

Endotracheal Intubation Attempts During Neonatal Resuscitation: Success Rates, Duration, and Adverse Effects

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ABSTRACT

OBJECTIVE. Endotracheal intubation of newborn infants is a mandatory competence for many pediatric trainees. The Neonatal Resuscitation Program recommends a 20-second limit for intubation attempts. Intubation attempts by junior doctors are frequently unsuccessful, and many infants are intubated between 20 and 30 seconds without apparent adverse effect. Little is known about the proficiency of more senior medical staff, the time taken to determine endotracheal tube (ETT) position, or the effects of attempted intubation on infants' heart rate (HR) and oxygen saturation (SpO₂) in the delivery room (DR). The objectives of this study were to determine (1) the success rates and duration of intubation attempts during DR resuscitation, (2) whether experience is associated with greater success rates and shorter time taken to intubate, (3) the time taken to identify ETT position after intubation, and (4) the frequency with which infants deteriorated during intubation attempts and the time at which this occurred.

METHODS. We reviewed videos of DR resuscitations; identified whether intubation was attempted; and, when attempted, whether intubation was attempted by a resident, a fellow, or a consultant. We defined the duration of an intubation attempt as the time from the introduction of the laryngoscope blade to the mouth to its removal, regardless of whether an ETT was introduced. We determined the time from removal of the laryngoscope to the clinicians' decision as to whether the intubation was successful and noted the basis on which this decision was made (clinical assessment, flow signals, or exhaled carbon dioxide [ETCO₂] detection). We determined success according to clinical signs in all cases and used flow signals that were obtained during ventilation via the ETT or ETCO₂ when available. When neither was available, the chest radiograph on admission to the NICU was reviewed. For infants who were monitored with pulse oximetry, we determined their HR and SpO₂ before the intubation attempt. We then determined whether either or both fell by $\geq 10\%$ during the attempt and, if so, at what time it occurred.

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Key Words

infant, newborn, resuscitation, positive pressure respiration, endotracheal intubation

Abbreviations

ETT—endotracheal tube
NRP—Neonatal Resuscitation Program
DR—delivery room
SpO₂—oxygen saturation
HR—heart rate
ETCO₂—exhaled carbon dioxide

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RESULTS. We reviewed 122 video recordings in which orotracheal intubation was attempted 60 times in 31 infants. We secondarily verified ETT position using flow signals, ETCO_2 , or chest radiographs after 94% of attempts in which an ETT was introduced. Thirty-seven (62%) attempts were successful. Success rates and mean (SD) time to intubate successfully by group were as follows: residents: 24%, 49 seconds (13 seconds); fellows: 78%, 32 seconds (13 seconds); and consultants: 86%, 25 seconds (17 seconds). Of the 23 unsuccessful attempts, 13 were abandoned without an attempt to pass an ETT and 10 were placed incorrectly. The time to determine ETT position in the DR was longer when clinical assessment alone was used. Infants who were monitored with oximetry deteriorated during nearly half of the intubation attempts. Deterioration seemed more likely when HR and SpO_2 were low before the attempt.

CONCLUSIONS. Intubation attempts often are unsuccessful, and successful attempts frequently take >30 seconds. Greater experience is associated with greater success rates and shorter duration of successful attempts. Flow signals and ETCO_2 may be useful in determining ETT position more quickly than clinical assessment alone. Infants frequently deteriorate during intubation attempts. Improved monitoring of infants who are resuscitated in the DR is desirable.

INTERNATIONAL CONSENSUS STATEMENTS¹ and guidelines on neonatal resuscitation^{2,3} advise that infants with inadequate respiration and/or bradycardia at birth be given positive pressure ventilation with a manual ventilation device with a face mask or endotracheal tube (ETT). Endotracheal intubation of newborn infants is a mandatory competence for basic training in pediatrics in many countries.^{4,5} The Neonatal Resuscitation Program (NRP) recommends that intubation attempts be limited to 20 seconds.²

A United Kingdom study of the care of preterm infants and its effect on their survival identified difficulties with intubation and the level of experience of staff present as the most common concerns about neonatal resuscitation.⁶ In a US study of pediatric residents, none met the authors' definition of procedural competence for intubation (successful at first or second attempt $\geq 80\%$ of the time) over a 2-year period.⁷ An additional US study of delivery room (DR) intubations that were performed mainly by residents and fellows found that few were successful within 20 seconds and that more infants were intubated between 20 and 30 seconds without apparent adverse effect.⁸ Another study from the same center reported that just over half of all intubation attempts that were performed by junior doctors were successful and that residents there currently have inadequate opportunity to become proficient.⁹

There is little information on the success rates or duration of intubation attempts of more experienced operators. Also, although adverse effects of endotracheal intubation in the intensive care setting have been described,¹⁰ there is little information on the effects of intubation attempts on infants' oxygen saturations (SpO_2) and heart rate (HR) as determined by pulse oximetry in the DR. Using video recordings, we wished to determine (1) the success rates and duration of intubation attempts during neonatal resuscitation at our hospital, (2) whether the success rates and duration of successful attempts by staff varied with different levels of experience, (3) the time taken to identify ETT position after attempted intubation, and (4) the frequency with which infants deteriorated during intubation attempts and the time at which this occurred.

METHODS

Setting

The Royal Women's Hospital Melbourne is a tertiary-level perinatal center with ~ 5000 deliveries per year. Approximately 450 infants are admitted to the NICU per year, 100 to 110 of whom have a gestational age of <28 weeks or birth weight of <1 kg. We do not have advanced neonatal nurse practitioners or respiratory therapists; thus, all infants are intubated by medical staff: residents, fellows, or consultants. In general, the residents are pediatric trainees whose first exposure to neonatal medicine or intensive care occurs during their 6-month rotation at our hospital. Usually, they have no previous experience with intubation. The fellows have variable but at least 18 months' experience of neonatal intensive care and thus intubation. Consultants at our hospital have a range of 5 to 35 years' experience in neonatal medicine and extensive intubation experience.

Resuscitation Practice

All staff who attend deliveries at our hospital complete an in-house resuscitation training program based on international consensus statements¹ and the NRP.² The Neopuff Infant Resuscitator (Fisher & Paykel, Auckland, New Zealand) t-piece and the Laerdal Infant Resuscitator (Laerdal, Oakleigh Victoria, Australia) self-inflating bag are the manual ventilation devices used at our hospital. Peak inflating and positive end-expiratory pressures are set at 30 and 5 cm H_2O , respectively, on the Neopuff. In the DR, ETT position is judged from clinical signs as recommended in international consensus statements¹; on occasion, an exhaled carbon dioxide (ETCO_2) detector (Pedi-Cap Nellcor Puritan Bennet, Pleasanton, CA) is used for secondary confirmation. A time limit for intubation attempts is not enforced rigidly at our institution. Infants who are intubated in our DR are transferred to the NICU, where they have a chest radiograph to confirm ETT position.

Resuscitation Studies

Since January 2004, we have recorded DR resuscitations at our hospital with the endorsement of our Human Research and Ethics Committee. When available, a member of the investigating team attended deliveries for which the need for resuscitation was anticipated and made detailed recordings. When time allowed before delivery, the parents were approached and their permission was sought to record the resuscitation. When time did not allow, the resuscitation was recorded and the parents were approached as soon as practicable thereafter. Their permission then was sought to view the recordings and to use them for data extraction and educational purposes.

We recorded resuscitations using a digital video camera that was mounted above the resuscitation cot and positioned to acquire a clear view of the infant and resuscitative interventions. Sound was audible from these recordings. The sensor of a Masimo Radical (Masimo Corp, Irvine, CA) pulse oximeter was placed on the infants' right hand or wrist as soon as practicable after delivery. The oximeter was set to capture HR and SpO₂ with maximal sensitivity and average data over 2-second intervals.

Many of the infants who were videotaped had pulmonary mechanics measured during positive pressure ventilation using the Florian Respiratory Monitor (Acu-tronic, Zug, Switzerland). This monitor measures pressures in the respiratory circuit directly and uses a sensor placed between the ventilation device and the ETT to measure gas flow. These data were recorded and analyzed using a laptop computer with Spectra software (Grove Medical, London, United Kingdom), a program designed specifically for the recording and analysis of respiratory signals (see Fig 1). Although not usually available to the resuscitation team in the DR, these signals were used occasionally to determine ETT position during the resuscitation. They were used to determine ETT position retrospectively for this study.

Evaluation of Video Recordings

All video recordings were reviewed; those in which intubation was attempted were identified, and the reason for intubation was determined. The number of attempts, the timing of these attempts, and the grade of doctor who performed the procedure were noted. In keeping with previous reports,⁸ the duration of an intubation attempt was defined as the time from introduction of the laryngoscope blade into the mouth to the time it was removed, irrespective of whether an ETT was introduced. When an ETT was introduced, we determined the time from removal of the laryngoscope to the decision by the resuscitating team whether the attempt was successful.

For infants who were monitored with pulse oximetry during the procedure, we determined the times of life at which the sensor was applied and oximetry data were available. We determined whether preoxygenation was given before the attempt and the HR and SpO₂ before and after the attempt. We considered the infants' condition to have deteriorated when their HR and/or SpO₂ fell by $\geq 10\%$ during the procedure and noted the time at which this occurred.

Statistical Analysis

Mean (SD) duration of intubation attempts by different grades of doctors were compared using 1-way analysis of variance and test for linearity. Proportions of successful intubations by different grades of doctors were compared using χ^2 test and linear-by-linear association. SPSS version 12.0.1 (SPSS Inc, Chicago IL) was used for analysis.

RESULTS

We attended 123 deliveries and were given parental permission to extract data from 122. Intubation was attempted a total of 60 times in 31 infants whose mean (SD; range) gestational age and birth weight were 28 weeks (5; 23–40) and 1227 g (939; 495–3870), respec-

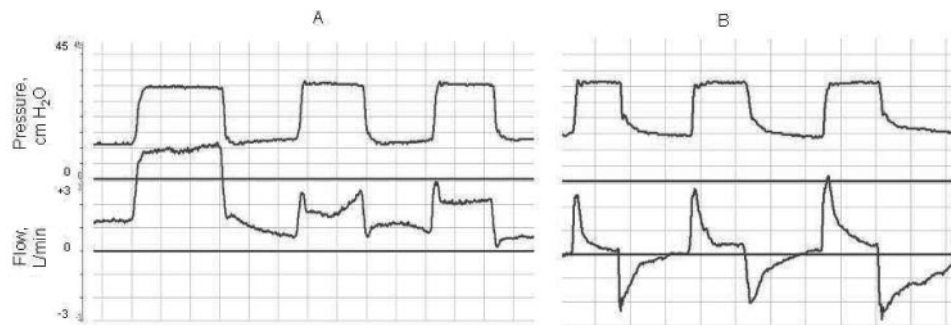


FIGURE 1

Pressure and flow traces recorded at 200 Hz using a flow sensor placed between the Neopuff and an ETT during positive pressure ventilation of an infant who was born at 26 weeks' gestation and weighed 621 g. Trace A was obtained after an esophageal intubation; no gas returns through the ETT when inflation stops. Trace B was obtained subsequently through a correctly placed ETT; gas returns through the ETT when inflation stops.

tively. Twenty-one attempts were made by 12 residents, 18 by 6 fellows, and 21 by 10 consultants. All were orotracheal intubation attempts. The mean (SD; range) number of intubation attempts per infant was 2 (1; 1–5). The indications for intubation are shown in Table 1 and included treatment allocation in our randomized trial comparing continuous positive airway pressure with endotracheal intubation and ventilation (the COIN trial).¹¹ To be eligible for randomization, infants of 25 to 28 weeks' gestation had to have regular spontaneous respiration by 5 minutes of age. The infants for whom the indication for intubation was extreme immaturity and/or low birth weight per se had a mean (SD) gestational age and birth weight of 24 weeks (1 weeks) and 681 g (111 g), respectively.

In the DR, ETT position was determined by clinical assessment alone after 46 (76%) attempts and by using flow signals and ETCO₂ on 7 (12%) occasions each. We verified the ETT position retrospectively using flow signals for 32 attempts and by examining the chest radiographs that were taken on admission to the NICU after 6 attempts. We thus secondarily confirmed ETT position using flow signals, ETCO₂, or chest radiograph after 94% (44 of 47) of attempts in which an ETT was introduced.

Successful Attempts

Overall, 37 (62%) intubation attempts were successful. In the DR, ETT position was determined by clinical assessment alone after 26 attempts; flow signals (see Fig 1B) and ETCO₂ were used in addition after 7 and 4 attempts, respectively. Twenty-seven attempts were subsequently verified as successful using flow signals. For the remaining 6 infants who had neither a flow sensor nor an ETCO₂ detector in the circuit in the DR, review of the chest radiographs on admission to the NICU confirmed correct placement of the ETT.

The rates of success and duration of intubation attempts overall and by group are shown in Table 2. The time taken to intubate successfully differed between grades of doctors ($P < .01$, analysis of variance), with more senior doctors intubating more rapidly ($P < .01$, test of linear trend; Table 2, Fig 3). Similarly, success rates differed between grades of doctors ($P < .001$, Pearson χ^2), with senior doctors more successful ($P < .001$, linear-by-linear trend; Table 2). The 2 shortest successful

TABLE 2 Success Rates and Duration of Attempts According to the Grade of Doctor Attempting Intubation

	Total	Residents	Fellows	Consultants
No. of attempts	60	21	18	21
No. (%) of successful attempts	37 (62)	5 (24)	14 (78)	18 (86)
Duration of attempts, mean (SD), s	33 (19)	38 (20)	36 (16)	28 (19)
Duration of successful attempts, mean (SD), s	31 (17)	51 (13)	32 (13)	25 (17)

attempts were 8 seconds. Ten (17%) attempts were successful within 20 seconds, an additional 12 (20%) were successful between 20 and 29 seconds, and the remaining 15 (25%) successful intubations took >30 seconds. The longest successful attempt took 70 seconds.

Of note, 1 successful intubation attempt was erroneously thought not to be successful on clinical grounds and on cursory examination of the flow signals. Close retrospective examination of these signals revealed that tiny quantities of gas were passing through the ETT (see Fig 2). In the DR, this correctly placed ETT was removed from this extremely preterm infant. The infant subsequently was reintubated by an experienced fellow who was confident that the ETT was positioned correctly. An ETCO₂ detector was placed in the circuit but did not change color. The ETT was confirmed to be passing through the cords on direct laryngoscopy by a consultant 90 seconds after reintubation. The peak inflating pressure was increased from 30 to 40 cm H₂O, and the HR increased >100 beats per minute at 108 seconds. The infant's own breathing effort improved at 131 seconds; only then was color change evident on the ETCO₂ detector. This suggests that insufficient exhaled gas and, thus, CO₂ passing through a correctly placed ETT was the reason that the reagent strip did not change color. This is the second such "false-negative" result that we have seen during the resuscitation of a preterm infant with noncompliant lungs.¹²

TABLE 1 Indications for Intubation

Indication for Intubation	No. of Infants (% of Total) (n = 31)	No. of Attempts (% of Total) (n = 60)
Bradycardia despite mask ventilation	9 (29)	16 (27)
Extreme prematurity and/or low birth weight	10 (32)	27 (45)
Congenital diaphragmatic hernia	3 (8)	3 (5)
Treatment allocation in COIN trial	5 (16)	9 (15)
Apnea/inadequate respiration	2 (7)	3 (5)
Poor respiration and other congenital problem	2 (7)	2 (3)



FIGURE 2

Traces recorded at 200 Hz during positive pressure ventilation that was given to an infant who was born at 28 weeks and weighed 1354 g. The flow sensor was placed between the ETT and Neopuff, which delivered a peak inflating pressure of 30 cm H₂O and positive end expiratory pressure of 5 cm H₂O. Minute quantities (0.1 mL) of gas are delivered during inflation and return when inflation stops.

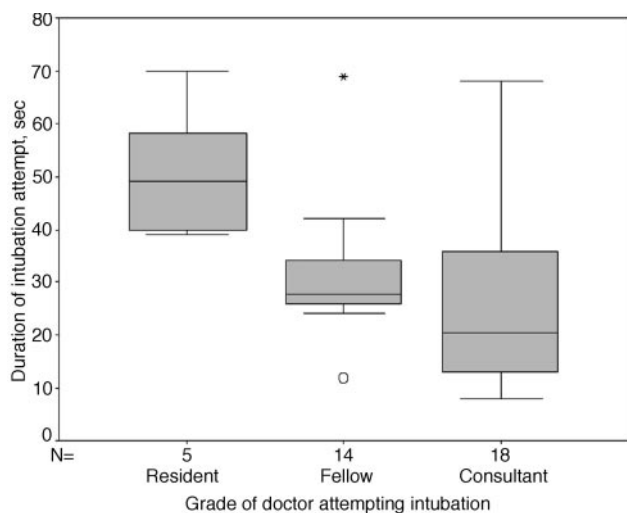


FIGURE 3 Box plot showing median, interquartile range, outliers, and extremes of duration of successful intubation attempts by grade of doctor.

Unsuccessful Attempts

Of the 23 unsuccessful attempts, 13 were abandoned without an attempt to pass the ETT as the vocal cords could not be visualized adequately. Seven attempts were determined to be unsuccessful by clinical assessment alone in the DR. Of these, 4 were verified using flow signals (see Fig 1A) and the infant could be heard to cry after 2 attempts. ETCO₂ was used in addition to clinical assessment after 3 attempts. No intubation attempt was determined unsuccessful using flow signals in the DR.

Time to Determination of ETT Position

Overall and excluding the 13 abandoned attempts for which no assessment of tube position was required, the mean (SD; range) time taken to determine ETT position was 33 seconds (28; 1–127). The mean (SD [range]) time to identify successful and unsuccessful attempts was not significantly different (32 [26] vs. 38 [37]; *P* = .55). The mean (SD; range) time taken for clinical assessment of ETT position (*n* = 33) was 39 seconds (30; 1–127); for flow signals (*n* = 7) and ETCO₂ (*n* = 7), it was 19 seconds (16; 8–53) and 17 seconds (20; 4–60), respectively. The time taken to assess tube position exceeded the time taken to intubate the infant on 15 (45%), 1 (14%), and 2 (29%) occasions for which clinical assessment, flow signals, and ETCO₂, respectively, were used.

Pulse Oximetry During Intubation Attempts

Twenty-seven infants had pulse oximetry during 51 intubation attempts. The oximetry sensor was applied to the infant at a mean (SD) of 53(20) seconds of life, and data were displayed at a mean (SD) of 80 (27) seconds of life. The mean (SD; range) time at which intubation was attempted was 253 seconds (135; 86–699).

Overall, infants deteriorated during 25 (49%) of these

attempts. Compared with the value just before the intubation attempt, SpO₂ alone fell by ≥10% in 9, HR alone fell by ≥10% in 4, and both fell by ≥10% in 12. The time at which infants deteriorated during intubation was variable, ranging from 2 to 55 seconds (mean: 20; SD: 13). Of the 12 attempts that were <20 seconds, no infant deteriorated during the attempt. Infants deteriorated during 4 of the 12 attempts that were between 20 and 29 seconds and 20 of the 27 attempts that were ≥30 seconds. Infants were monitored during 30 successful intubation attempts and deteriorated during 14; during the 21 failed attempts, 11 deteriorated.

As the reasons for intubation varied, so did the infants' condition before the attempt, eg, infants who were intubated for bradycardia despite mask ventilation had lower HR than infants who were randomly assigned in the COIN trial. Sixteen infants had HR <100 before intubation was attempted; 10 of these infants deteriorated during the attempt. Of the 35 infants who had HR ≥100, 15 deteriorated. The mean SpO₂ of the infants at the time intubation was attempted was 70%. Of the 25 infants with SpO₂ <70%, 17 deteriorated; of the 26 infants with SpO₂ ≥70%, 8 deteriorated.

DISCUSSION

Endotracheal intubation of the newborn is an important skill that seems to be difficult to acquire and improves with experience. Routine intubation of infants who are born through meconium-stained liquor is no longer recommended; it is no longer acceptable to practice intubation on infants who have died; working hours for doctors in training have been reduced internationally; and, in our hospital at least, there is a reduction in endotracheal ventilation as a result of increasing use of continuous positive airway pressure. These factors mean that the decline in opportunity to learn and practice neonatal intubation and the consequent decline in proficiency that has been described⁷ may well continue. This highlights the need for more anatomically suitable and life-like mannequins of premature infants.

This study shows that intubation is successful only ~60% of the time. Even when practitioners with considerable experience attempt intubation, many infants are not intubated within the 20-second limit suggested by the NRP.² In addition to fellows who are always present, consultant neonatologists frequently attend high-risk deliveries at our hospital, reflected by the relatively high proportion (35%) of attempts made by this group in our study. Our findings that consultants are more likely to intubate infants successfully and more quickly support the practice of having experienced senior staff present for back-up at high-risk deliveries.

An interval that rarely is considered in the time taken for intubation is the time taken for clinicians to decide whether the ETT is placed correctly. In our study, this frequently took longer than intubation itself when clin-

ical assessment alone was used. Our study suggests that, as has already been suggested for ETCO₂,^{13,14} flow signals may be useful in determining ETT position more quickly than clinical assessment alone. However, as also shown in this study, neither method is fool-proof, and both require additional evaluation.

In our study, infants frequently deteriorated during intubation attempts as determined by pulse oximetry. It seems that the more unwell the infant at the time of intubation, as indicated by the lower HR and SpO₂, the more likely they were to deteriorate during the procedure. For most of these infants, deterioration was not readily apparent on observation, and it is unlikely that it would have been identified quickly by intermittent assessment of the HR, by either auscultation or palpation. Although infants deteriorated more frequently during longer intubation attempts, the timing of deterioration was highly variable. For example, of the 20 infants who deteriorated during attempts of >30 seconds' duration, 12 had already done so by 20 seconds. Thus, rather than impose a general time limit for intubation attempts, we advocate improved monitoring of infants in the DR (eg, the use of pulse oximetry) and limiting the duration of intubation attempts according to their individual response.

CONCLUSIONS

Intubation attempts are often unsuccessful, and successful attempts frequently require >30 seconds. Greater experience is associated with greater success rates and shorter duration of successful attempts. The time taken to determine ETT position often exceeds the time taken to intubate and may be reduced by assessing flow signals or ETCO₂. Infants frequently deteriorate during intubation attempts. Improved monitoring of infants who are resuscitated in the DR is desirable.

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