Objective: To report a new technique of pediatric tracheotomy that reduces the problems of pneumothorax and recannulation after accidental decannulation in a recently performed tracheotomy.


Patients: Sixty-eight children aged between 2 days and 14 years.

Method: The starplasty procedure is based on the geometry of a 3-dimensional Z-plasty. The technique of the procedure is described and illustrated in detail.

Results: There were 27 short-term complications, including 4 accidental decannulations. There were no instances of pneumothorax or tracheotomy-related deaths. There were 23 long-term minor complications. There were no instances of tracheotomy-related death, suprastomal collapse, or tracheal stenosis. Thirty-eight children remain tracheotomy tube dependent, 17 underwent decannulation, 7 died of primary disease, and 6 were lost to follow-up. All 17 children who underwent decannulation have a persistent tracheocutaneous fistula.

Conclusions: I conclude that starplasty reduces the incidence of major complications and death. Its only drawback seems to be persistent tracheocutaneous fistula.


Pediatric tracheotomy remains of interest to surgeons who perform this operation. A MEDLINE computer search rendered 75 references on the subject for the 20 years between 1977 and 1997. There are many reasons why pediatric tracheotomy continues to be of compelling concern, perhaps none more than that the operation saves lives. The indications for pediatric tracheotomies reflect the changes that have occurred in the treatment of critically ill children over the last 50 years.1-3 Also, a low but predictable rate of complications persists along with the search for strategies to reduce them.4-6 Historically, pediatric tracheotomies were usually performed for acute airway obstruction due to infection. With the evolution in antibiotics, vaccinations, and the specialty of pediatric intensive care, today most of these children are treated with endotracheal intubation. Nevertheless, the need for pediatric tracheotomy has increased as a consequence of our success in the treatment of premature infants and chronically, often neurologically impaired children. It is the unresolved difficulties and changing indications that have kept this topic percolating within our literature.

The complications associated with tracheotomy can be divided into short- and long-term categories.7-9 The short-term complications that most demand attention are pneumothorax and the accidental displacement of a newly placed tracheotomy tube. Attempts to reduce the risk of pneumothorax have focused primarily on refinements of surgical technique, with careful confined anatomical dissection, identification of fascial planes between the skin and the trachea, and maintenance of hemostasis. The goal has been to control the operative field, maximizing visual exposure and minimizing trauma to the site. Despite these refinements, pneumothorax still occurs because of a fundamental design characteristic of most tracheotomy techniques that allows air from the trachea to have direct access to the tissue layers confluent with the parietal pleura.

Of even greater concern than pneumothorax is the life-threatening accidental dislodgment of a recently inserted tracheotomy tube. In a child the tolerance between a tracheotomy tube being too long, resulting in hypoinflation of a lung,
PATIENTS AND METHODS

The hospital and office records of 68 children younger than 16 years who underwent tracheotomy at the Section of Pediatric Otolaryngology, Albany Medical College, Albany, NY, were reviewed. The operations were performed between 1990, when the procedure was first conceived, and 1997 by 1 surgeon (P.J.K.) and resident assistants. Operative and postoperative records were available for all patients; however, 7 children were lost to follow-up and their parents could not be contacted by telephone.

The data analysis included sex, age at time of tracheotomy, primary diagnosis, presence of airway pathology, corrective airway surgery, duration of tracheotomy, short-term tracheotomy-related complications, long-term tracheotomy-related complications, overall mortality, and tracheotomy-related mortality.

The child is endotracheally intubated and given general anesthesia while in the operating room. The patient is positioned with a roll under the shoulder and the head is hyperextended to stretch the airway and bring it into relief. Halfway between the sternal notch and the cricoid cartilage, a 1-mL injection of 1% lidocaine with 1:100 000 U of epinephrine is made into the skin and subcutaneous tissues. At this same site, an x-shaped incision is drawn on the skin (Figure 2, A). The length of each cross member of the x is the diagonal of a square with a side that is 1 cm long (Figure 2, B). For children older than 1 year, the size of the x needs to be proportionally increased, so that for an adolescent, the side of the square is 2 cm long. The x is incised with a No. 15 blade (Figure 2, C).

The triangular skin flaps thus created are circumferentially undermined with scissors (Figure 3, A), and the subcutaneous fat between the skin and strap muscles is sharply excised (Figure 3, B). The strap muscles are divided in the midline (Figure 3, C), retracted laterally, and the trachea is exposed. The thyroid isthmus is generally superior to the opening in the neck, but if it is in the way, it can be divided with cautery or incision and ligature (Figure 3, D). The paratracheal fascia is dissected off the front of the trachea and a plus-shaped incision is made in the anterior trachea wall with a No. 15 blade. The horizontal limb extends from the lateral tracheal wall on one side to the other. The vertical midline limb is through 2 tracheal rings above and 2 tracheal rings below the horizontal limb (Figure 3, E).

The next step is to circumferentially interdigitate the triangular skin flaps with the triangular tracheal flaps. Since the skin and tracheal incisions are offset by 45°, the tips of the skin flaps align with the troughs of the trachea flaps, and the tips of the trachea flaps align with the troughs of the skin flaps. I begin by sewing the tip of the right upper trachea flap to the right upper skin trough with 5-0 poly(glycolic) (vicryl, Ethicon Inc, Somerville, NJ) sutures on a cutting needle. The needle is matrassed through the skin, 4 mm from the notch of the trough, then through the distal tip of the trachea flap, back through the skin again 2 mm from the notch, and then tied (Figure 3, F). Next, the needle is matrassed through the upper skin flap 4 mm from the tip, then through the upper tracheal trough, back through the skin again 2 mm from the tip, and then tied (Figure 3, G). The remainder of the flaps are similarly sutured in place in an orderly circumferential manner (Figure 3, H-L).

The final stoma tends to be slightly vertically elliptical in shape and curved like the center of a doughnut (Figure 4, A and C). The endotracheal tube is easily observed through the trachea fenestration, and after it has been pulled back, an appropriately sized tracheotomy tube can be gently guided into the flared, funnel-shaped stoma (Figure 4, B and D).

An antibiotic-impregnated gauze dressing is placed between the stoma and the tracheotomy tube, which is secured with cotton tapes and circumferentially tied around the neck. After the operation, the child is cared for in the intensive care unit. The first tracheotomy tube change is on the fifth day after the operation and then weekly afterward.
required trachea stenosis in children. Evidence suggests that clinically relevant stenosis is not related to the design of the technique, but is more likely to occur as a consequence of infection of the trachea cartilages surrounding the tracheotomy site.

Some degree of anterior trachea wall collapse leading to mild flattening above the tracheotomy site is seen in most children and is generally not clinically relevant. Nevertheless, in some children collapse can be significant and cause decannulation failure. This result may be the combined consequence of pressure from the tracheotomy tube on the superior part of the anterior tracheal wall and infection of the involved cartilages.

The experience gained between 1980 and 1990 in performing, teaching, and studying the history of pediatric tracheotomy has provided a conceptual and pragmatic understanding of the utility of the various techniques. This knowledge, as well as experience with a few catastrophic complications, kindled an insight of a procedure that might address the limitations of existing methods. The starplasty, a design based on the geometry of a 3-dimensional Z-plasty, is the practical manifestation of that idea. The following is a description of the new technique and an analysis of the clinical course of 68 children in whom it has been used.

RESULTS

Sixty-eight children aged between 2 days and 14 years had starplasty-type tracheotomies performed at Albany Medical College between 1990 and 1997. Thirty-six of the patients were males and 32 were females.

Thirty-five children (51%) had neurologically related airway problems. Thirty-three children (49%) had previous airway problems.

Forty-three children (63%) underwent tracheotomy in the first year of life, with 18 (26%) within the first month of life. Twenty-five children (37%) underwent tracheotomy between ages 1 and 14 years.

There were 27 short-term complications, including 4 accidental decannulations. There were no instances of pneumothorax or tracheotomy-related deaths.

There were 25 long-term complications. There were no tracheotomy-related deaths in the long-term. There were no cases of clinically relevant suprastomal collapse that compromised decannulation. There were no instances of tracheal stenosis.

Thirty-eight children (56%) remain tracheotomy tube dependent, 17 (25%) underwent decannulation, 7 (10%) died of their primary medical disease, and 6 (9%) have been lost to follow-up. Of the 17 children who underwent decannulation, 15 (88%) had primary airway-related causes (P = .001). Of the 38 children who remain tracheotomy tube dependent, 27 (71%) had neurologically related airway problems (P = .001).

Of the 17 children who underwent decannulation, all (100%) have an obvious persistent tracheocutaneous fistula, 7 (41%) of which are closed to airflow, and 10 (59%) of which are open to airflow. Four children (24%) underwent uneventful reconstruction of their tracheocutaneous fistula.

COMMENT

The ideal tracheotomy technique would have the following qualities: (1) technical ease, (2) separation of the wound from tracheal secretions and airflow, (3) ready postoperative replaceability, (4) rapid maturity, (5) minimal stomal maintenance, (6) minimal tracheal deformation, (7) ready reversibility, and (8) minimal scarring.

Unfortunately, tracheotomy, like most surgical procedures, involves compromise, a relative valuation of the goals trying to be achieved. In this light, the starplasty operation fulfills the most important of the characteristics described.

The starplasty procedure is technically straightforward and its logic readily apparent, especially for surgeons familiar with performing tracheotomy. From in-
The triangular skin flaps are circumferentially undermined with scissors. B, The subcutaneous fat between the skin and the strap muscles is sharply excised. C, The strap muscles are divided in the midline. D, The thyroid isthmus is generally superior to the opening in the neck, but if it is in the way, it can be divided with cautery or incision and ligature. E, After the paratracheal fascia has been dissected off the trachea, a plus-shaped incision is made in the anterior tracheal wall with a No. 15 blade. F, The construction of the starplasty begins with sowing the tip of the right upper trachea flap to the right upper skin trough, with a 5-0 polyglactin (Vicryl, Ethicon Inc, Somerville, NJ) suture on a cutting needle. The needle is mattressed through the skin 4 mm from the notch of the trough, then through the distal tip of the tracheal flap, back through the skin again, 2 mm from the notch, and then tied. G, Next, the needle is mattressed through the upper skin flap, 4 mm from the tip, then through the upper tracheal trough, back through the skin again, 2 mm from the tip, and then tied. H-L, The remainder of the flaps are similarly sutured into place in an orderly circumferential manner.

The starplasty procedure addresses the problem of pneumothorax by isolating the tracheotomy site from the fascial layers that potentially communicate with the pleura by the use of the interdigitating tracheal and cutaneous flaps. The low but predictable risk of pneumothorax associated with standard tracheotomy, reported between 3% and 6%, is usually a consequence of the basic design of the operation and not due to technical error by the surgeon. This design flaw is highlighted in children who typically require mechanical ventilation after tracheotomy. Because pediatric tracheotomy tubes are cuffless, the pressurized air from the ventilator leaks around the newly placed tracheotomy tube and can dissect into the tissue planes around the recent trachea wound, resulting in pneumothorax and pneumomediastinum. The absence in the series of any episodes of pneumothorax, pneumomediastinum, and subcutaneous emphysema is favorable evidence that my conceptual solution to this well-recognized problem has practical relevance. It is unlikely that the starplasty design will totally eliminate pneumothorax, and when there are a large enough number of these procedures performed, an incidence of higher than 0% will emerge. Nevertheless, any decrease in this complication will save lives.

The feature of starplasty that isolates the tissue planes from the respiratory tract, thereby reducing the risk of pneumothorax, is also the quality that facilitates replacement of an inadvertently displaced tracheotomy cannula. Accidental decannulation has variable causes, including insecure tracheotomy ties, patient motion, and inexpert tracheotomy tube care. These variables cannot be prevented by the form of the tracheotomy; however, the design of the starplasty stoma does change a potential crisis into a controlled event. The funnellike shape, the tissue tension that maintains the opening, and the smooth mucocutaneous suture line provide a guiding path back into the tracheal lumen. The 4 episodes of accidental decannulation with uneventful recannulation in our series support the effectiveness of the design.

Figures 3. A, The triangular skin flaps are circumferentially undermined with scissors. B, The subcutaneous fat between the skin and the strap muscles is sharply excised. C, The strap muscles are divided in the midline. D, The thyroid isthmus is generally superior to the opening in the neck, but if it is in the way, it can be divided with cautery or incision and ligature. E, After the paratracheal fascia has been dissected off the trachea, a plus-shaped incision is made in the anterior tracheal wall with a No. 15 blade. F, The construction of the starplasty begins with sowing the tip of the right upper trachea flap to the right upper skin trough, with a 5-0 polyglactin (Vicryl, Ethicon Inc, Somerville, NJ) suture on a cutting needle. The needle is mattressed through the skin 4 mm from the notch of the trough, then through the distal tip of the tracheal flap, back through the skin again, 2 mm from the notch, and then tied. G, Next, the needle is mattressed through the upper skin flap, 4 mm from the tip, then through the upper tracheal trough, back through the skin again, 2 mm from the tip, and then tied. H-L, The remainder of the flaps are similarly sutured into place in an orderly circumferential manner.

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Deaths of children with indwelling tracheotomy tubes, reported between 7% and 42%, are overwhelmingly the consequence of the child’s underlying illness. The 10% incidence of nontracheotomy-related mortality among our patients is well within this range. On the other hand, 1% to 3% of tracheotomy-related deaths are a consistent feature of most reports on the topic, with the 0% incidence reported by Carter and Benjamin being the exception. The absence of any tracheotomy-related mortality among our patients speaks well for the care they received after the operation in our intensive care unit, but may also reflect the safety of this technique.

The construction of a continuous circumferential mucocutaneous suture line leads to isolation of trachea secretions from the tracheotomy wound and thus to early maturity of the starplasty stoma. The circumferential suture line reduces the intensity of postoperative wound care but does not eliminate it. Moreover, the techniques are not entirely immune from infection because we had 2 instances of postoperative peristomal cellulitis, one of which resulted in dehiscence of the inferior portion of the stoma. While we did see 2
instances of transient tracheotomy tube plugging in which the tube had to be emergently replaced, it seems that by having a shorter period with a raw open wound, the quantity of crusting around and within the tracheotomy tube is reduced.

Early and late tracheitis, seen in 34% and 26% of our patients, respectively, is not typically reported in the literature as a complication of pediatric tracheotomy, perhaps because it is so ubiquitous or because it is not thought to be related to the performance of

Figure 4. A, The final stoma tends to be slightly vertically elliptical in shape and curved inward like the center of a doughnut. B, After the endotracheal tube has been pulled back above the tracheotomy site, an appropriately sized tracheotomy tube is gently guided into the flared, funnel-shaped stoma. C, Clinical photograph of a recently constructed.starplasty. D, Clinical photograph of tracheotomy tube placement after a recently constructed starplasty.
the tracheotomy itself. The organisms that were most commonly responsible for these infections in our patients were *Staphylococcus aureus* and *Pseudomonas aeruginosa*. While we had 1 child with trachea granulations associated with tracheitis, we did not see the eschar and cast formation previously seen in children without tracheotomies with life-threatening bacterial tracheitis. It appears that the 2 processes are distinct despite their common name.

Once a stoma has matured, maintenance can be simple or frustrating, depending on the care given the stoma, the shape of the child’s neck, the weather, and the sensitivity of the child’s skin. The starplasty procedure has a low incidence (3%) of cutaneous peristomal granulomas. However, their occurrence suggests that even a surgically created mucocutaneous junction can be prone to an irritation and infection and highlights the necessity of careful and continuous tracheotomy care.

Most children in this series (56%) remain tracheotomy tube dependent as a consequence of their underlying illnesses. No child remains cannulated as a consequence of tracheal stenosis, anterior trachea wall collapse, or any other problem that can be attributed to the starplasty procedure (Figure 5 A and B). The absence of stenosis and anterior wall collapse is probably related to the low stomal infection rate but may also be a function of the geometry of the procedure. The superior and inferior parts of the stoma are lined with skin so that the pressure of the tracheotomy tube is not on the trachea itself. Additionally, the integrity and memory of the trachea cartilages within the triangular flaps may remain partially intact reverting to the normal anatomy following decannulation. Further animal studies may clarify the dynamics of this process.

Our main concern with the starplasty procedure is the tracheocutaneous fistula that universally persists after decannulation (Figure 6). Many (41%) fistulae completely seal off but most leak air, and some remain distinctly open with an aperture up to 2 mm in diameter. It has been previously reported that a pediatric tracheotomy tube, if left in place long enough, will result in tracheocutaneous fistulae. Nevertheless, because the starplasty stoma is constructed as a tracheocutaneous fistula, it is not unexpected that it consistently results in a belly-buttonlike dimple that requires secondary surgical correction. This result is the compromise made for the early safety of the procedure.

For many children, especially those with chronic neurologic illness, the tracheotomy tube is permanent, and for them the starplasty procedure is truly ideal. Tracheocutaneous fistula is a problem only for those who can expect decannulation, typically children with airway problems. The decision about which tracheotomy design to use for these children should be based on the expected length of cannulation. Tracheotomy intended for less than 1 month should have a temporary design. On the other hand, when the airway problem is more complex and the tracheotomy entubation is for a longer period, then starplasty procedure is appropriate.

In summary, I present my experience with 68 children who underwent starplasty, a new pediatric tracheotomy technique that is based on the geometry of a 3-dimensional Z-plasty. I describe and illustrate the steps for its successful performance in detail. The new technique is an alternative to existing methods. More importantly, it results in a quantifiable reduction...
in the risk of the major early complications of pneumothorax and death from accidental decannulation. Its only drawback appears to be the need for a secondary reconstruction of a persistent tracheocutaneous fistula. Based on my experience, I recommend its consideration.

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REFERENCES