Clinical question.
For infants and children who require endotracheal intubation (prehospital or inhospital) (P) does the use of a specific formula to guide cuffed endotracheal tube size (I), as opposed to the use of 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/therapy
State if this is a proposed new topic or revision of existing worksheet: New topic

Conflict of interest specific to this question
Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet?

Potential intellectual conflicts: Editor of ERC paediatric guidelines. Co-editor of ERC EPLS and EPILS manual

Search strategy (including electronic databases searched).
In PubMed Embase, Google Scholar and AHA ENL text terms tracheal tube size OR endotracheal tube size. Limits ‘all child 0 – 18 years’. No date limits.
Hand search of 176 results. 27 hits. Hand search of references from these articles and forward search from ‘Khine’ article.

State inclusion and exclusion criteria
Included publications in peer review journals. Excluded – abstracts, articles in press and articles without available English translation (there were only 2 of the latter, both in Japanese and neither addressed cuffed tracheal tubes).

Number of articles/sources meeting criteria for further review:
8 articles specifically addressed the clinical question
## Summary of evidence

### Evidence Supporting Clinical Question

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<th>Level of evidence</th>
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<th>Fair</th>
<th>Poor</th>
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**Level of evidence**

- A = Return of spontaneous circulation
- B = Survival of event
- C = Survival to hospital discharge
- D = Intact neurological survival
- E = Other endpoint
- *Italics* = Animal studies
### Evidence Neutral to Clinical question

| Good |  |  |  |  |  |
| Fair |  |  |  |  |  |
| Poor |  |  |  |  |  |
| 1 | 2 | 3 | 4 | 5 |

**Level of evidence**

- A = Return of spontaneous circulation
- B = Survival of event
- C = Survival to hospital discharge
- D = Intact neurological survival
- E = Other endpoint

**Italicics** = Animal studies

### Evidence Opposing Clinical Question

| Good |  |  |  |  |  |
| Fair | Khine 1997 E |  |  |  |  |
| Poor |  |  |  |  |  |
| 1 | 2 | 3 | 4 | 5 |

**Level of evidence**

- A = Return of spontaneous circulation
- B = Survival of event
- C = Survival to hospital discharge
- D = Intact neurological survival
- E = Other endpoint

**Italicics** = Animal studies
REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

The main requirements of a tracheal tube during resuscitation are that they are of the correct size to pass into the trachea without causing damage and that they facilitate effective pulmonary ventilation. With a cuffed tracheal tube, the cuff fills the gap between the tube outer wall and the tracheal wall permitting the application of positive pressure to the lungs, consequently a tube that is slightly too small can still be effective. The main disadvantage of having too small a cuffed tube is that the lumen is narrower making the clearance of viscous secretions more difficult.

The original ‘Khine’ paper [Khine 1997. LOE 2] found that the formula age/4 + 3 resulted in the selection of the correct tube size in all but 3 of 251 children (1.2%). In all 3 of these, the tube was changed to a larger size (study criteria for change was a leak of gas past the tube at an inflation pressure of 10 or less cmH2O following cuff inflation to a pressure of 25cmH2O). Careful analysis of this paper however, reveals that the aggressive ‘rounding up’ with respect to age employed by the authors commonly resulted in a tube size 0.5mm greater than the literal application of the formula would suggest.

Subsequent studies have suggested that a 0.5mm larger cuffed tube could be used. Newth [Newth 2004. LOE 4] compared the complication rated between cuffed and uncuffed tubes in PICU. Tubes were selected according to the preference of the intubator and the formula used for selection of uncuffed tubes was age/4 + 4 - cuffed tubes were one size (0.5mm i.d.) smaller. The complication rates, specifically the use of nebulised adrenaline, were similar between the groups. There is no comment on the incidence of tube changes. Three further studies suggest that larger cuffed tube sizes, than those suggested by the ‘Khine’ formula, could be used [Duracher 2008 (LOE2) Dullenkopf 2005 , Salgo 2006 (LOE 4)] and all found low re-intubation rates. The Dullenkopf and Salgo studies were examining a purpose made paediatric (Microcuff) tube and both suggested the optimum diameter to be 0.5mm greater than that suggested by the ‘Khine’ formula. Re-intubation rates were as follows: Dullenkopf 1.6%, Salgo 2.6%. In both, re-intubation only occurred because the tube was too large. The authors in both studies included the designers of the new tube.

The Duracher study compared the tube size selected by an experienced anaesthesiologist to that predicted by the ‘Khine’ formula – the formula predicted the size chosen in 21%, too large a size in 7% and too small a size in 72%. In 12 children a change of tube was required – in 4 cases to a smaller size and 8 to a larger one (3.9%).

A recent prospective randomized multi-centre study [Weiss 2009. LOE 1] provides excellent evidence supporting the use of a larger cuffed tube than suggested by the Khine formula. The authors selected tracheal tubes with an internal diameter of 3.0mm from birth(>3kg) to 8 months, 3.5mm from 8 to 18 months, 4.0mm from 18 to 36 months and 4.5mm from 36 to 60 months. They had very strict criteria for tube exchange and an exchange rate of 2.1% for cuffed tubes as compared to 30.8% for uncuffed tubes. The tubes studied were the purpose made ‘Microcuff’ tubes, however.

In conclusion:
The evidence suggests that the ‘Khine’ formula predicts a cuffed tube that is slightly (0.5mm) smaller than optimum for elective intubation, all children requiring re-intubation (1.2% of total) required a larger tube. Other studies (the majority examining a specific, purpose made, ‘Microcuff’ tube) strongly support the use of a cuffed tube of internal diameter 0.5mm greater than suggested by the Khine formula but are all in elective surgical patients. Children requiring resuscitation may have poorly compliant lungs, copious pulmonary secretions and/or laryngeal oedema. These condition may require the use of different tube diameters to children undergoing elective anesthesia in the above studies.

Acknowledgements:
**Citation List**


LOE 5, Neutral
Very large observational study of prediction of uncuffed tube sizes using age based or length based formulae in children of normal stature and those of short stature. Both methods of determining tube diameter had a high correlation with correct tube size, even in children with short stature.


LOE 4, Supporting (but examined purpose made tube).
Prospective observational study (no control group) of microcuff tracheal tubes. With formula age/4 + 3.5mm (3kg - 1yr: 3mm, 1 - 2 years: 3.5mm), only 8 of 500 tubes were too large (1.6%) and all the remaining tubes provided an adequate seal with a cuff inflation pressure of <=20 cm H20 (i.e. none too small). The main problem with this paper is that it is an evaluation of a specific tube and may only apply to this device. There is also a potential CoI in that the authors are the inventors of the microcuff tube under evaluation.


LOE 4, Supportive
Observational study of tube sizes, confirming correlation with weight, height and age.


LOE 2, Supporting
Relatively large observational study (no control group) comparing the tracheal tube diameter predicted by the Khine formula (age/4+3) to that judged optimal by attending anesthesiologist. Main finding that the Khine formula underestimates the tracheal tube size by 0.5mm in comparison to the anesthesiologist's judgement in 72% of cases and overestimates it by 0.5mm in 7%. There was no comparison of efficacy of ventilation but the authors suggest that the formula (age/4 + 3.5) is preferable for elective anaesthesia as it results in a larger lumen.


LOE 5, Neutral
Very large observational study of the predictive ability age, height and weight on uncuffed tracheal tube size. The authors concluded that no one variable is completely accurate and that a multi-variate analysis would better predict tube size. They suggest the formula: 2.44 + (age x 0.1) + (height x 0.02) + (weight x 0.016)!!!! Study included as reference only, not included in table.

LOE 5, Neutral
This study did not address tracheal tube size formula directly but the authors used age/4 + 4 to select cuffed tracheal tube size.
Study included as reference only, not included in table.


LOE 5, Neutral
Post mortem study of laryngeal anatomy in premature neonates.
Study included as reference only, not included in table.


LOE 5, Neutral
A retrospective case note review of the accuracy of the Broselow tape in European children. Tracheal tube size was better estimated by the Broselow tape than by an age based formula.
Study included as reference only, not included in table.


Study included as reference only, not included in table.


LOE 5, Neutral
A retrospective case note review of the accuracy of the Broselow tape in Korean children. Tracheal tube size was better estimated by the Broselow tape than by an age based formula.
Study included as reference only, not included in table.


LOE 1, Opposing
This paper formed the basis for the 'Khine formula' - the current standard. PRCT of tracheal tube formula for cuffed and uncuffed tubes in 488 children from full term neonate to 8 years of age. The authors used age/4 + 3 (for cuffed) and + 4 (for uncuffed) tubes. An upward rounding was used (e.g. once the child had passed the 1st birthday, it was assumed to be 2 years of age). The accuracy for cuffed tubes was 99% but it was only 77% for uncuffed tubes. The 3 tubes which were changed in the cuffed group, were exchanged for a tube 0.5mm larger because of a leak around the tube at an inflation pressure of <10cmH2O. Three further children (1.2%) required a FGF >2L/min to achieve effective ventilation; this figure was 26(11%) for the uncuffed group. For resuscitation, the most important point is whether the tube will fit first time and whether it will facilitate effective ventilation. The formula cited in this study suggested a 99% chance of this.

Study included as reference only, not included in table.


LOE 5, Neutral
PRCT of optimum method of selecting tracheal tube length.
Study included as reference only, not included in table.


LOE 4, Supporting (but not designed to examine optimum tracheal tube size)
Comparative Study between cuffed and uncuffed tracheal tubes in PICU. Prospective, observational design. Authors used age/4 + 3.5 to size cuffed tracheal tubes. There was no greater complication rate with cuffed tubes but study was not directly comparing tube sizes, just adrenaline nebuliser use between groups.


Study included as reference only, not included in table.


LOE 5, Neutral
PRCT of optimum method of selecting tracheal tube length.
Study included as reference only, not included in table.


Study included as reference only, not included in table.


LOE 4, Supporting (but using purpose made tube)
Prospective observational study (no control group) in elective patients, of appropriate diameter of the microcuff tracheal tube suggesting a 0.5mm size larger than that suggested by the Khine formula is appropriate. Nine of 350 tubes (2.6%) were too large. This is a study of a purpose made tube and the authors have a potential CoI as they are the devices designers.

Study included as reference only, not included in table.


LOE 5, Neutral
Prospective observational study examining the accuracy of a length based formula in predicting uncuffed tracheal tube diameter in Chinese children. Formula has an accuracy of 82.4% there was no comparison with other methods.
Study included as reference only, not included in table.


Study included as reference only, not included in table.


Evaluation of appropriate TT size in trisomy 21.
Study included as reference only, not included in table.


LOE 5, Neutral
Study of the reliability of 'little finger' size to predict correct tracheal tube size, showing that the formula age/4 + 4.5 is more accurate for selecting uncuffed tubes.
Study included as reference only, not included in table.


Evaluation of Broselow tape in Indian children confirming its validity in this ethnic group.
Study included as reference only, not included in table.


Prospective observational study of the accuracy of the depth markings in guiding correct tube placement in a micro-cuff tracheal tube. The depth markings proved superior to the standard formula.
Study included as reference only, not included in table.


Review article on cuffed tracheal tubes
Study included as reference only, not included in table.


Evaluation study showing inappropriate placing of cuff on conventional paediatric tracheal tubes.
Study included as reference only, not included in table.


Editorial on current practice with cuffed tracheal tubes in children
Study included as reference only, not included in table.


Prospective evaluation of accuracy of depth markings ability to aid correct placement of tracheal tube tip in microcuff tracheal tubes
Study included as reference only, not included in table.


LOE2. Supporting. Very large multi-centre RCT comparing cuffed to uncuffed tubes. Not designed to examine tube size but supporting the use of tubes 0.5mm greater I.D. than suggested by the Khine formula.