique for the new tracheostoma. Absorbable sutures, typically at four points, are placed between the dermis and the anterior tracheal wall with the aim of hastening the formation of a stable, "mature" stoma.[6] It is hoped that this technique decreases the risk associated with accidental decannulation and expedites wound healing. A correlation with persistent tracheocutaneous fistula postdecannulation has not been established.[7,8] Figure 2 demonstrates a vertical tracheotomy with positioning of "stay" and maturation sutures.

If the patient has an endotracheal tube in place, this is visualized through the tracheotomy. The endotracheal tube is slowly withdrawn by the anesthetist and an appropriate tracheostomy tube inserted. The obturator (introducer) provided with the tube should be removed immediately and the tube connected to monitoring equipment. Appropriate gas exchange should be confirmed before complete withdrawal of the endotracheal tube. An absorbent dressing and tracheostomy tapes are then secured. This must

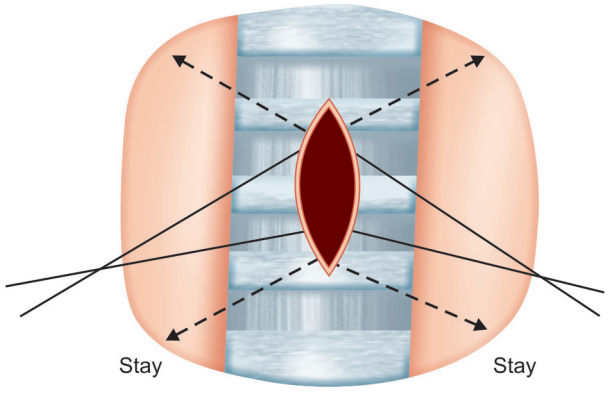


Fig. 2: Vertical tracheotomy: Schematic diagram of positioning of "stay" sutures and stomal maturation sutures (dotted lines)

be done with the child in either a neutral or flexed position and the tapes should be sufficiently tight. It is recommended that only a single finger should be able to pass under the tapes. At the time of tracheostomy insertion, the appropriate size and length of suction catheter should also be measured and recorded for postoperative care.

TRACHEOSTOMY TUBES

Appropriate selection of tracheostomy tube is of upmost importance.[9] Guides such as the "Great Ormond Street Hospital chart for Pediatric airways" indicate size and length according to patient age (Table 2). A range of tubes are available; Bivona® and Shiley® tubes are examples of tubes available in the UK. These tubes are numbered according to the internal diameter in millimeters and may be available in two principal lengths depending on tube size. These are termed neonatal (neo) and pediatric (ped). Neonatal tubes also commonly have a shorter neck flange. The tip of a "pediatric" length tube used in a neonate may contact the carina or sit within a main bronchus, causing airway irritation and trauma; ventilation may also be impaired. Conversely, use of a tube that is too short may increase the risk of accidental decannulation. The proximity of the tracheostomy tube tip to the carina may be assessed by plain radiograph, flexible endoscopy through the tracheostomy tube, or bronchoscopy. It is inadvisable to cut or trim the tip of a tracheostomy tube as this may create a sharp and traumatic edge.

The variety of tracheostomy tubes differ in design and material (Figs 3A to D). Both Shiley® and Bivona® tubes have a built-in standard 15 mm connector on the proximal end of the tube for direct connection to standard ventilation and anesthetic equipment. Silicone tubes (e.g., Bivona®) may be used for up to 29 days and may be sterilized and reprocessed for single patient use up to five times. A polyvinyl chloride (PVC) tube (e.g., Shiley®)

Table 2: The Great Ormond Street Hospital chart for pediatric airways

		Preterm–1 month		*1–6 months*	*6–18 months*	*18 months–3 years*	*3–6 years*	*6–9 years*	*9–12 years*	*12–14 years*
Trachea (transverse diameter mm)		*5*		*5–6*	*6–7*	*7–8*	*8–9*	*9–10*	*10–13*	*13*
Great Ormond Street	ID (mm)		3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.0
	OD (mm)		4.5	5.0	6.0	6.7	7.5	8.0	8.7	10.7
Shiley	Size		3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
	ID (mm)		3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
	OD (mm)		4.5	5.2	5.9	6.5	7.1	7.7	8.3	9.0
	Length (mm) neonatal		30	32	34	36				
*Cuffed tube available	Pediatric		39	40	41*	42*	44*	46*		
	Long Pediatric						50*	52*	54*	56*
Portex (Blue Line)	ID (mm)		3.0	3.5	4.0	4.5	5.0	5.0	6.0	7.0
	OD (mm)		4.2	4.9	5.5	6.2	6.9	6.9	8.3	9.7
Portex (555)	Size		2.5	3.0	3.5	4.0	4.5	5.0	5.5	
	ID (mm)		2.5	3.0	3.5	4.0	4.5	5.0	5.5	
	OD (mm)		4.5	5.2	5.8	6.5	7.1	7.7	8.3	
	Length neonatal		30	32	34	36				
	Pediatric		30	36	40	44	48	50	52	
Bivona	Size	2.5	3.0	3.5	4.0	4.5	5.0	5.5		
	ID (mm)	2.5	3.0	3.5	4.0	4.5	5.0	5.5		
	OD (mm)	4.0	4.7	5.3	6.0	6.7	7.3	8.0		
All sizes available with Fome Cuff, Aire Cuff & TTS Cuff	Length neonatal	30	32	34	36					
	Pediatric	38	39	40	41	42	44	46		
Bivona Hyperflex	ID (mm)	2.5	3.0	3.5	4.0	4.5	5.0	5.5		
	Usable length (mm)	55	60	65	70	75	80	85		
Bivona Flextend	ID (mm)	2.5	3.0	3.5	4.0	4.5	5.0	5.5		
	Shaft length (mm)	38	39	40	41	42	44	46		
	Flextend length (mm)	10	10	15	15	17.5	20	20		
TracoeMini	ID (mm)	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	
	OD (mm)	3.6	4.3	5.0	5.6	6.3	7.0	7.6	8.4	
	Length (mm) Neonatal (350)	30	32	34	36					
	Pediatric (355)	32	36	40	44	48	50	55	62	
Alder Hey	FG		12–14	16	18	20	22	24		
Negus	FG			16	18	20	22	24	26	28
Chevalier Jackson	FG		14	16	18	20	22	24	26	28
Sheffield	FG		12–14	16	18	20	22	24	26	
	ID (mm)		2.9–3.6	4.2	4.9	6.0	6.3	7.0	7.6	
Cricoid (AP diameter)	ID (mm)		3.6–4.8	4.8–5.8	5.8–6.5	6.5–7.4	7.4–8.2	8.2–9.0	9.0–10.7	10.7
Bronchoscope (Storz)	Size		2.5	3.0	3.5	4.0	4.5	5.0	6.0	6.0
	ID (mm)		3.5	4.3	5.0	6.0	6.6	7.1	7.5	7.5
	OD (mm)		4.2	5.0	5.7	6.7	7.3	7.8	8.2	8.2
Endotracheal tube (Portex)	ID (mm)	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0
	OD (mm)	3.4	4.2	4.8	5.4	6.2	6.8	8.2	9.6	10.8

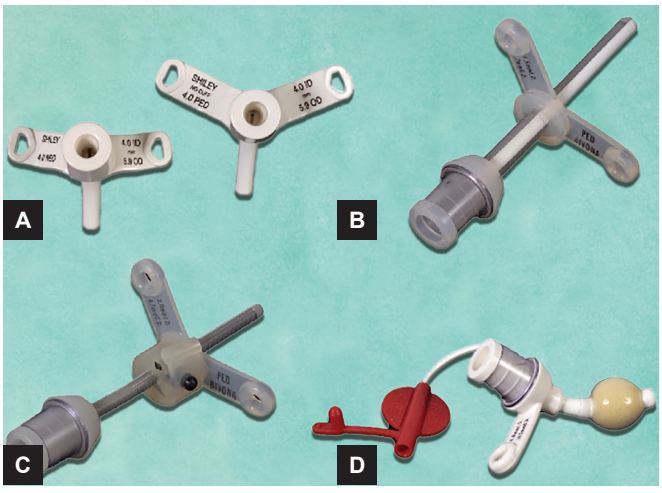
PLASTIC

SILVER

Table reproduced from 'Choosing a Pediatric tracheostomy: an update on current practice', DJ Tweedie, CJ Skilbeck, LA Cochrane, J Cooke, ME Wyatt. The Journal of Laryngology & Otology, 2007

is more rigid in comparison and may be easier to insert than a silicone tube. This may therefore be a useful a "back-up tube." Weekly changes are recommended for PVC tubes and their use is recommended for a maximum of 29 days. Metal tubes have the advantage of a thinner wall, which maximizes the lumen of the tube relative to tube size; however, they do not lend themselves to use in a neonatal setting as the rigid material may cause trauma to both the trachea and skin.

A longer length of pediatric tube is available from several manufacturers as are cuffed tubes; these are limited to exceptional circumstances. The length of a Bivona Hyperflex® tube may be titrated as the flange is adjustable. This is, however, a temporary tube best used



Figs 3A to D: Examples of pediatric tracheostomy tubes: (A) Shiley® Neonatal and pediatric; (B) Bivona Flextend® pediatric; (C) Bivona Hyperflex®; and (D) Bivona Fome Cuff®

Fig. 4: The emergency tracheostomy box

only in an inpatient setting as the securing button may loosen or become undone. Customized tubes may also be ordered.

A technique of bronchoscopic-assisted neonatal tracheostomy (BANT) has also been described. This incorporates an upper airway assessment and may facilitate accurate tracheostomy placement.[10] Percutaneous tracheostomy using a Seldinger technique is not recommended in either the neonate or the child. The pediatric trachea is soft, mobile, and collapsible; one cannot adequately locate and stabilize the airway. There is also no potential for placement of "stay sutures" or for maturation of the stoma.

POSTOPERATIVE CARE

A spare tube of identical size and a tube one size smaller should accompany the patient from the operating theater following tracheostomy surgery. The introducer of the tube should also be kept with the patient at all times. An "emergency tracheostomy box" may be created and should include all necessary equipment for a tube change and tube care (Fig. 4). This contains, but is not limited to, a spare tracheostomy tube of the same size, a tracheostomy tube a half size smaller (e.g., a Shiley® tube), a suction catheter (for Seldinger technique tube changes), blunt-tipped scissors, tracheostomy tapes, and water-based lubricant.

Many centers routinely obtain a postoperative chest radiograph on the basis that it may verify the length of tube and aid in the detection of complications, such as pneumothorax and pneumomediastinum. Several recent articles have examined the utility of routine postoperative radiography. Clear benefit has not typically been found and it has been suggested that imaging be reserved for cases where there is suspicion of a complication.[11]

Humidification

The need for warm and humid air is greatest in the immediate postoperative period and may be provided by use of a mechanical humidification device or by tubing connected through bottled water. This is typically employed for the first postoperative week and may be required for a longer period in the young infant. Without appropriate humidification, secretions can become increasingly thick, tenacious, and difficult to clear. This may lead to blockage of the tube or retention of secretions in the lower airways. A heat and moisture exchange (HME) device can be used in the longer term. Several types of HME devices are available and consist of multiple membranous paper or foam layers that are able to retain heat and moisture. An HME should be changed as needed. Nebulized saline may provide additional humidity and supplement other primary methods of humidification in times of need.

Suction Tube Clearance

Suctioning should be performed on an as required basis to prevent blockage of the tube. In the first 24 hours in particular, suctioning is recommended at least a half-hourly intervals. It is vital that a suction catheter of an appropriate size is used to a premeasured length in order to prevent tracheal trauma.

Care of the Securing Tapes and Skin

The deep and moist skin folds of the short neonatal neck in combination with a thin and vulnerable skin dictate that utmost care should be taken in order to minimize the risk of cutaneous complications related to the tracheostomy tube and its securing tapes. Conversely, the risk of accidental decannulation associated with

inadequately tight tapes may result in a serious adverse event or death.

Postoperative care protocols may vary from institution to institution. They share a common basis of reduction of tracheostomy-related morbidity and mortality. The importance of care provision by appropriately trained staff cannot be overstated. A "TRACHE" care bundle has been developed at Great Ormond Street Hospital (Table 3). This mnemonic acts to highlight six main aspects of tracheostomy care.

Several sources of pediatric tracheostomy care guidance are available. The National Tracheostomy Safety Project (NTSP) has been established in the UK and is associated with the Global Tracheostomy Collaborative. Guidance documents have been developed by consensus and are available on both websites alongside other professional resources. An NTSP mobile device application is also currently available. Furthermore, the International Pediatric Otolaryngology Group has also recently developed a pediatric-specific guideline, "Routine perioperative Pediatric tracheotomy care: consensus recommendations" and is pending publication.[12]

COMPLICATIONS

Pediatric tracheostomies are associated with significant morbidity and mortality and are often performed in patients with significant comorbidities. Ozmen et al[13] recently reported complications in 19% of a series of 282 patients. This mirrors much of the published literature, although complications may well be underreported. Table 4 classifies complications into early, late, and general adverse events.

Of note, tracheostomy-related mortality typically ranges between 1 and 5%. For example, a tracheostomy-related death rate was estimated to be 3.6% in a recent series of 204 patients.[14] The incidence of nontracheostomy-related mortality is also high and reflects the frequency of significant comorbidities in this patient population.

Accidental decannulation may result from neck ties that are too loose or from traction on the tube by connecting humidification or ventilator tubing. An accidental decannulation in the first week following a tracheostomy is associated with significant risk given that the "fresh" stoma has not matured, causing difficulty in reinsertion and creation of a false passage. Use of a suction catheter to guide safe passage of a new tube using the Seldinger technique has been recommended.[15] Appropriate nursing care, use of stomal maturation techniques, and stay sutures may reduce the risk associated with accidental decannulation.

Table 3: Management of a pediatric tracheostomy: the "TRACHE" bundle

Tapes: keep the tracheostomy tube secure
Resus: know the resuscitation procedure
Airway clear: use the correct suction technique
Care of the stoma and neck
Humidity: essential to keep the tube clear
Emergency equipment: have the emergency tracheostomy box present

Table 4: Complications of tracheostomy

General	Accidental decannulation
	Tube blockage
	Tracheostomy-related death
Early	Hemorrhage
	Damage to posterior tracheal wall/esophagus
	Pneumothorax/pneumomediastinum
	Subcutaneous emphysema
Late	Tracheal/stomal granulation tissue
	Peristomal infection
	Lower airway infection
	Localized tracheomalacia
	Localized stenosis (suprastomal collapse)
	Speech delay
	Olfactory disturbance
	Persistent tracheocutaneous fistula postdecannulation

As the tracheostomy bypasses the oronasal airway, several normal functions are also disturbed. Olfactory disturbance and concerns regarding changes in neural plasticity relating to olfaction have been recognized.[16] Verbal communication and speech development may also be impaired.[17] Decannulation at the earliest opportunity is associated with better long-term speech outcomes.

FURTHER CARE

The first tracheostomy tube change is typically performed around 1 week postoperatively. This should be performed in an appropriate setting by either an otolaryngologist or by a specialized tracheostomy nurse practitioner. Following the tube change, any "stay sutures" may be removed.

The discharge process following a tracheostomy in an infant may be both lengthy and detailed. International practices regarding mandatory length of inpatient stay are known to vary widely. In summary, several goals need to be achieved before discharge from a tracheostomy care perspective. The caregivers need to be trained and competent in comprehensive tracheostomy care and in basic resuscitation techniques. Communication and preparation with primary care services including home-care staff is essential prior to discharge. Should home ventilation be required, this creates additional care concerns, training and support needs.

Decannulation should be considered when the initial indication for tracheostomy has resolved, either by growth of the child or as a result of medical intervention. In brief, the process of decannulation is complex, requiring considerable preparation and careful predecannulation assessment. The authors recommend an elective microlaryngobronchoscopy prior to any decannulation attempt. Valuable information may be gained regarding the structure and rigidity of the airway and a suprastomal granuloma removed. Decannulation is often best managed according to an established protocol.

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