SWISS SOCIETY OF NEONATOLOGY

Winner of the Case of the Year Award 2015

What is the appropriate endotracheal tube insertion depth in a 345 g extremely preterm infant?

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Most extremely preterm infants born at the limit of viability will require endotracheal intubation in the delivery room. When correctly placed, the tip of the endotracheal tube (ETT) should be positioned in the mid-tracheal region, halfway between the clavicles and the carina; this corresponds to the ETT tip projecting over T1-T2. If the ETT is inserted to far, main stem intubation (usually on the right side) will result. If unrecognized, this may lead to volutrauma to the right lung (pneumothorax, pulmonary interstitial emphysema), atelectasis of the left lung and unilateral surfactant deposition.

In 1979, Tochen described a simple calculation to determine the depth of ETT insertion for orotracheal intubations based on birth weight (1): estimated depth of insertion = 1.17 × birth weight (kg) + 5.58. This translated into an infant weighing 1 kg being intubated to a depth of 7 cm, a 2 kg infant to a depth of 8 cm, and a 3 kg infant to a depth of 9 cm. The calculation became known as the «7-8-9 Rule» and continues to be endorsed by the American Academy of Pediatrics / American Heart Association Textbook of Neonatal Resuscitation. Simply, it adds 6 cm to the infant's weight (e.g., for a 1 kg baby: 1 kg + 6 = 7 cm) to estimate the depth of ETT insertion (2). When nasotracheal intubation is performed, depth of ETT insertion must be increased by 20 % (e.g., for a 2 kg baby: (2 kg + 6) × 1.2 = 9.6 cm).

In addition, many brands have specific vocal cord guides at the tip of the ETT to help avoid bronchial main stem intubation. If the proximal part of these marks remains visible above the vocal cords, the ETT should be positioned above the carina.

Obviously, proper intubation should be verified clinically (adequate chest rise, bilateral air entry on auscultation, detection of end-expiratory CO_2) and can be expected to stabilize heart rate and oxygen saturation (SpO_2). However, as this case will illustrate, clinical assessment can be challenging in the smallest patients.

This female infant was born to a 28-year-old G2/P1/A1 at 25 0/7 weeks of pregnancy by primary Caesarean section. The mother's first pregnancy had ended in intrauterine fetal demise (IUFD) of a severely growth restricted infant at 26 4/7 weeks of gestation. The current pregnancy was again characterized by early severe intrauterine growth restriction. At 24 0/7 weeks of gestation, a full course of antenatal corticosteroids had been administered. When an Oxford CTG one week later suggested that IUFD was imminent, the parents requested that the infant be delivered and resuscitation be attempted.

After delivery, the infant was initially supported with bag-mask ventilation, followed by CPAP from the fourth minute of life. Apgar scores were 5, 8, and 8 at 1, 5 and 10 minutes, respectively. An umbilical venous catheter was inserted, and, at 20 minutes of life following premedication with fentanyl, atropine and rocuronium, nasotracheal intubation with a 2.0 ETT was successful at the first attempt. Given an estimated birth weight of 400 g, using the «7-8-9 Rule», a nasotracheal insertion depth of $(0.4\,\text{kg} + 6) \times 1.2 = 7.7$ cm was calculated. However, the operator insisted on an intubation depth of 7 cm because of the ETT depth mark (Mallinckrodt® I.D. 2.0). There was adequate chest rise, bilateral air entry and the heart rate remained above 100 / min and SpO_2 increased steadily. As per unit protocol, the ETT position was double

checked by a second attending physician, and surfactant was administered prior to transfer to the NICU.

On admission, a birth weight of 345 g was recorded. On chest X-ray, the ETT tip was lodged in the right mainstem bronchus (Fig. 1). Fortunately, there was no evidence of volutrauma, atelectasis or unequal distribution of surfactant. Based on the measurements on the chest X-ray, the ETT was retracted by 0.8 cm and fixed at 6.2 cm (Fig. 2). The case was entered into the Critical Incident Reporting System of our unit and later analyzed in detail.

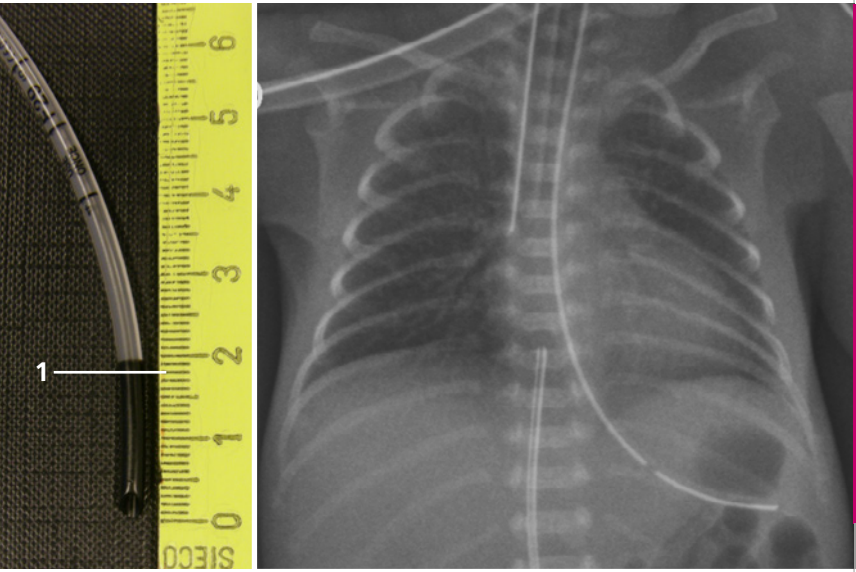


Fig. 1

Chest X-ray shortly after admission to the NICU. While the positions of umbilical venous catheter and nasogastric tube are adequate, the ETT placed at 7 cm is lodged in the right mainstem bronchus despite the fact that the ETT depth mark was still visible above the vocal cords (1).

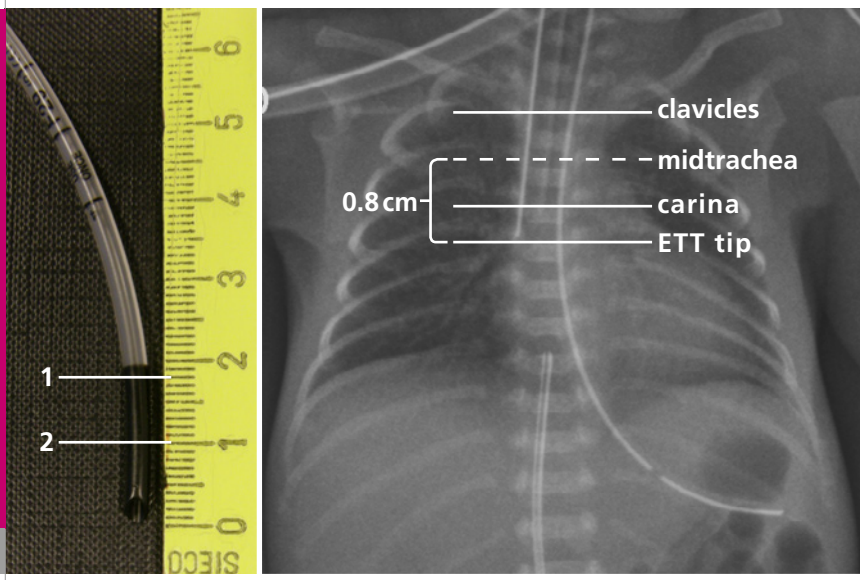


Fig. 2

When placed at 7 cm (based on the ETT depth mark, 1), the ETT was positioned in the right mainstem bronchus; it needed to be retracted by 0.8 cm to 6.2 cm to be positioned in the midtracheal region (2).

Our case illustrates that commonly used methods to calculate or control ETT insertion depths may fail in the most immature and/or growth restricted infants. Both the «7-8-9 Rule» (3) as well as the ETT depth marks (4) overestimate the insertion depth in our smallest patients. Gill and colleagues have described that the design and position of the vocal cord guide on ETTs used in newborns differ substantially between different models of ETTs (4) (Fig. 3). The most recent edition of NICU Tools, a free source of browser-based neonatal and infant calculators (www.nicutools.org), provides a more accurate estimate for ETT insertion depth for infants with birth weights < 750 g (Fig. 4).

In one of his recent blogs (5), Keith Barrington suggested to use a table of ETT length against gestation and weight published by Kempley et al. (6).

Gestational age (weeks)	Current weight (kg)	ETT length at the lips (cm)	ETT length at the nostril (cm)
23 – 24	0.5 – 0.6	5.5	6.5
25 – 26	0.7 – 0.8	6.0	7.0
27 – 29	0.9 – 1.0	6.5	7.5
30 – 32	1.1 – 1.4	7.0	8.0
33 – 34	1.5 – 1.8	7.5	8.5
35 – 37	1.9 – 2.4	8.0	9.0
38 – 40	2.5 – 3.1	8.5	9.5
41 – 43	3.2 – 4.2	9.0	10.0

***Table**. ETT insertion depth for oro- and nasotracheal intubation in neonates (5, 6).*

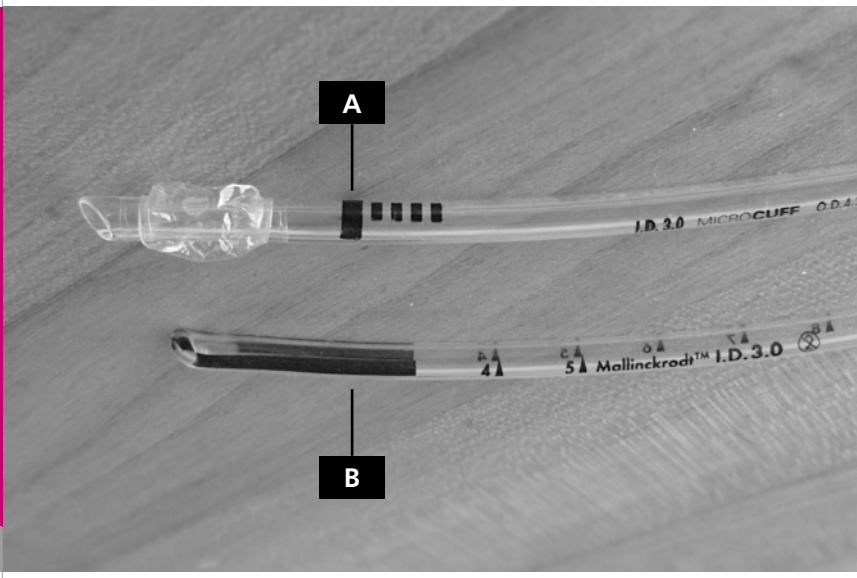


Fig. 3

Various ETT depth marks designed to facilitate ETT placement (A: Microcuff®, B) Mallinckrodt®); note that there can be substantial differences in design and position of vocal cord guides depending on the ETT model used (4).

NICU TOOLS

www.nicutools.org

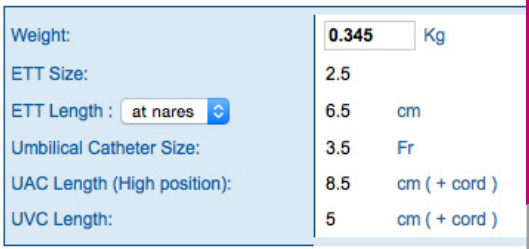
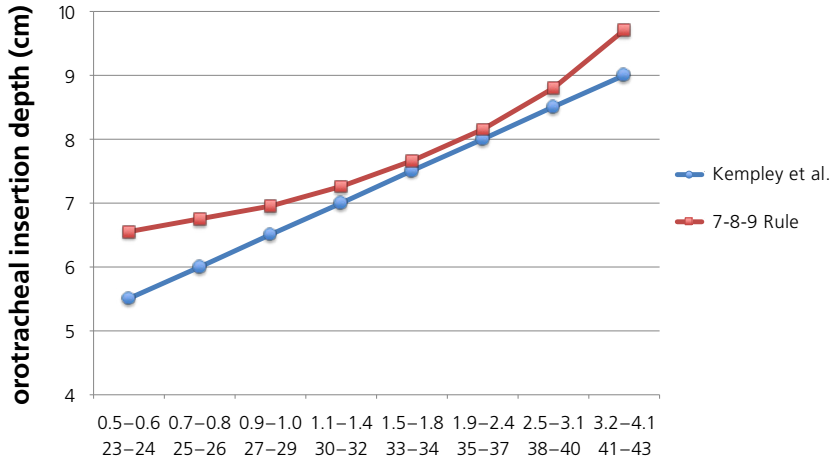


Fig. 4

The most recent edition of NICU Tools, a free source of browser-based neonatal and infant calculators, provides a more accurate estimate for ETT insertion depth for infants with birth weights < 750 g (for our patient, a nasotracheal insertion depth of 6.5 cm would have been predicted).

A comparison of the orotracheal insertion depth calculated by the 7-8-9 Rule and the values of the table presented above are shown in Fig. 5. The 7-8-9 Rule overestimates insertion depth in infants weighing less than 1000 g and infants weighing more than 3000 g. The distance from nostril to carina is almost 1.2 cm on average longer than the distance from lip to carina (7); to account for this, one rule suggests that 20% are added to the orotracheal insertion depth calculated by the 7-8-9 Rule; this increases the overestimation error even further (data not shown). In addition to the usual clinical assessment of proper placement, palpation of the ETT tip in the suprasternal notch might be helpful (8, 9); however, this seems quite delicate in the smallest of our patients.

Obviously, a chest X-ray should be obtained in all infants following intubation to verify ETT position; insertion depth should then be adjusted so that the ETT tip projects over T1-T2 (10). Head position is important: Rost et al. have demonstrated the effect of head position on ETT tip position in a small autopsy study of eight orotracheally intubated low birth weight infants (11). They obtained anteroposterior chest radiographs with the neck in a neutral position, in 55 degrees flexion, and in 55 degrees extension. Measurements from the thoracic inlet to the ETT were obtained in each position. The ETT always moved caudad with neck flexion and cephalad with neck extension. The mean extent of ETT displacement was 3.1 mm (SD, 1.7 mm) with



top: current weight (kg)

bottom: gestational age (weeks)

Fig. 5

Comparison of the orotracheal insertion depth calculated by the 7-8-9 Rule and values published by Kempley et al. (6) for ETT insertion depth: overestimation of insertion depth is more pronounced at very low and very high birth weights.

neck flexion, and 7.4 mm (SD, 5.2 mm) with extension ($P < 0.05$). Rothschild et al. made similar observations (7): in infants weighing less than 1000 g, maximum flexion decreased nasal-carina (NC) distance by 1.0 cm and oral-carina (OC) distance by 1.5 cm, whereas maximum extension increased NC distance by 0.8 cm and OC distance by 1.3 cm.

In summary, both the 7-8-9 Rule and ETT vocal cord guides overestimate the insertion depth in the smallest patients. It may be more appropriate to use the values listed in the table above in infants with a birth weight of less than 1000 g (5, 6).

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