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Prevention of Kinking of a Percutaneous Transtracheal Intravenous Catheter

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Background: **Transtracheal jet ventilation (TTJV) through a percutaneously inserted intravenous/TTJV catheter, using a high-pressure oxygen source and noncompliant tubing is a simple and quick method of effective ventilation, especially in a patient in whom the lungs cannot be ventilated *via* mask and/or whose trachea cannot be intubated. TTJV becomes impossible if any part of the plastic portion of the TTJV catheter kinks; although the incidence of this problem is not known, kinking of the catheter is most likely to occur as the catheter turns from a predominantly posterior to a predominantly caudad direction. These experiments tested the hypothesis that a small-angle bend in the tip of the TTJV catheter would reduce the requirement to aim the entire TTJV catheter in a caudad-directed orientation.**

Methods: **A model of the trachea was designed using polyvinylchloride tubing to observe TTJV catheter insertion and plastic catheter kinking. The TTJV catheters were inserted at 0, 5°, 10°, 15°, 20°, 25°, and 30° angles in trials of 15 times each. Small-angle bends, placed at 2.5 cm from the distal end of the TTJV catheter, of 0, 5°, 10°, 15°, and 20° were used, and each bent TTJV catheter was inserted at each of the above insertion angles 15 times.**

Results: **Increasing the angle of insertion decreased the incidence of kinking of the TTJV catheter at every small-angle bend in the tip of the TTJV catheter. Increasing the small-angle bend in the tip of the TTJV catheter decreased the incidence of kinking with every angle of insertion. A small-angle bend in the tip of the TTJV catheter and the angle of insertion often were complementary in their ability to decrease the incidence of kinking. With a cumulative angle of 10°, 98% of the plastic catheters kinked, compared to 0 in trials involving a cumulative angle of 30° or more. Analysis *via* the chi-squared test yielded a *P* value of <0.0001 when comparing incidence of kinking for cumulative angles of 10–30°.**

Conclusions: **A modest bend in the tip of the TTJV catheter greatly reduces the sharpness of the angle of insertion required to eliminate kinking of the plastic catheter. Because the risk/benefit ratio is so low, we suggest that a small-angle bend of 15° should always be created and, combined with a 15° angle of insertion, should result in a rare incidence of kinking. (Key words: Equipment: intravenous catheter; percutaneous catheter. Management: airway; difficult airway; trachea. Ventilation: jet ventilation; transtracheal jet ventilation.)**

TRANSTRACHEAL jet ventilation (TTJV) through a percutaneously inserted intravenous/TTJV catheter, using a high-pressure oxygen source and noncompliant tubing is a simple, quick, effective method of ventilation, especially in the patient in whom the lungs cannot be ventilated *via* mask or whose trachea cannot be intubated. However, TTJV will not be possible if the percutaneous plastic portion of the TTJV catheter kinks. Although we do not know the incidence of this problem, kinking of the catheter is most likely to occur as the shaft of the plastic catheter turns from a predominantly posteriorly directed axis to a predominantly caudad-directed axis. Obviously, at the time of percutaneous insertion, the greater the caudad orientation of the shaft of the TTJV catheter, the smaller will be the risk of kinking. Unfortunately, the tip of the jaw can severely limit the caudad-directed insertion orientation of the TTJV catheter, and in this situation, the risk of kinking is increased. Putting a small-angle bend near the distal end of the needle stylet gives extra caudad-direction to the distal end of the TTJV catheter. This small-angle bend near the distal end of the TTJV catheter should reduce the initial insertion caudad-directed orientation requirement for the rest of the TTJV catheter shaft, thereby possibly preventing kinking. These experiments tested this hypothesis in an artificial model.

Methods

Experimental Model

A model of the trachea was designed to simulate and allow for observation of TTJV catheter insertion and

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plastic catheter kinking. Polyvinylchloride tubing with an internal diameter of 16 mm was used. A 3 × 12-cm rectangle of the anterior surface of the polyvinylchloride tubing was cut out, and a similarly sized rectangle of rubber-band material (Esmark bandage/tourniquet) was stretched with a moderate amount of tension over the cut-out area and secured.

Fourteen-gauge intravenous/TTJV catheters (Insyte, 2-inch, Becton Dickinson Vascular Access, model #H-2491A, Vialon material) were used. (TTJV catheter refers to the plastic catheter-needle stylet combination.) The TTJV catheters were inserted into the tubing through the rubber-band material in a caudad direction (angle of insertion) approximately 8 mm deep. The angle of insertion was defined as the angle created between a line drawn perpendicular to the long axis of the trachea and the long shaft of the TTJV catheter at the onset of insertion (fig. 1). The needle stylet was held steady while the plastic catheter was advanced into the polyvinylchloride tubing by threading it over the needle stylet. Once the plastic catheter was completely inserted (the hub of the plastic catheter touched the anterior surface of the rubber membrane), the needle stylet was completely removed. Fresh intravenous catheters were used after five insertions that did not result in kinking and/or any insertion that did result in kinking. The rubber-band material was changed as needed so that each insertion of a TTJV catheter was through a fresh portion of the rubber-band material.

Angles of insertion and small-angle bends in the TTJV catheter were measured by a protractor. Small-angle bends of 0 (straight needle), 5°, 10°, 15°, and 20° were placed in the TTJV catheter 2.5 cm proximal to the needle stylet tip (fig. 1). Bends were limited to 20° because bends of 25° or more did not allow the plastic catheter to be threaded over the needle stylet easily. Small-angle bends were made by placing the tip on a hard-surface and pushing downward using the thumb to place the bend in the TTJV catheter. The method used to place the bend in the catheter did not interfere with the structural integrity of the catheter tip.

What Was Measured

Kinking of the catheter was defined as the touching of diametrically opposite sides of the plastic catheter alone (without needle stylet) at a point of sharp curvature (caving-in of one side of the plastic catheter wall toward the other) and was observed visually. Kinking always occurred at the point of sharpest posterior-to-caudad direction change.

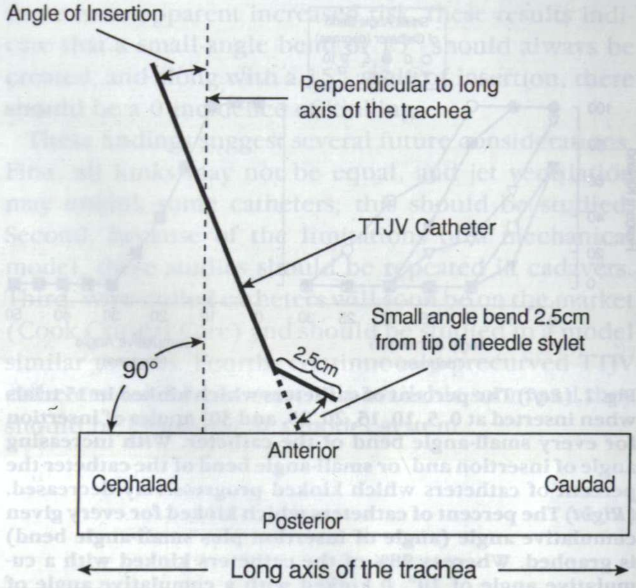

Fig. 1. The schematic diagram shows our definition of angle of insertion and small-angle bend 2.5 cm from the distal end of the needle stylet.

Experimental Sequence

The TTJV catheters were inserted at 0, 5°, 10°, 15°, 20°, 25°, and 30° angles in trials of 15 times each. Small-angle bends of 0, 5°, 10°, 15°, and 20° were used, and each bent TTJV catheter was inserted at each of the above insertion angles 15 times.

Statistics

The chi-squared test was used to determine whether the cumulative angles were significantly associated with kinking of the catheter.

Results

Increasing the angle of insertion decreased the incidence of kinking of the TTJV catheter at every small-angle bend in the tip of the TTJV catheter, and increasing the small-angle bend in the tip of the TTJV catheter decreased the incidence of kinking with every angle of insertion (fig. 2, left). The small-angle bend in the tip of the TTJV catheter and the angle of insertion summated in decreasing the incidence of kinking (fig. 2, right). With a cumulative angle of 10°, 98% of the plastic catheters kinked, compared to 0 in trials involving a cumulative angle of 30° or more. Analysis *via* chi-squared test yielded a *P* value of < 0.0001 when

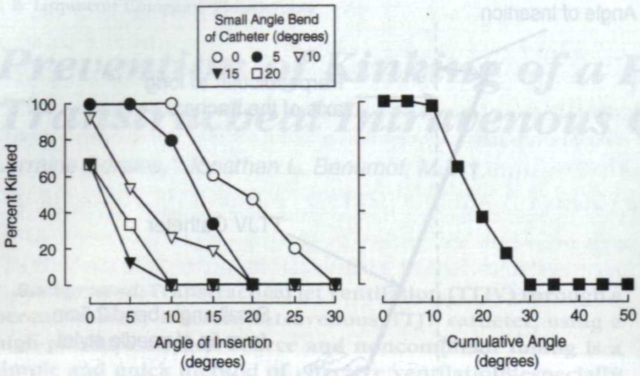

Fig. 2. (*Left*) The percent of catheters which kinked in 15 trials when inserted at 0, 5, 10, 15, 20, 25, and 30° angles of insertion for every small-angle bend of the catheter. With increasing angle of insertion and/or small-angle bend of the catheter the percent of catheters which kinked progressively decreased. (*Right*) The percent of catheters which kinked for every given cumulative angle (angle of insertion plus small-angle bend) is graphed. Whereas 98% of the catheters kinked with a cumulative angle of 10°, 0 kinked with a cumulative angle of 30°. Analysis *via* the chi-squared test yielded a *P* value of <0.0001 when comparing incidence of kinking for cumulative angles 10–30°.

comparing incidence of kinking for cumulative angles 10–30°.

Discussion

We found that a small-angle bend placed in the TTJV catheter before insertion significantly decreases the incidence of kinking of the plastic catheter at every given angle of insertion. Before discussing the clinical importance of these findings, consideration should be given to the limitations of our experimental model.

Several aspects of our experimental model may not accurately reflect clinical practice. First, the technique of creating a small-angle bend near the tip of the TTJV catheter was chosen to simulate the method an anesthesiologist might use in an emergent situation. Nevertheless, it is obvious that an anesthesiologist in a great hurry might bend the catheter shaft at a point different from that employed here (2.5 cm back from the tip) and thereby alter the risk of kinking. Second, kinking of the plastic catheter could only be secondary to hitting the back of the polyvinylchloride tubing (posterior trachea) on insertion. However, in clinical practice the plastic catheter may also kink at the skin line if the skin were severely retracted in one direction at the time of insertion and then subsequently quickly released. Third, in situations in which head and neck extension is severely limited (or the neck is fixed in some degree of flexion), the tip of the jaw may not permit a TTJV catheter with a syringe attached to enter the trachea at any caudad-directed angle of insertion. Fourth, the results obtained apply to entry into the trachea 8 mm deep. Clinically, there is variability in tracheal size and layers of adipose and connective tissue, other pathologic subcutaneous material may be present (*e.g.*, edema, air, blood, infection), and it may be difficult to determine exactly where the TTJV catheter lies within the trachea. Variability in intratracheal location will cause variability in the risk of kinking. Fifth, our Esmark bandage has elasticity in all directions, whereas the cricothyroid membrane has elastic fibers running in a cephalocaudad direction. It is possible that multiple separate puncture holes in the Esmark bandage could have created unrealistic/unequal pulling forces or tensile strength of the Esmark bandage, thereby altering the incidence in kinking. Sixth, it is possible that the incidence of kinking may be higher in our mechanical model compared to patients because the tip of the catheter impacts on a relatively rigid plastic surface compared to the relatively compliant posterior membrane of the trachea. Seventh, the Insyte intravenous catheters used in our study were made of 100% Vialon material. However, other intravenous catheters used in the United States are made of 100% Teflon. Vialon has been shown to have less kink resistance than Teflon; *i.e.*, the force required to kink a straight tube of Teflon is greater than that for Vialon. However, the kink recovery of Vialon is 97% after 1 min, which is superior to that of Teflon. Finally, Teflon material has a higher kink memory, or a greater propensity to rekink at the same point it kinked in the past. Therefore, the results obtained here may differ if Teflon material were used. Finally, no air flow was used. Kinking as we have defined it may not hinder the oxygen supply to the patient or may be eliminated by jet ventilation.

Two other techniques of placing the TTJV catheter were not included in the full study because of important negative preliminary findings. In one method, after penetration of the trachea, both the needle stylet and plastic catheter are advanced together after pulling the needle stylet approximately 2 mm from the catheter tip. This method of TTJV insertion caused plastic catheter kinking at every angle of insertion as the catheter hit the posterior wall of the polyvinylchloride tubing, unless the needle-stylet/plastic catheter combination was almost parallel to the long axis of the trachea. In addition, this method of insertion might predispose to shearing of the catheter tip. This method of catheter advancement is suboptimal. In a second technique, the needle stylet is pulled out, and the plastic catheter is advanced alone after the initial 8-mm-deep insertion. This method was not used, because with the needle stylet removed, the TTJV catheter behaved as if it had 0 bend at every angle of insertion.

The clinically relevant message is simple: putting a small bend in the tip of the TTJV catheter greatly reduces the sharpness of the angle of insertion required to eliminate kinking of the plastic catheter. Because there is no apparent increased risk, these results indicate that a small-angle bend of 15° should always be created, and along with a 15° angle of insertion, there should be a 0 incidence of kinking.

These findings suggest several future considerations. First, all kinks may not be equal, and jet ventilation may unkink some catheters; this should be studied. Second, because of the limitations of a mechanical model, these studies should be repeated in cadavers. Third, wire-coiled catheters will soon be on the market (Cook Critical Care) and should be studied in a model similar to ours. Fourth, continuously precurved TTJV catheters may be commercially available soon, and they should be evaluated in a model system.