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Title : PHYSICAL CHARACTERISTICS OF ENDOTRACHEAL TUBES

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Introduction. Concern over laryngeal and tracheal injury from endotracheal (ET) tubes has prompted changes in tube material and design. This study was done to compare physical characteristics of currently used ET tubes.

Methods. Radius of curvature, angle and direction of bevel, effective cuff length, wall thickness, internal diameter (ID), collapse force to 50% ID and angle of kink were measured on 50 size 8 endotracheal tubes supplied by 9 manufacturers (6 from 8 companies and 2 ET tubes from 1). Collapse force and kink angle were measured twice 30 seconds apart at 37°C. Durometry was measured on 3 size 9 Ohio, Shiley, Argyle, Lanz, Portex (2 lots), and National Catheter Polyvinyl Chloride (PVC) tubes. Three smaller PVC Rusch tubes were also measured for hardness. Dimensions were measured according to the 1974 American National Standards Institute (ANSI) standard for Murphy tracheal tubes (Z-79.5). Compass, ruler, adjustable protractor, vernier caliper, spring scale, and Shore durometer hardness meter were used.

Results. Data is summarized in the following three charts.

Endotracheal Tube	Radius of Curvature (cm)	Bevel Angel (°)	Bevel Direction (°)	Distance Bevel to Cuff (mm)	Cuff Length (mm)
Rusch (red rubber) n=6	15.78 ± 1.48	56 ± 1.63	85 ± 3.94	27.22 ± 1.27	27.59 ± 12.08
Bivona n=6	13.95 ± 2.02	46 ± 1.10	80 ± 27.22	29.12 ± .66	44.93 ± 1.69
Portex (blue line) n=6	13.57 ± .66	42 ± 1.03	107 ± 7.36	31.52 ± .80	35.12 ± .88
Lanz n=6	13.35 ± .73	49 ± .98	107 ± 17.51	29.67 ± .49	38.45 ± .60
Shiley n=6	15.12 ± .44	47 ± 1.64	88 ± 13.35	23.35 ± .61	45.28 ± 1.20
Ohio n=6	13.42 ± 1.22	46 ± 1.33	97 ± 12.47	27.42 ± .63	43.58 ± .80
Argyle n=6	13.23 ± .59	47 ± 1.47	92 ± 2.28	29.50 ± .63	41.80 ± .79
National Catheter Hi-Lo n=6	13.07 ± .52	39 ± 1.03	89 ± 2.79	23.12 ± .78	40.75 ± .55
Rusch (safety) n=2	13.60 ± .71	49 ± 1.41	73 ± 2.83	32.60 ± 1.41	39.90 ± .42

Endotracheal Tube	Wall Thickness (mm)	Internal Diameter (mm)	Collapse Force (gms)	Kink Angle (°)
Rusch (red rubber) n=6	1.77 ± .12	7.58 ± .17	3103 ± 634 3058 ± 594	87 ± 3.60 96 ± 4.00
Bivona n=6	1.86 ± .05	8.13 ± .15	2803 ± 259 2766 ± 267	60 ± 1.90 78 ± 4.90
Portex (blue line) n=6	1.39 ± .02	8.06 ± .29	1633 ± 154 1421 ± 145	77 ± 3.10 87 ± 2.60
Lanz n=6	1.38 ± .03	8.24 ± .21	1126 ± 166 1020 ± 148	84 ± 2.80 94 ± 2.80
Shiley n=6	1.49 ± .02	8.04 ± .15	1655 ± 212 1489 ± 199	79 ± 3.20 91 ± 3.40
Ohio n=6	1.35 ± .04	8.08 ± .11	1580 ± 168 1534 ± 158	76 ± 2.80 85 ± 3.50
Argyle n=6	1.50 ± .00	7.78 ± .16	1784 ± 106 1670 ± 112	74 ± 1.40 87 ± 4.30
National Catheter n=6	1.39 ± .05	8.10 ± .22	1897 ± 266 1731 ± 275	67 ± 2.70 78 ± 4.70
Rusch (Safety) n=2	1.65 ± .07	7.85 ± .17	1610 ± 288 1474 ± 352	52 ± 2.80 67 ± 2.10

Endotracheal Tube	Number of Readings	Durometer Reading (70°F)	Durometer Reading (37°C)
Portex n=2	10	82.00 ± 1.60	75.70 ± 1.57
Portex n=1	5	72.80 ± 1.64	65.40 ± 1.82
Lanz n=3	15	81.67 ± 1.05	74.33 ± 1.23
Shiley n=3	15	81.13 ± 1.19	75.40 ± 1.06
Ohio n=3	15	82.13 ± 1.55	75.87 ± 1.41
Argyle n=3	15	83.13 ± 1.46	76.33 ± 1.29
National Catheter n=3	15	82.93 ± 1.28	75.13 ± 1.06
Rusch n=1	5	82.00 ± 1.00	75.00 ± .71
Rusch n=1	5	76.40 ± .89	71.40 ± 1.52
Rusch n=1	5	82.80 ± .45	73.40 ± 1.14

Discussion. The American National Standard for Murphy tracheal tubes, recommending tube and cuff dimensions and tolerance, is intended as a guide to aid the manufacturer, the consumer, and the general public. Our data indicates deviation from the standard among tubes and variability in physical characteristics between tubes. The bevel of all tubes studied faced left, but bevel direction deviated widely from 90°. Portex and Lanz were 17° above and Rusch "safety" tube 17° below 90°. The Rusch "safety" tube resisted kinking the best and was thicker than other PVC tubes. It is hard to explain the variability in collapse force between PVC tubes of similar thickness and hardness. The silastic Bivona tube's geometry and thickness may account for the large force necessary to collapse the tube to 50% of its ID and its resistance to kink. It also appears to have the greatest memory (kinked easier the second time). Silastic and rubber hardness could not be measured with our durometer hardness meter. As expected durometry decreased as PVC tubes warmed to body temperature. One Portex and one Rusch tube were much less hard than other PVC tubes. These softer tubes may well collapse and kink easier. Hardness appears to vary with different batches of PVC suggesting the need for a durometer standard. The force necessary to deform a tube to conform to airway anatomy is also influenced by hardness, thickness and geometry. Anatomically shaped tubes undergo less deformation when properly placed and presumably will be less traumatic to the airway. Checking the severity of tube trauma against tube physical characteristics may help to establish a standard for the ideal ET tube.