Tracheostomy Tube Types

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Introduction

The word *tracheostomy* is derived from the Greek *trachea arteria* (hard artery) and *tome* (cut) [1]. The procedure consists of an incision in the trachea. It has been reported since ancient times [1, 2], but it was only at the beginning of the twentieth century that its technique and indications were defined and described by Chevalier Jackson [3].

A tracheostomy tube is used to secure the airway in this procedure, which can be performed in patients on prolonged invasive mechanical ventilation [4, 5], with upper airway obstruction, undergoing laryngectomy, or at high risk of recurrent aspiration [6].

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Tracheostomy cannulae, when compared with endotracheal tubes, allow a reduction in respiratory work, less laryngeal injury, and easier oral hygiene, and may also enable oral feeding [1].

There is a wide range of tracheostomy tubes available, with different materials, sizes, and styles. On the tube's neckplate, its characteristics are marked, such as its inner and outer diameters and its length. Clinicians, intensive care professionals, and surgeons must know the differences between them in order to select suitable tubes for patients' needs [7–9].

Structure

Tracheostomy tubes have a main shaft (cannula) attached to a neckplate (or flange), and cuffed tubes have a pilot balloon, which shows whether the cuff is inflated. The neckplate has a slot where ties can be placed, and fenestrated tubes can have a cuff and/or inner cannula. Their insertion is aided with an obturator [10]. Figures 1 and 2 show the tracheostomy tube parts.

Materials

Tracheostomy tubes can be made from metal (silver or stainless steel) or, most commonly, from plastic (polyvinyl chloride, silicone, or polyurethane) [11, 12].

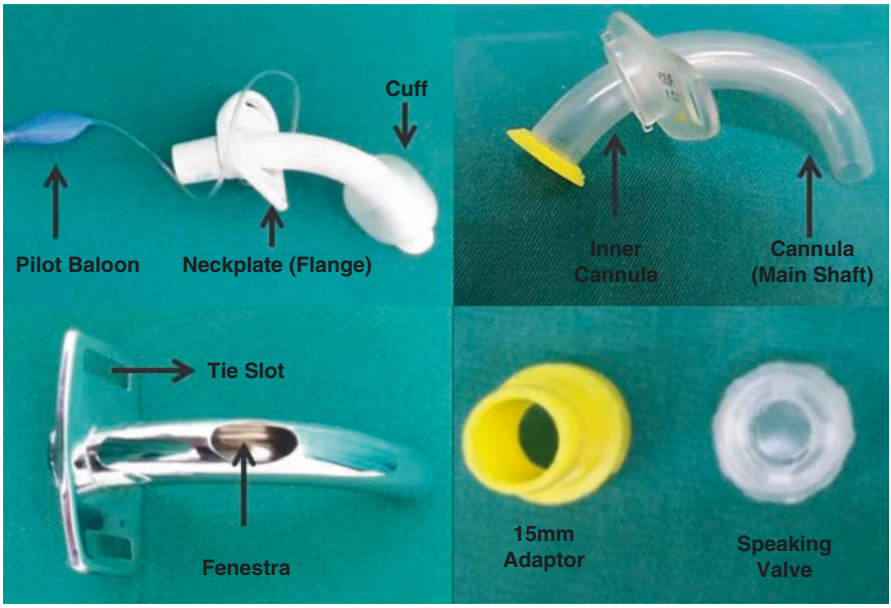

Fig. 1 Tracheostomy tube structure and parts

Fig. 2 Obturator and cuffed tracheostomy tube without an inner cannula

Metallic Tubes

The advantages of metal tubes are that they are endurable, inert, and resistant to biofilm formation; they limit bacterial growth; they are easily sanitized and can be sterilized [12]; and they are more cost effective for long-term use [10]. On the other hand, they are inelastic, do not have a cuff or a connector for mechanical ventilation, and can harm the trachea by heat or cold injury, hence they are not suitable for patients on radiation therapy whose radiation field is near the device [10, 12]. They are available from size 00 to size 12. Figure 3 shows standard metallic tubes and their inner cannulae from sizes 2 to 6.

The tube is inserted with the aid of a rounded-tip obturator through its lumen [12]; it has an inner cannula, and it can have fenestration and/or a speaking valve (Figs. 4, 5, and 6).

Plastic Tubes

Plastic tubes can be semiflexible or rigid. The first type adapts to the patient's anatomy, normally has a right angle, and has a longer cannula. The second type does not collapse or deflect, does not have a right angle, and is usually used for neck swelling, but it is not suitable for patients with thick necks, since its main shaft is short [10]. As with metal tubes, their insertion is aided by an obturator.

Fig. 3 Metallic conventional tracheostomy tube sizes 2, 3, 4, 5, and 6 with inner cannulae inserted

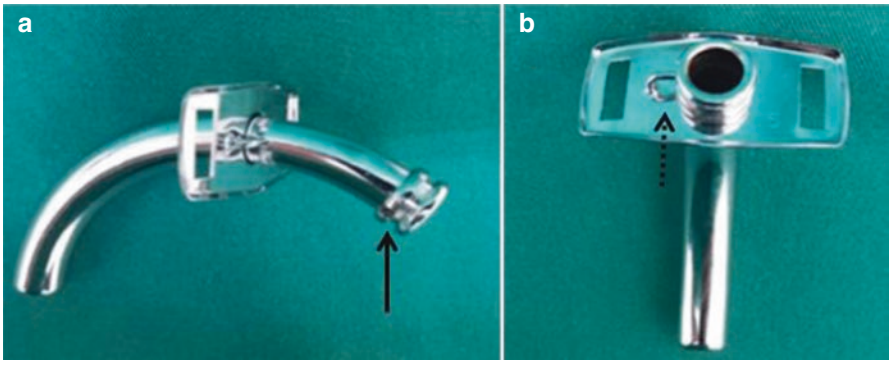

Fig. 4 (**a**) Metallic conventional tube and its inner cannula being inserted. The *arrow* points to the notch for the locking device (hook). (**b**) Front view of the same tube with the inner cannula already inserted. The inner cannula is turned (either clockwise or counterclockwise) after it is fitted to the hook (shown by the *dotted arrow*)

Fig. 5 The metallic speaking valve is a cap with a mobile plate; it is attached to the cannula and allows speech and breathing without manual occlusion or a cap

Fig. 6 Long conventional and fenestrated metallic tubes. The long tube is used for large necks or where there is a tumor in the stoma. The fenestrated tube is used to enable speech and can be used with or without a speaking valve

Polyvinyl chloride (PVC) adjusts to the patient's temperature and anatomy; silicone is soft, does not retain heat or cold, is resistant to colonization and biofilm, and can be sterilized [12] (Figs. 7, 11, 12, and 14).

Some authors recommend the use of plastic-cuffed tracheostomy tubes with an inner cannula, such as Bjork-Shiley tubes or Portex® tubes [1].

Cannula Types

Tracheostomy tubes may have an inner cannula or not. Those that do are dual-cannula tracheostomy tubes, and this feature allows periodic cleaning without removing the tube's main shaft or, when it occludes, ensures a patent airway [10–12]. Nonetheless, there is a lack of evidence that this helps to prevent pneumonia, and changing the inner cannula regularly in critical care units is not necessary [13]. Some inner cannulae may have an attachment for mechanical ventilation or fenestration [12]. Figure 8 shows capped, conventional, and 15 mm adapter inner cannulae.

On the other hand, an inner cannula decreases the inner diameter, resulting in additional work for breathing and paradoxical secretion adhesion [14, 15]. Carter et al. evaluated the effect of the inner tube of the Portex® Blueline Ultra® on the resistance and work of breathing through tracheostomy tubes. It was observed that the placement of the inner cannula significantly increased the work of breathing,

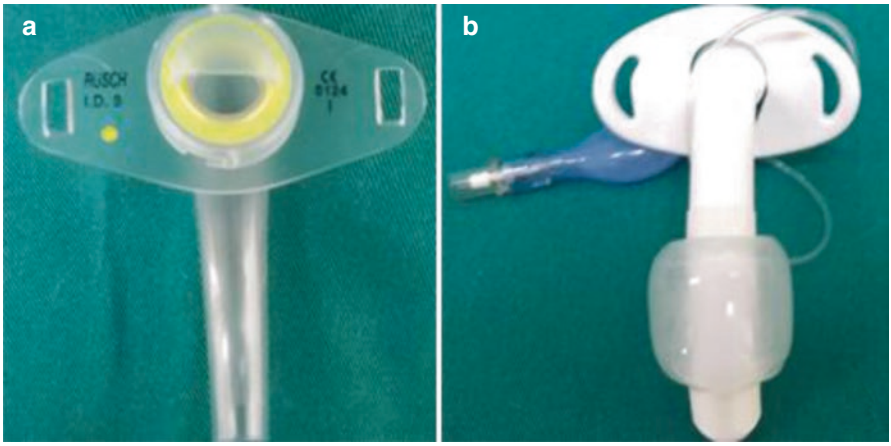

Fig. 7 **a** Rüsch® number 9 (inner diameter 9.0 mm) plastic uncuffed tube with an inner cannula and cough cap. **b** Shiley™ number 8 (inner diameter 7.6 mm) cuffed tube with an inner cannula

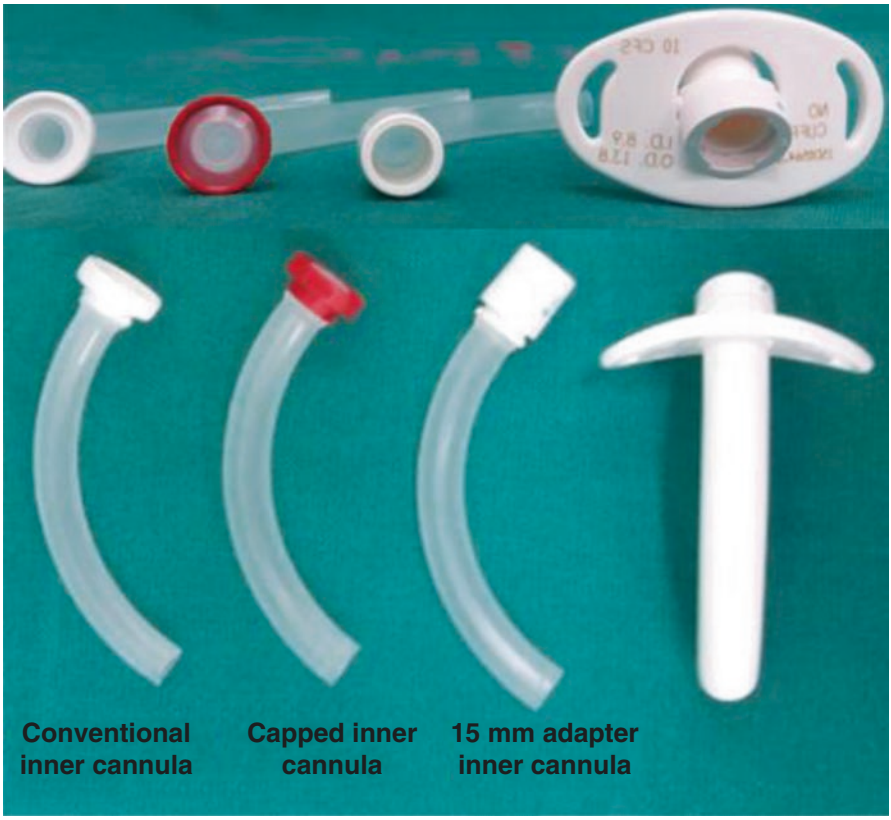

Fig. 8 Different inner cannulae. The capped inner cannula is used when the patient is being weaned, and it can be used with an uncuffed tube or a deflated cuffed tube. The 15 mm adapter connects to a mechanic ventilator, but a cuffed tube is needed in this scenario

Fig. 9 Portex® number 9 tube without an inner cannula, and Shiley™ number 9 tube with an equivalent outer diameter; there is an important difference between their inner diameters

and this effect was greatest with a size 7.0 tube [16]. However, this disadvantage must be weighed against the benefits of cleaning, and encrusted secretions may also reduce the inner tube diameter [17]. Figure 9 shows the difference in the inner diameters of plastic cannulae with the same outer diameter size but with and without an inner cannula.

A single cannula prevents an increase in the work of breathing, but it is not suitable for patients with excessive secretions or poor clearing [10].

Dimensions

The specifications of tracheostomy tubes are related to the dimensions of their length, curvature, and inner and outer diameters. These dimensions are not standardized; different manufacturers' tube sizes are not equivalent to each other, and the size usually corresponds to neither the inner nor the outer diameter [10–12]. Hence, different tube brands with the same size numbers might actually be quite different [12]. The size and the inner and outer diameters are usually marked on the neckplate of the tracheostomy tube (see Fig. 10) [10].

The International Organization for Standardization (ISO) has determined a sizing method based on the inner diameter of the outer cannula at its smallest dimension. Dual-cannula sizing considers the inner cannula as the functional diameter and the outer diameter as its largest diameter [12] (Table 1).

I.D. inner diameter, *NA* not available, *O.D.* outer diameter

With regard to tube length, tubes may be angled, standard, extra-length, or adjustable flange. For patients with large necks, long-flange tubes are necessary [11], and adjustable-flange tubes enables changing the tube's lenght when necessary—for instance, when there is granulation tissue or a tumor within the airway or between the skin and the trachea [18]. Figures 11, 12, and 13 show the distinctions

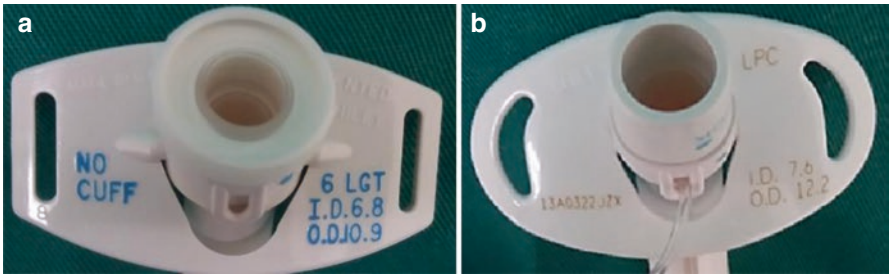

Fig. 10 Tracheostomy measurement specifications for a Shiley™ tube flange. **a** LGT (laryngectomy tube) number 6. **b** LPC (low-pressure cuff). Both have a nondisposable inner cannula. *I.D.* inner diameter, *O.D.* outer diameter

Table 1 Tracheostomy tube sizes

Size	Portex®		Shiley™		Jackson (metallic)	
	I.D. (mm)	O.D. (mm)	I.D. (mm)	O.D. (mm)	I.D. (mm)	O.D. (mm)
4	–	–	5.0	9.4	5.0	9.4
5	NA	NA	NA	NA	6.0	9.0
6	6.0	8.2	6.4	10.8	6.4	10.8
7	7.0	9.6	–	–	7.0	11.0
8	8.0	10.9	7.6	12.2	7.6	12.2
9	9.0	12.3	–	–	8.3	13.0
10	10.0	13.7	8.9	13.8	8.9	13.8

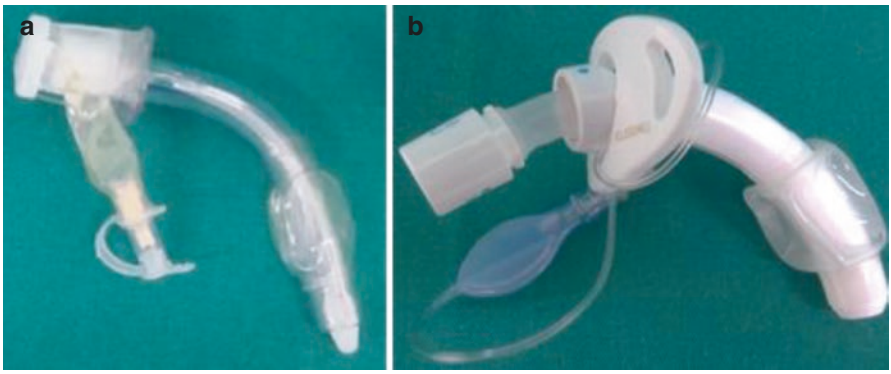

Fig. 11 (**a**) Plastic-cuffed angled tube without an inner cannula. (**b**) Plastic-cuffed curved tube with an inner cannula

in the curvature and length of tracheostomy tubes. The locking device must be secured so the tube will not be dislodged or move out of position [18]. In Fig. 14, an adjustable Portex® locking device mechanism is demonstrated.

When choosing the tracheostomy tube size, some factors must be considered, such as the size of the patient's neck, the stoma and trachea size, the presence of tumors or granulation tissue, the quality and quantity of secretions, and ventilator

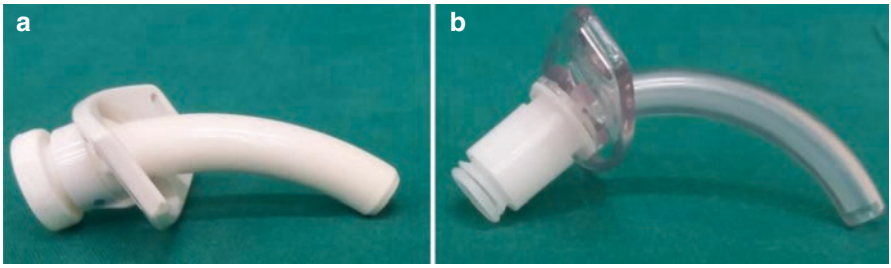

Fig. 12 (**a**) The Shiley™ LGT (laryngectomy tube) is shorter than the conventional Shiley™ DCFS (cuffless with disposable inner cannula) tube; the 6LGT length is 50 mm and the 6DCFS length is 76 mm. (**b**) The Portex® Blue Line size 6 is a standard cuffless tube with a disposable inner cannula tube, like the Shiley™ 6DCFS. Its length is 64.5 mm

Fig. 13 Extra-length and standard metallic tubes

and weaning needs [10]. If the inner diameter is too small, the resistance through it and respiratory work will be increased, and the cuff pressure required to seal the tracheal lumen will be higher. A large outer diameter prevents the patient from speaking when the cuff is deflated [12]. Figure 15 shows a schematic drawing of the difference between inner and outer diameter sizes.

The trachea in adult females has a smaller inner diameter than that in males, and tubes with a 6.0–6.5 mm inner diameter (10 mm outer diameter) are usually adequate for females, while tubes with a 7.0–8.0 mm inner diameter (11 mm outer diameter) are suitable for males [10, 12, 18]. In children, the diameter of the fifth finger is similar to the trachea size [10].

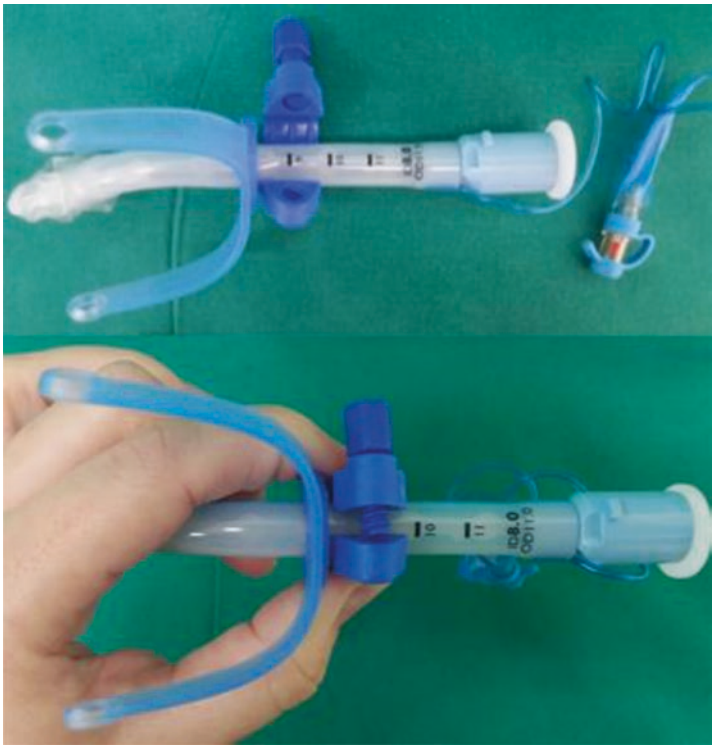

Fig. 14 Adjustable-flange tracheostomy tube. The flange size is set and then the locking device must be closed with the plastic screw

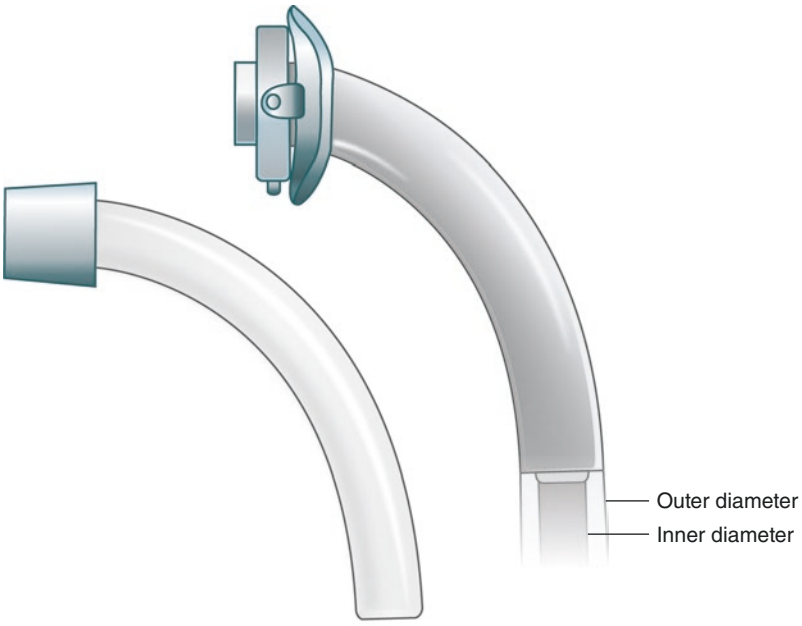

Fig. 15 Difference between inner and outer diameters

Fenestration

Fenestrated tubes have an opening on the posterior wall of the cannula, which allows the air to flow and be exhaled through it. This opening may consist of one large opening or several small ones [10–12]. A dual-cannula tube may or may not have a fenestrated inner cannula and may be cuffed or cuffless [10]. Figure 16 shows examples of metallic tube size 3, 4, 5, and 6 fenestrated cannulae.

This feature is important for preparing the patient for decannulation and phonation. When it is plugged and the cuff (if present) is deflated, the air flows to the upper airway through this opening and around the cannula. This makes it possible to assess the patient's ability to breathe using the upper airway, and allows phonation. When the patient is using a cuffed tube, it must be deflated before occluding the cannula [10–12]. A fenestrated tube model, showing its inner cannula and cap, is shown in Fig. 17.

Fig. 16 Metallic fenestrated tubes with fenestrated inners

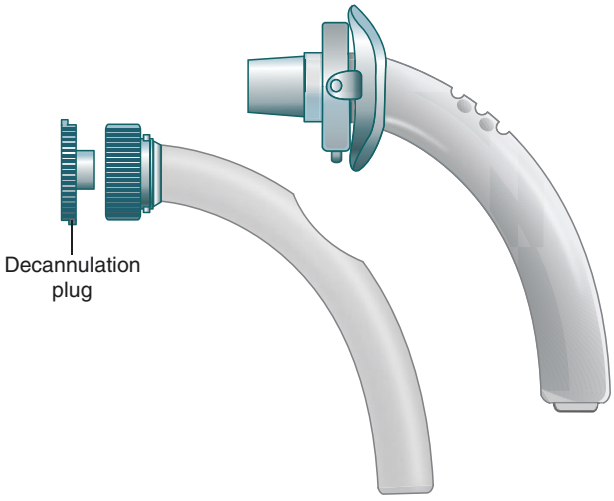

Fig. 17 Model of a fenestrated tube and inner cannula. The decannulation plug can be used while the patient is being weaned

These tubes may be difficult to fit, and the distance from the neckplate to the fenestration should be 1 cm longer than the stoma tract length for better adaptation [19]. Otherwise, the air will not pass to the upper airway and there will be an increase in flow resistance. Despite correct positioning, there may be other problems—such as granulation tissue induced by the fenestrations, resulting in impairment of the airway—and the position of the fenestrations should be checked periodically [20].

Cuffed and Cuffless Tracheostomy Tubes

Cuffed Tubes

Tracheostomy tubes may be cuffed or uncuffed (cuffless). The cuff is a rounded dilatation located in the distal part of the cannula, which seals the airway, providing a closed system for airway protection and ventilation [10–12, 21]. There are high-volume low-pressure, low-volume high-pressure, and foam cuffs [12].

High-volume low-pressure cuffs are the most commonly used type. They have a large diameter and a large residual volume, so the resting volume is larger than the patient's tracheal diameter, and the thin flexible material of the wall adapts easily to the tracheal wall when inflated [22]. Nonetheless, if excessive pressure is applied to the tracheal wall, there may be damage to its mucosa [23].

The cuff pressures used in current standard practice range from 20 to 30 cm H_20 (15–22 mmHg) to provide sealing of the airway and to prevent aspiration, preventing damage to the tracheal wall [12, 23]. Monitoring of the intracuff pressure should be performed at least once per shift and more often if necessary (e.g., if a leak occurs, if the position or the tube are changed, or if the volume of air is changed) [12]. Besides the risk of tracheal wall injury, higher cuff pressure impairs the swallowing reflex [24].

High pressure is commonly caused when the tube is small and the cuff must be overfilled in order to seal the trachea, or by tube malpositioning, low-pressure high-volume cuffs, and tracheal dilatation [12].

A low-volume high-pressure cuff is suitable for patients receiving intermittent cuff inflation, because it allows the air to flow around the tube while deflated, so speech and upper airway use are possible. It is a silicone cuff, which should be filled with sterile water, because if it is inflated with air, it will deflate due to gas permeability [12]. Figure 18 compares low-volume high-pressure cuffs and high-volume low-pressure cuffs, demonstrating how those cuffs interact with the tracheal wall.

Foam cuffs are not commonly used; they contain autoexpanding foam composed of polyurethane foam covered by a silicone sheath, which conforms to the patient's airway shape [12, 25]. These cuffs inflate passively at ambient atmospheric pressure and, if used properly, this pressure will not exceed 27 cm H_20 (20 mmHg). Their insertion and removal are harder, and the air should be removed with a syringe, which is disconnected when the tube is in place. The pilot tube is opened and the cuff keeps its pressure balanced with the atmospheric pressure (observe in Fig. 19 the Bivona® tube device for cuff inflation control). Nonetheless, they have to be

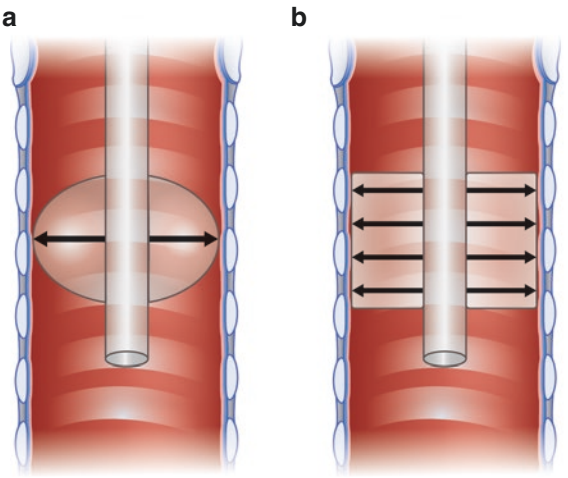

Fig. 18 Pressure is force per unit area. (**a**) Low-volume high-pressure cuffs are spherical and have a smaller area of contact with the tracheal wall, thus a higher pressure. (**b**) High-volume low-pressure cuffs are barrel-shaped and touch a bigger area, with lower pressure applied to the tracheal mucosa

Fig. 19 The Bivona® Adult Fome-Cuff® has a foam cuff and comes with a 60 mL syringe, which helps in controlling the cuff's inflation while attached to a three-way stopcock, aiding insertion and measurement of the cuff volume. (Reproduced from Smiths Medical [34])

Fig. 20 Plastic tube with a supraglottic suction device. *Blue dye* highlights the suction port path in this picture

periodically deflated so that humidity is removed from the sponge and to keep the silicone sheath from adhering to the tracheal wall. They are not suitable for patients with one-way speaking valves, since they seal the lower airway, and so they are reserved for patients with tracheal injury caused by cuffed cannulae [12, 26].

Cuffs, either deflated or inflated, may increase the work of breathing, and they should be replaced with a cuffless tube while the patient is in the process of weaning [27].

Some cuffed tracheostomy tubes have a suction port above the cuff to remove subglottic secretions [18]. Their role in preventing ventilator-associated pneumonia (VAP) in patients with endotracheal tubes has been shown in meta-analyses, with a reduction in VAP of approximately 50% [28, 29]. Ledgerwood et al. also observed fewer cases of VAP and trends toward reductions in the intensive care unit stay and the time of mechanical ventilation in patients with a tracheostomy tube and a subglottic suction port [29]. Nonetheless, there have been no large clinical trials, nor meta-analyses, on subglottic suction devices in tracheostomy tubes. A tracheostomy tube with a suction port is shown in Fig. 20, with its path highlighted and distal port magnified.

Cuffless Tubes

Cuffless (uncuffed) tracheostomy tubes allow air to flow to the upper airway and allow stomal maintenance. They are used when mechanical ventilation is no longer required but the airways still need to be accessed. There are plastic and metal models available. Figure 21 shows plastic and metallic uncuffed tubes.

Some factors must be addressed before a cuffless tracheostomy tube is used. First the patient has to be able to breathe spontaneously and swallow without significant aspiration. Once the patient is fitted with the cuffless tube, its opening can

Fig. 21 Plastic and metallic cuffless tubes

Table 2 Sizing chart for Portex® cuffed tracheostomy tubes (Blue Line Ultra® with Suctionaid® and Blue Line Ultra®)

Size	I.D. (mm)	I.D. with inner cannula (mm)	O.D. (mm)	Length (mm)	Cuff O.D. (mm)
6	6.0	5.0	9.2	64.5	20.0
7	7.0	5.5	10.5	70.0	24.0
7.5	7.5	6.0	11.3	73.0	30.0
8	8.0	6.5	11.9	75.5	30.0
8.5	8.5	7.0	12.6	78.0	30.0
9	9.0	7.5	13.3	81.0	30.0
10	10.0	8.5	14.0	87.5	30.0

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

be closed with the patient's (or caregiver's) finger, be capped, or a speaking valve can be used for speech.

Plastic uncuffed tubes are used in patients receiving head and neck radiotherapy to prevent stoma and tracheal wall burn [10, 12, 18, 26].

Tracheostomy Tube Sizes

The sizing charts shown in Tables 2, 3, 4, 5, 6, 7, 8, 9, and 10 are adapted from the Austin Health Tracheostomy Review and Management Service (TRAMS) tracheostomy sizing chart [30] (see also Figs. 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, and 33).

Table 3 Sizing chart for Portex® adjustable-flange tracheostomy tubes (Blue Line Ultra®)

Size	I.D. (mm)	O.D. (mm)	Length (mm)	Cuff O.D. (mm)
6	6.0	8.3	59–81	20.0
7	7.0	9.7	64–84	24.0
8	8.0	11	73–97	30.0
9	9.0	12.4	78–111	30.0
10	10.0	13.7	84–123	30.0

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 4 Sizing chart for Portex® Uniperc™ Adjustable Flange Tracheostomy Tubes

Size	I.D. (mm)	I.D. with inner cannula (mm)	O.D. (mm)	Length (mm)
7	9.3	7.0	11.6	62
8	10.3	8.0	12.6	68
9	11.3	9.0	13.6	74

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 5 Sizing chart for Bivona® foam cuff tracheostomy tubes (Bivona® Adult Fome-Cuff®)

Size	I.D. (mm)	O.D. (mm)	Length (mm)
5	5.0	7.3	60.0
6	6.0	8.7	70.0
7	7.0	10.0	80.0
8	8.0	11.0	88.9
9	9.0	12.3	98.0
9.5	9.5	13.3	98.0

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 6 Sizing chart for Shiley™ cuffed tracheostomy tubes: cuffed with an inner cannula (LPC) and fenestrated (FEN)

Size	I.D. (mm)	O.D. (mm)	Length (mm)
4	5.0	9.4	65
6	6.4	10.8	76
8	7.6	12.2	81
10	8.9	13.8	81

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 7 Sizing chart for Shiley™ tracheostomy tubes with a disposable inner cannula: cuffed (DCT), cuffed and fenestrated (DFEN), percutaneous (PERC), cuffless (DCFS), and cuffless and fenestrated (DCFN)

Size	I.D. (mm)	O.D. (mm)	Length (mm)
4	5.0	9.4	62
6	6.4	10.8	74
8	7.6	12.2	79
10	8.9	13.8	79

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 8 Sizing chart for Shiley™ flexible tracheostomy tubes: cuffed and uncuffed (CN/UN)

Size	I.D. (mm)	I.D. with inner cannula (mm)	O.D. (mm)	Length (mm)
4	6.5	5.5	9.4	62.0
5	7.0	6.0	10.1	68.0
6	7.5	6.5	10.8	74.0
7	8.0	7.0	11.4	77.0
8	8.5	7.5	12.2	79.0
9	9.0	8.0	12.7	79.0
10	10.0	9.0	13.8	79.0

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 9 Sizing chart for Shiley™ XLT tracheostomy tubes with extra length

Size	I.D. (mm)	O.D. (mm)	Proximal length (mm)	Distal length (mm)	Total length (mm)
5 distal	5.0	9.6	5.0	48.0	90
5 proximal	5.0	9.6	20.0	33.0	90
6 distal	6.0	11.0	8.0	49.0	95
6 proximal	6.0	11.0	23.0	34.0	95
7 distal	7.0	12.3	12.0	49.0	100
7 proximal	7.0	12.3	27.0	34.0	100
8	8.0	13.3	15.0	50	105
8	8.0	13.3	30.0	40.0	105

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Table 10 Sizing chart for Cook® Versa™ tracheostomy tubes

Size	I.D. (mm)	I.D. with inner cannula (mm)	O.D. (mm)	Length (mm)	Cuff O.D. (mm)	Angle (°)	Color
7	7.0	6.0	10.0	78.0	25.0	96	Green
8	8.0	7.0	11.0	86.0	28.0	96	White
9	9.0	8.0	12.0	98.0	30.0	98	Blue

Adapted from the Austin Health Tracheostomy Review and Management Service [30]
I.D. inner diameter, *O.D.* outer diameter

Fig. 22 Two tube models with inflated cuffs. The first is a model with a subglottic suction port and the second is without one. (Reproduced from Smiths Medical [34])

Fig. 23 Portex® Blue Line Ultra® adjustable-flange tube. (Reproduced from Smiths Medical [34])

Fig. 24 The Portex® UniPerc® adjustable-flange tube is a percutaneous tube with a flexible polytetrafluoroethylene (PTFE) inner cannula with a nonstick surface. (Reproduced from Smiths Medical [34])

Fig. 25 Bivona® Fome-Cuff® and cuff maintenance device (CMD™). (Reproduced from Smiths Medical [34])

Fig. 26 Shiley™ LPC (low-pressure cuff). (Reproduced from Medtronic [31])

Fig. 27 Shiley™ FEN (fenestrated) tube with its cap (in *red*), inner cannula with a 15 mm adapter, obturator, and fenestrated inner cannula. (Reproduced from Medtronic [31])

Fig. 28 Shiley™ DCT (disposable cuffed tube) and Shiley™ DFEN (cuffed and fenestrated tube). The *red plug* is the cap for tube occlusion. (Reproduced from Medtronic [31])

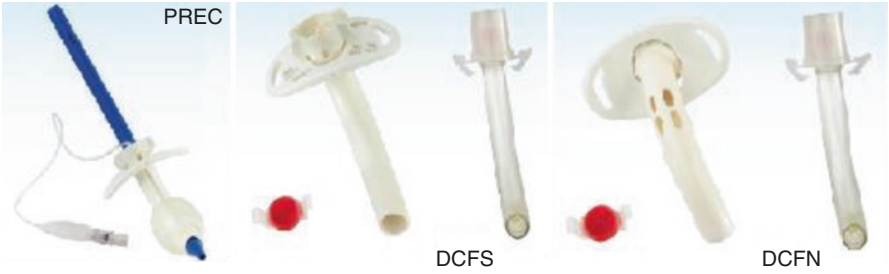

Fig. 29 Shiley™ PERC (percutaneous) tube with its introducer, Shiley™ DCFS (cuffless with disposable inner cannula) tube, and Shiley™ DCFN (cuffless and fenestrated) tube, each with its inner cannula and cap. (Reproduced from Medtronic [31])

Fig. 30 Cuffed and uncuffed Shiley™ flexible tubes. (Reproduced from Medtronic [31])

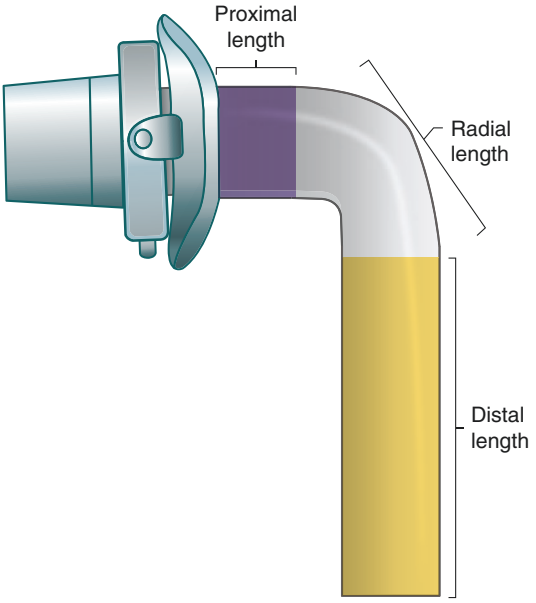

Fig. 31 Tracheostomy tube length measurements

Fig. 32 Uncuffed and cuffed Shiley™ XLT tubes. (Reproduced from Medtronic [31])

Fig. 33 Cook® Versa™ tracheostomy tube size 7. (Reproduced from Austin Health Tracheostomy Review and Management Service [30])

Conclusion

There is a wide range of tracheostomy tubes available for different clinical settings. The clinician must be familiar with them to choose a suitable tube for each patient and occasion.

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