### WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

**Worksheet author(s)**

| Eugene Freid, | Date Submitted for review: 11/09/09 |

**Clinical question.**

For infants and children who require endotracheal intubation (prehospital or inhospital) (P), does a specific formula (I) to guide endotracheal tube size (I), as opposed to the existing formula of 3 + age/4 (C) achieve better outcomes (eg. successful tube placement) (O)?

**Is this question addressing an intervention/therapy, prognosis or diagnosis?** Intervention

**State if this is a proposed new topic or revision of existing worksheet:** New topic

**Conflict of interest specific to this question**

No relevant conflicts of interest.

**Search strategy (including electronic databases searched).**


- 1. MESH heading: Intubation, intratracheal/ *adverse effects/instrumentation.
- 2. MESH heading: laryngeal edema/*etiology/*prevention and control
- 3. Endotracheal tube size
- 4. Endotracheal tube and formula
- 5. Endotracheal tube and complications

**State inclusion and exclusion criteria**

**Include:** all child 0-18 years, formula or length based tracheal tube size

**Exclude:** uncuffed endotracheal tube, review articles

**Number of articles/sources meeting criteria for further review:**

- 70 articles initially reviewed, 6 meet criteria for inclusion in worksheet
## Summary of evidence

### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Evidence Supporting Clinical Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Dullenkopf 2006 (B), Salgo 2006 (B)</td>
</tr>
<tr>
<td>Fair</td>
<td>Dullenkopf 2005 (B), Duracher 2008 (A)</td>
</tr>
<tr>
<td>Poor</td>
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</tbody>
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**Level of evidence**

A: Supports specific new formula, standard tracheal tube

B: Supports specific new formula, Microcuff tracheal tube
### Evidence Neutral to Clinical question

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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<tr>
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<td></td>
</tr>
<tr>
<td>Good</td>
<td>Khine 1997 (A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>Daugherty 2006 (A)</td>
<td></td>
<td></td>
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<td>Poor</td>
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</table>

Level of evidence

A: Supports specific new formula, standard tracheal tube
B: Supports specific new formula, Microcuff tracheal tube

### Evidence Opposing Clinical Question

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
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<tr>
<td>Fair</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Poor</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
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</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
</tbody>
</table>

Level of evidence

A: Supports specific new formula, standard tracheal tube
B: Supports specific new formula, Microcuff tracheal tube
REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

Studies by Daugherty 2006 (ref 4), Dullenkopf 2006 (ref 3) demonstrate minimal difference between age based and length based formulas for sizing cuffed endotracheal tubes. The current age-based recommended formula for cuffed endotracheal tubes 3+ age/4 is based on data from Khine 1997 (ref. 5) where the use of this formula in 250 children led less than 1% reintubation rate and a 1.2% requirement for treatment of stridor. However the authors themselves suggest that the data supports the formula only in children older than 2 years. In-depth review of the article reveals a peculiar methodology of up-rounding the age such that a child just over 2 received a tube sized for a 3 year old. (see charts below) This up-rounding is not used in the current treatment recommendation and the tracheal tubes used clinically will be smaller than that used by Khine in some children.

Table 1: Khine formula tube sizes versus uncuffed versus current PALS guideline

<table>
<thead>
<tr>
<th>cuffed</th>
<th>uncuffed</th>
<th>age (Khine study)</th>
<th>PALS guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>NB-1 year</td>
<td>NB-1.99 years</td>
</tr>
<tr>
<td>3.5</td>
<td>4.5</td>
<td>1- 3rd birthday</td>
<td>2- 3.99 years</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>3- 5th birthday</td>
<td>4- 5.99 years</td>
</tr>
<tr>
<td>4.5</td>
<td>5.5</td>
<td>5- 7th birthday</td>
<td>6- 7.99 years</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7-9th birthday</td>
<td>8- 9.99 years</td>
</tr>
</tbody>
</table>

The table below demonstrates that for children older than 12 months, the current PALS formula for tracheal tubes leads to tubes that are 0.5 mm smaller than Khine actually utilized in that study in the 1-2, 3-4 and 5-6 year old age groups. In children over 12 months, the PALS formula leads to a smaller tube than in all age groups in the Daugherty (2006), Duracher *2008), Dullenkopf (2005, 2006) studies.

Table 2: Age vs. tracheal tube selected for 6 studies.

<table>
<thead>
<tr>
<th>Tube size</th>
<th>Current PALS</th>
<th>“Khine”</th>
<th>Daugherty/ Duracher Dullenkopf 2005*,2006*</th>
<th>Salgo*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to &lt;0.5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>0.5 to &lt;1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>1 to &lt;1.5</td>
<td>3</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>1.5 to &lt;2</td>
<td>3</td>
<td>3.5</td>
<td>3.5</td>
<td>4</td>
</tr>
<tr>
<td>2 to &lt;3</td>
<td>3.5</td>
<td>3.5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3 to &lt;4</td>
<td>3.5</td>
<td>4</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>4 to &lt;5</td>
<td>4</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>5 to &lt;6</td>
<td>4</td>
<td>4.5</td>
<td>4.5</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Microcuff tube

There is reasonable evidence (LOE 2) from 3 prospective studies (Dullenkopf 2006, Salgo 2006 (ref 6), Dullenkopf 2005 (ref 3) that cuffed tracheal tubes in newborn to 1 year and 1 to 2 years should be 3.0 and 3.5 mm inside diameter respectively.

There is reasonable evidence (LOE 2) from 3 prospective studies (Dullenkopf 2006, Salgo 2006 (ref 6), Dullenkopf 2005 (ref 3) that when using Microcuff tubes, after 2 years of age, the formula 3.5 + age/4 will be appropriate with a low number of reintubations. In these 3 studies the reintubation rate ranged from 0 (Dullenkopf 2006) to 2.3% (Salgo 2008). The Salgo study had slightly higher intubation and stridor rates than the others but used larger sized tubes than the Motoyama formula (3.5+ age/4) for some of the age groups.

When using standard endotracheal tubes, the evidence is not as convincing. Studies by Duracher 2008 (LOE 2) and Daugherty 2006 (LOE 3), in addition to the Khine data (if the up-rounding is considered) supports using Motoyama formula for children over age 2 (3.5+ age/4) however the risk of an oversize external diameter is greater than with the Microcuff tube. The risk of stridor in the Duracher study was comparable to the Khine study.
Table 3: Summary of 6 utilized studies:

<table>
<thead>
<tr>
<th>Study</th>
<th>Age</th>
<th>Number</th>
<th>ET too large</th>
<th>Stridor</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daugherty</td>
<td>1 m-12 y</td>
<td>5175</td>
<td>&lt;10%, age and length same</td>
<td></td>
<td>Retrospective, Anes pref. Only 2 sites-one =Khine</td>
</tr>
<tr>
<td>(2006): 710</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dullenkopf</td>
<td>NB-teen</td>
<td>500</td>
<td>1.6%</td>
<td>1.2%</td>
<td>0.4% treated</td>
</tr>
<tr>
<td>(2005):232 M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dullenkopf</td>
<td>NB-teen</td>
<td>145</td>
<td>0 (less than trachea width) age=length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2006): 201 M</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Duracher</td>
<td>1d-15 yr</td>
<td>204</td>
<td>2% (72% Khine formula-too small)</td>
<td>2.9%</td>
<td>1.4% treated</td>
</tr>
<tr>
<td>(2008): 113</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Anesthesia preference</td>
</tr>
<tr>
<td>Khine (1997): 627</td>
<td>NB-8 years</td>
<td>251</td>
<td>0</td>
<td>1.2%</td>
<td>Up-rounding age</td>
</tr>
<tr>
<td>Salgo (2006):557-M</td>
<td>NB-5 years</td>
<td>350</td>
<td>2.6%</td>
<td>2.3%</td>
<td>Larger than Motoyama</td>
</tr>
</tbody>
</table>

M=Microcuff tube

Acknowledgements:
Citation List

Reference Type: Journal Article
Record Number: 1
Author: R. J. Daugherty, V. Nadkarni and B. R. Brenn
Year: 2006
Title: Endotracheal tube size estimation for children with pathological short stature
Journal: Pediatr Emerg Care
Volume: 22
Issue: 11
Pages: 710-7
Epub Date: 2006/11/18
Date: Nov
Short Title: Endotracheal tube size estimation for children with pathological short stature
ISSN: 1535-1815 (Electronic)
DOI: 10.1097/01.pec.0000238743.96606.69 [doi]
0006565-200611000-00005 [pii]
Accession Number: 17110862
Keywords: Age Factors
Anesthesiology/ instrumentation
Anthropometry
Body Height
Child
Child, Preschool
Cross-Sectional Studies
Data Collection
Dwarfism/ therapy
Equipment Design
Female
Humans
Infant
Infant, Newborn
Intubation, Intratracheal/ instrumentation
Male
Osteochondrodysplasias/therapy
Pediatrics
Retrospective Studies
Surgical Procedures, Operative/statistics & numerical data
Research Notes: Retrospective cross sectional survey comparing length-based (Broselow) and age- based (3.5 +age/4 if cuffed, 0.5 mm larger if uncuffed) estimates of ETT size with anesthesiologist-selected ideal ETT size in normal children 1 mos-12 yrs vs. children with pathological short stature (PSS). PSS was defined as less than 5% length for age. The proportions of clinically relevant predicted ETTs, within +/-0.5 mm of the anesthesiologist-selected ideal ETT size, based on both age- and length-based formulas for each group were then compared. 5175 children studied.

Normal stature: age-predicted ETT size was clinically relevant range in 89.8% (95% CI, 88.9%-90.7%), and length-predicted ETT size was within the clinically relevant range in 92.8% (95% CI, 92.0%-93.6%). PSS, age-predicted ETT size was within the clinically relevant range in 86.6% (95% CI, 84.3%-89.0%), and length-predicted ETT size was within the clinically relevant range in 92.2% (95% CI, 90.3%-94.0%). Normal
children: 57% used different than anesthesiologist chosen ET size - was underestimated in 7%, overestimated 50%.

CONCLUSION: Age-based prediction of ETT size is at least as accurate as length-based estimation in both normal and pathologically short children. The formula 3.5 plus age/4 would tend to overestimate more often than underestimate.

Limitations: Retrospective study. Most but not all cuffed tubes (percentage not described). Anesthesiologist chosen tube in 2 institutions, one of whom uses Khine formula for cuffed ET, not Motoyama formula.


Author Address: Division of Pediatric Emergency Medicine, The Children's Hospital of Philadelphia, Philadelphia, PA, USA. rdaugher@nemours.org

Database Provider: Nlm

Language: eng

Reference Type: Journal Article

Record Number: 2

Author: A. Dullenkopf, A. C. Gerber and M. Weiss

Year: 2005

Title: Fit and seal characteristics of a new paediatric tracheal tube with high volume-low pressure polyurethane cuff

Journal: Acta Anaesthesiol Scand

Volume: 49

Issue: 2

Pages: 232-7

Epub Date: 2005/02/18

Date: Feb

Short Title: Fit and seal characteristics of a new paediatric tracheal tube with high volume-low pressure polyurethane cuff

ISSN: 0001-5172 (Print)

DOI: AAS599 [pii]


Accession Number: 15715626

Keywords: Adolescent
Anesthesia, General/methods
Child
Child, Preschool
Croup/drug therapy/etiology
Equipment Design/methods
Female
Humans
Infant
Infant, Newborn
Intubation, Intratracheal/ adverse effects/ instrumentation
Male
Polyurethanes
Pressure
Trachea/anatomy & histology/physiology
Research Notes: Prospective non blinded study of Microcuff HVLP cuff tube. Birth >3kg to adolescence. Used formula up to 1 year old = 3.0mm, 1-2 year old used 3.5 mm tube, Motoyama formula (3.5+Age/4) in those older than 2. 500 subjects. 100 patients with 3.0 tube, 50 for each size above 3.0. If no air leak less than or equal to 20 cm H2O, smaller ET inserted. If cuff not sealed at 20 cm H2O, ET increased. Results: 8 children of 500 (1.6 percent) tube replaced with one size smaller. Mostly in kids small for age (ages not noted). None too small to seal cuff. Stridor in 1.8 percent requiring therapy in 0.4 %.

Conclusion: Age related formula 3.5 + age/4 OK 98.4 % of time on 1st attempt with Microcuff tube.

Limitations: Observational study.


Author Address: Department of Anaesthesia, University Children's Hospital Zurich, Zurich, Switzerland.

Database Provider: Nlm

Language: eng

Reference Type: Journal Article

Record Number: 3


Year: 2006

Title: Comparison of tracheal tube cuff diameters with internal transverse diameters of the trachea in children

Journal: Acta Anaesthesiol Scand

Volume: 50

Issue: 2

Pages: 201-5

Epub Date: 2006/01/25

Date: Feb

Short Title: Comparison of tracheal tube cuff diameters with internal transverse diameters of the trachea in children

ISSN: 0001-5172 (Print)

DOI: AAS943 [pii]

10.1111/j.1399-6576.2006.00943.x [doi]

Accession Number: 16430542

Keywords: Adolescent

Age Factors

Body Height/physiology

Body Weight/physiology

Child

Child, Preschool

Female

Fluoroscopy/methods

Humans

Infant

Infant, Newborn

Intubation, Intratracheal/ instrumentation

Male

Trachea/ anatomy & histology

Research Notes: Prospective observational nonrandomized study. of Microcuff ET in cardiac cath lab evaluating ET size vs tracheal transverse diameter by fluoroscopy. Weight 3kg to age 16. Khine formula under 2 (newborn to 1, 3.0mm, 1-2 y/o 3.5mm). After age 2, 3.5+ age 4 used. 145 children studied. Tube changed if no leak at 20 cm H2O or if significant air leak when cuff inflated to 20 cm H2O. Fluoroscopy for measurement tracheal size with cuff deflated. Results: Internal tracheal diameter correlated well with age, r=0.89, weight
r=0.89, and length 0.90. Internal tracheal diameter greater than outer tracheal tube diameter in all children. Leak and sealing OK in all. Confirms use of Khine less than 2, Motoyama greater than 2 for microcuff tubes.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Size pred</th>
<th>Median</th>
<th>% used&gt;pred</th>
<th>% used&lt;pred</th>
<th>% used=pred</th>
</tr>
</thead>
</table>


Author Address: Department of Anaesthesia, University Children's Hospital Zurich, Switzerland.
alex.dullenkopf@kispi.unizh.ch

Database Provider: Nlm
Language: eng

Reference Type: Journal Article
Record Number: 4
Author: C. Duracher, E. Schmautz, C. Martinon, J. Faivre, P. Carli and G. Orliaguet
Year: 2008
Title: Evaluation of cuffed tracheal tube size predicted using the Khine formula in children
Journal: Paediatr Anaesth
Volume: 18
Issue: 2
Pages: 113-8
Epub Date: 2008/01/11
Date: Feb
Short Title: Evaluation of cuffed tracheal tube size predicted using the Khine formula in children
ISSN: 1155-5645 (Print)
DOI: PAN2382 [pii]
10.1111/j.1460-9592.2007.02382.x [doi]
Accession Number: 18184241
Keywords: Adolescent
Anesthesia, General/ adverse effects
Child
Child, Preschool
Equipment Design
Equipment Failure
Humans
Infant
Infant, Newborn
Intubation, Intratracheal/ instrumentation
Pediatrics
Postoperative Complications/ etiology/physiopathology
Predictive Value of Tests
Prospective Studies
Research Notes: Prospective study comparing cuffed ET using Khine formula. Leak check with pressure of 20. Age 1day-15 years. Mallinkrodt LPHV cuff tubes. 7 groups: 3, 3.5, 4, 4.5, 5, 5.5, 6 mm ID ET tubes. Tube size per discretion of anesthesiologist. Cuff pressure manometer maintained 20-25 and air leak measured. If leak greater than 25% of tidal volume, tube was upsized. Results: 204 children studied. In 21% Khine formula was correct. The only group that was in agreement with Khine was the 3.0 ET group. In 72 percent Khine formula was too small. In 7% the tube was smaller than predicted by Khine. Croup in 2.9%, 1.4% requiring treatment. In only 1 of 6 with stridor was tube same as Motoyama but larger than Khine.
<table>
<thead>
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<th>(khine)</th>
<th>Used-pred</th>
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<tbody>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>3.5</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>4.5</td>
<td>41</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>5.5</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>204</td>
</tr>
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</table>

Conclusion: Size predicted by Khine formula underestimates size of cuffed tracheal tube. The choice of a tube, 0.5 mm larger than Khine formula was not associated with increased risk of stridor.

Limitation: Single institution, small numbers.

**Author Address:** Departement d'Anesthesie Reanimation Chirurgicale et SAMU de Paris, Universite Rene Descartes Paris, Paris Cedex, France.

**Database Provider:** Nlm

**Language:** eng

**Reference Type:** Journal Article

**Record Number:** 5


**Year:** 1997

**Title:** Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia

**Journal:** Anesthesiology

**Volume:** 86

**Issue:** 3

**Pages:** 627-31; discussion 27A

**Epub Date:** 1997/03/01

**Date:** Mar

**Short Title:** Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia

**ISSN:** 0003-3022 (Print)

**Accession Number:** 9066329

**Keywords:** Anesthesia, General/ instrumentation/ methods

Child

Child, Preschool

Humans

Infant

Infant, Newborn
Intubation, Intratracheal/ instrumentation/ methods

**Research Notes:** Prospective study of cuffed vs uncuffed tracheal tube in term newborn to 8 years. Odd medical records cuffed, even uncuffed. Mallinckrodt tubes- regular or RAE. Cuffed tubes used formula $3 + \frac{\text{age}}{4}$ except if age less than 1 the anesthesiologist could use discretion. Upward rounding of age- eg., after 1st birthday, calculated as 2 year old. Tube exchanged for smaller if resistance to passage or no leak $< 20-30 \text{ cm H}_2\text{O}$. Upsized if unable to ventilate without loss of 25% of Vt.

Results: 251 children studied in cuffed group. 3 children (ages 3, 4 and 6) required tube upsize. 3/251 (1.2%) treated for croup and 1 admitted for croup.

Conclusion: Formula $3 + \frac{\text{age}}{4}$ was appropriate, but least certain in children younger than 2 years of age. Results retain significance if children less than 2 excluded.

**Limitation:** Upward rounding of age (after each birthday, rounded up to next age).

<table>
<thead>
<tr>
<th>cuffed</th>
<th>uncuffed</th>
<th>age (khine study)</th>
<th>PALS guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>NB-1 year</td>
<td>NB-1.99 years</td>
</tr>
<tr>
<td>3.5</td>
<td>4.5</td>
<td>1- 3rd birthday</td>
<td>2- 3.99 years</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>3- 5th birthday</td>
<td>4- 5.99 years</td>
</tr>
<tr>
<td>4.5</td>
<td>5.5</td>
<td>5- 7th birthday</td>
<td>6- 7.99 years</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7-9th birthday</td>
<td>8- 9.99 years</td>
</tr>
</tbody>
</table>

**Author Address:** duPont Hospital for Children, Wilmington, Delaware 19899, USA.

**Database Provider:** Nlm

**Language:** eng

**Reference Type:** Journal Article

**Record Number:** 6

**Author:** B. Salgo, A. Schmitz, G. Henze, K. Stutz, A. Dullenkopf, S. Neff, A. C. Gerber and M. Weiss

**Year:** 2006

**Title:** Evaluation of a new recommendation for improved cuffed tracheal tube size selection in infants and small children

**Journal:** Acta Anaesthesiol Scand

**Volume:** 50

**Issue:** 5

**Pages:** 557-61

**Epub Date:** 2006/04/29

**Date:** May

**Short Title:** Evaluation of a new recommendation for improved cuffed tracheal tube size selection in infants and small children

**ISSN:** 0001-5172 (Print)

**DOI:** AAS1003 [pii]

10.1111/j.1399-6576.2006.01003.x [doi]

**Accession Number:** 16643224

**Keywords:** Age Factors

Air Pressure

Child, Preschool

Female

Humans

Infant

Infant, Newborn
Intubation, Intratracheal/ instrumentation/ standards
Male
Respiratory Sounds/etiology

Research Notes: Prospective observational study of newborn to 5 year olds having tracheal intubation with second generation microcuff ET. Tracheal tubes were inserted per formula- 3.0 in newborn to <6 mos., 3.5 in 6 mos to <18 mos, 4 in 18 mos to <3 years and 4.5 in 3 to 5 years. Smaller tubes were inserted if no leak at less than 20 cm H2O pressure before cuff inflated.

<table>
<thead>
<tr>
<th>Tube size</th>
<th>Khine</th>
<th>Daugherty/ Duracher</th>
<th>Salgo*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to &lt;0.5</td>
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<tr>
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<td>3.5</td>
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<tr>
<td>3 to &lt; 4</td>
<td>4</td>
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<td>4.5</td>
</tr>
<tr>
<td>4 to &lt; 5</td>
<td>4</td>
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</table>

*microcuff tube

Results. 350 children studied (50 per group). In 9 children (2.6%) the tracheal tube was changed to smaller tube. No tube was changed for inadequate sealing. There was stridor in 2.3 percent, treated in 0.9%. Above rule was felt to be better than any existing formula for microcuff tube, allowing a larger tube without increasing the number of tube exchanges or postextubation stridor.

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