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Digital tracheal intubation and finger palpation to confirm endotracheal tube tip position in neonates: A systematic review and meta-analysis

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Abstract

Background: To evaluate digital tracheal intubation (DTI) when compared to laryngoscope-assisted TI; finger palpation of endotracheal tube (ETT) tip position when compared to any standard method.

Design: A systematic review of Medline, Embase, CENTRAL, and CINAHL with synthesis of data using meta-analysis was performed.

Main outcome measure: The proportion of successful TI and correct ETT tip positioning were the main outcome measures.

Results: Five studies (one observational study and four RCTs) enrolling 310 neonates were included. 94% (81%–98%) of the DTI were successful on the first attempt (certainty of evidence [CoE]: low). The proportion of successful intubation on the first attempt was higher with DTI when compared to laryngoscope-assisted TI (RR 95% CI: 1.81 [1.18; 2.76]) (CoE: very low). Time to successful TI with DTI was 7.4 (95% CI: 6.3, 8.5) s (CoE: low). Time to successful TI was significantly shorter with DTI when compared to laryngoscope assisted TI (MD [95% CI]: −4.9 [−7.3, −2.4] s) (CoE: very low). There was a trend towards a higher proportion of correct ETT tip positions with finger palpation when compared to weight-based formulae alone (RR 95% CI: 1.12 [0.96; 1.31]) (CoE: very low).

Conclusions: DTI and finger palpation to ascertain ETT tip position in neonates are promising strategies. Future studies with emphasis on their learning trajectory and generalizability are needed.

KEYWORDS

mechanical ventilation, neonatal pulmonary medicine

1 | INTRODUCTION

Tracheal intubation (TI) is a life-saving procedure, often performed under emergent circumstances.[1] Successful execution of the procedure in the first attempt within a short period of time is crucial. Multiple attempts or delay in its execution can often be detrimental to the neonate in terms of increased risk of short and long-term adverse events such as hypoxia, bradycardia, intraventricular hemorrhage, and long-term neurodevelopmental impairment.[2,3]

Traditionally, TI is done with the use of a laryngoscope with or without video assistance.[4] In a large multi-centric observational study enrolling neonates, it was shown that 14% of the TIs were difficult to perform.[5] Multiple factors determine the eventual success of the procedure including the gestational age and birth weight of the neonate, training level of the personnel performing the procedure, and use of adjuncts such as video assistance or premedication.[5] Also, laryngoscope-assisted TI is often associated with adverse effects such as cyanosis, bradycardia, hypertension, stress-response reflex, and local trauma.[6–8] In situations where difficult upper airway anatomy is encountered, alternative strategies such as a laryngeal mask airway (LMA), cricothyroidotomy or tracheostomy are often performed.[9]

Finger or digital intubation (DTI) is an old practice described centuries ago and is a method of choice for TI utilized by a select few.[10] Limited mentions of DTI in literature have indicated that the success rates are much higher and the time to successful completion of the procedure is shorter when compared to laryngoscopy-assisted TI.[11,12] Such findings might be of immense relevance for the care of neonates not only in high-income countries but more so in resource-limited settings where nonavailability of equipment such as laryngoscopes or other accessories needed for its use are often major barriers.[13] Most of the neonatal training courses tailored for low resource settings such as helping babies breath (HBB) do not include advanced resuscitation maneuvers such as TI in their curriculum, predominantly due to the requirement of such extensive resuscitation only in a select few, lack of adequate post-resuscitation care for severely asphyxiated neonates, limited scope for training of manpower and resource constraints.[14]

The other important aspect of TI is to ensure that endotracheal tube (ETT) tip is positioned appropriately. There is conflicting evidence to either suggest or refute the reliability of the birth weight-based mathematical formulas that are often used to calculate the depth of insertion of the ETT tip.[15,16] Although end-tidal capnography is often used to confirm correct ETT placement in trachea, chest radiography is the gold standard to check for the optimal placement of its tip.[17] Recent evidence had indicated the utility of ultrasound in ascertaining the tip of ETT with higher accuracy.[17] The use of finger palpation to confirm the correct placement of the ETT in the trachea and accurate positioning of its tip has been evaluated in prior studies.[18–20]

To date, DTI in neonates has not been evaluated in a systematic review. Performing TI and adjudging the success of the procedure along with securing the ETT at an appropriate position based on the use of the operator's fingers alone, without the requirement of any equipment such as a laryngoscope, end-tidal CO_2 detector or chest radiography would have a huge impact on the resuscitation of neonates born in resource-limited settings. Hence, in this systematic review and meta-analysis we analyzed the relative efficacy of DTI over laryngoscopy-assisted TI; and the utility of finger palpation in guiding the ETT tip to an appropriate depth in neonates.

2 | METHODS

The systematic review was registered with PROSPERO (CRD42021242256)[21] and is reported in accordance with the PRISMA statement.[22]

2.1 | Literature search

Four databases namely, Medline, Embase, CENTRAL, and CINAHL were searched from their inception till March 4th, 2021. Further, the references of the included studies were searched. Both English and non-English literature were eligible for inclusion. Both randomized controlled trials (RCTs) and observational studies were considered for inclusion. Conference abstracts were also eligible for inclusion. Case reports, study protocols, and review articles were excluded. An online software program, Rayyan-QCRI was used for the literature search.[23] Two authors (VVR, TB) searched the literature independently. Disagreements were resolved by discussing with a third author (DT). The literature search strategy for the various databases is given in Table S1.

2.2 | Inclusion criteria

Studies that had evaluated the interventions of interest in neonates of term and preterm gestation were eligible for inclusion.

2.3 | Interventions

The following interventions were evaluated:

- DTI versus laryngoscope-assisted TI.
- Finger palpation to adjust the ETT fixed at the lip versus fixing of the ETT based on any standard methodology.

2.3.1 | DTI[10–12]

The operator may position either at the side or the foot of the neonate. Moistening the end of ETT and gloved fingers might help in facilitating the procedure. The index finger of the nondominant hand of the operator is inserted into the oral cavity to reach the epiglottis. The thumb of this nondominant hand may be used to give cricoid pressure. The ETT held with the thumbs and index finger of the dominant hand is then guided into the oral cavity to an appropriate distance. The index finger of the nondominant hand is then used to guide the ETT into the glottis. A slight "give" is usually felt as the catheter crosses the glottis, though no force should be used during insertion. The little finger may be used in extremely low gestational neonates with small oral aperture. During the initial training, a stylet may be used. In experienced hands, even flexible suction catheters may be passed using this technique.

2.3.2 | Finger palpation to determine ETT tip[18–20]

Softer cartilage in neonates allows ETT to be palpated easily. The bevel of the ETT is guided to the level of the suprasternal notch by palpation using the index or little finger. This position at the suprasternal notch corresponds to the mid-tracheal point or to the line drawn between the medial ends of the two clavicles. Palpation can be done by the person who is intubating using the nondominant hand while securing and adjusting the ETT with the dominant hand or by another operator.

2.3.3 | Outcomes

Primary outcomes

- Proportion of successful TI
- Time to successful TI
- Incidence of trauma or bleeding
- Proportion of correct ETT tip position.

Risk of bias

The risk of bias of RCTs was evaluated by using Cochrane risk of bias tool version 2.0.[24] The risk of bias of observational trials and RCTs included in the proportion-based meta-analysis and meta-analysis of means was evaluated based on a modified QUIPS scale.[25] Two authors (TA, TB) performed the risk of bias assessment independently and conflicts were sorted by discussing with a senior reviewer (DT).

Data extraction and synthesis

Proportion based meta-analysis of logit transformed data and meta-analysis of means was performed using a random effects model. Pairwise random effects meta-analysis was utilized to synthesize data from RCTs. Heterogeneity was assessed based on Cochran Q, τ^2 and I^2 statistics. The estimates were depicted with forest plots as risk ratio (95% confidence interval [CI]) and mean difference (95% CI).

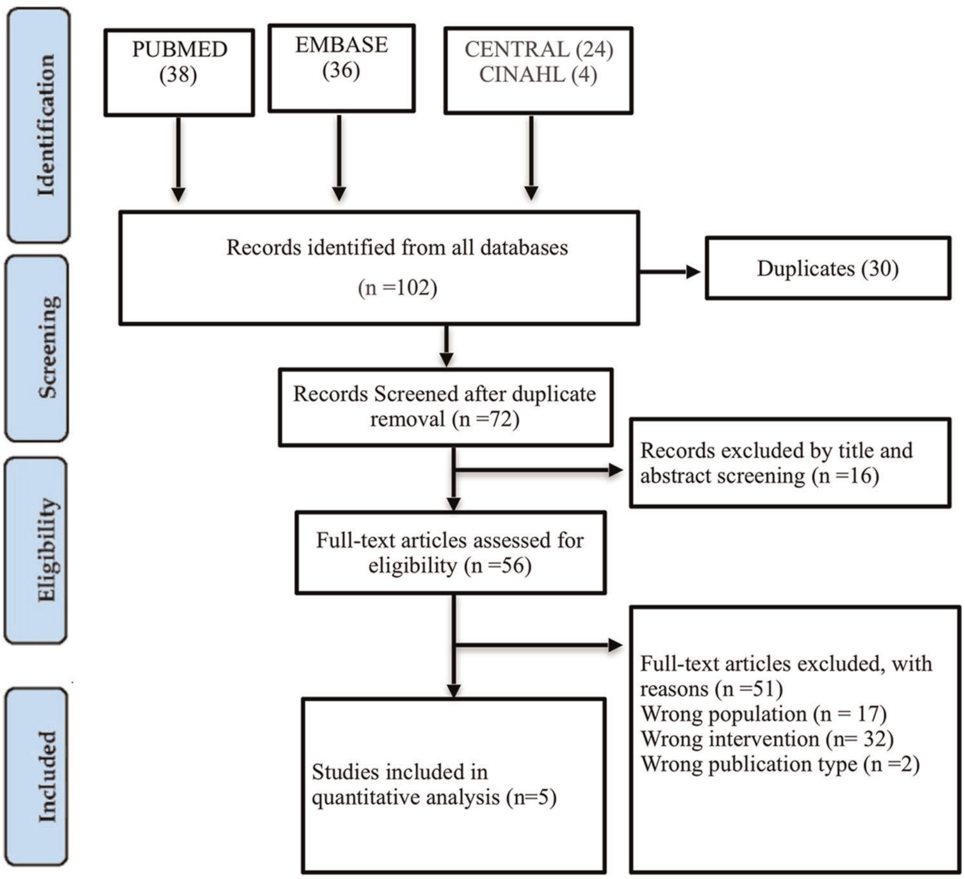

FIGURE 1 Literature search flow [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Characteristics of included studies

Author	Country	Design	Subjects, mean (*SD*)/ median (IQR) birth weight and gestational age	Intervention	Comparator	Outcomes	Comments
Digital/finger tracheal intubation							
Hancock 1992	USA	Prospective observational study	Term and preterm neonates 2330 (1100) g Range: 750–4620 g	DTI (*n* = 39)	None	- Time to TI - Decrease in heart rate - Decrease in saturation	DTI was the preferred method of many health personnel in the study center. DTI was performed under varied circumstances including in the delivery room, emergency and elective intubations in the NICU and during transport
Moura 2006	Brazil	RCT	Neonates >1000 g included IG: 1661 g, 32 w CG: 1686 g, 32.2 w	DTI (*n* = 21)	Laryngoscope TI (*n* = 24)	- Success rate - Time to TI - Complications (bleeding and trauma)	Only one experienced researcher performed the procedure. If DTI was not successful in 20 s, the procedure was abandoned and laryngoscope assisted intubation attempted. Neonates with facial malformations and those receiving premedication for intubation were excluded
Finger palpation to confirm endotracheal tube tip position							
Jain 2004	USA	RCT	Term and preterm neonates IG: 1887 g, 32.5 w CG: 1956 g, 32.2 w	Digital palpation to adjust the tip of ETT	ETT fixed at a distance based on weight dependant nomogram (*n* = 28)	- Proportion of correct placement of ETT - Death or complication in the 12 h following intubation - Need for ETT adjustment after its initial securing - Need for repeat chest radiography to confirm ETT tip position after manipulation	Correct position was defined as any position <0.5 cm above the interclavicular midpoint and >1 cm from carina. Suboptimal position was defined as >0.5 cm above the interclavicular mid-point, <1 cm above the carina or >.5 cm into a mainstem bronchus.

TABLE 1 (Continued)

Author	Country	Design	Subjects, mean (*SD*)/ median (IQR) birth weight and gestational age	Intervention	Comparator	Outcomes	Comments
Saboo 2013	India	3-armed RCT	Term and preterm neonates IG1:1516 (669) g, 31.5 (3) w IG2: 1615 (668) g, 32.2 (3) w CG: 1414 (883) g, 31 (5.7) w	IG1: Digital palpation to adjust the tip of ETT which was placed at a distance based on a weight dependent nomogram by trained doctors who had performed the procedure prior (*n* = 20) IG2: Similar to IG1 but the doctors were only taught the procedure verbally and pictorially (*n* = 22)	CG: ETT fixed based on a weight dependent nomogram and adjusted based on chest rise and breath sounds (*n* = 15)	- Proportion of correct placement of ETT	Correct position was defined similar to Jain et al. study
Murphy 2020	Ireland	RCT	Preterm neonates IG: 1220 (810–1960) g, 28 (25–32) w CG: 1120 (830–1630) g, 29 (26–34) w	ETT tip was positioned based on its palpation by an assistant. (*n* = 58)	ETT tip was positioned based on weight dependent formula (*n* = 60)	- Correct position of the ETT tip position in chest radiography - Low position of ETT tip defined as below T2 - High position of ETT tip defined as above T1 - Extubation before chest radiography - Air leak - Bronchopulmonary dysplasia (at 28 days and 36 weeks) - Death before discharge	The correct position of ETT was defined as between T1 and T2 as determined by chest radiography.

Abbreviations: CG, control group; DTI, digital tracheal intubation; ETT, endotracheal tube; IG, intervention group; TI, tracheal intubation; T1, T2, thoracic vertebra 1, 2.

The certainty of the evidence was evaluated using the GRADE working group guidelines.[26]

3 | RESULTS

Of the 72 titles and abstracts that were screened after the removal of duplicates, 56 full texts were evaluated, and 5 studies were included in the meta-analysis. The literature search flow is provided in Figure 1. Four were RCTs (one on DTI and three on finger palpation to confirm ETT tip position)[11,18–20] and one was a prospective observational study on DTI.[12] One of the RCTs was three-armed.[18] Though all the included studies had enrolled a mixture of term and preterm neonates, the mean gestational age of the neonates included in the RCTs was 32 weeks in three studies[11,18,19] and 28 weeks in one study.[20] The technique utilized for DTI was similar in all the included studies. The operator performing DTI was an experienced health personnel in the included studies.[11,12] Two RCTs evaluating the finger palpation technique for confirming the ETT tip position had evaluated one group in which the operators were taught finger palpation of ETT pictorially and did not received hands-on training.[18,20] Although two RCTs on finger palpation for ETT tip positioning had used similar criteria in chest radiography to define its correct position based on interclavicular point and carina,[18,19] one RCT had taken T1-T2 vertebrae as the correct tip position.[20] The characteristics of the included studies are listed in Table 1.

3.1 | Risk of bias

Although three RCTs had a low risk of bias overall,[11,18,19] one had some concerns.[20] As blinding of the intervention to the personnel performing the procedures was not possible, all studies had some concerns reagrding the domain 'deviations from intended interventions'. A published protocol was not accessible for three of the included RCTs[11,18,19] and hence the domain 'selection of reported result' was evaluated as having some concerns. Furthermore, one of the RCTs with a high risk of bias overall had issues with randomization and measurement of the outcome as well.[11] The two studies included in the meta-analysis of proportions and means had a low risk of bias.[11,12] The risk of bias is given in Figure 2A,B.

3.2 | Outcomes

3.2.1 | Proportion of successful ETI

Meta-analysis of proportions showed that 94% (81%–98%) of the DTI were successful in the first attempt (certainty of evidence: low) (Figure 3A). One RCT indicated that the chances of successful intubation in the first attempt were significantly higher with DTI when compared to laryngoscope-assisted TI (RR 95% CI: 1.81 [1.18; 2.76]) (certainty of evidence: very low) (Figure 3B).

3.2.2 | Time to successful TI

Meta-analysis of means showed that the time to successful TI was 7.4 (95% CI: 6.3, 8.5) s with DTI (certainty of evidence: low) (Figure 3C). The only RCT which compared DTI versus laryngoscopy assisted TI showed that the time to successful TI was significantly shorter with DTI (MD [95% CI]: −4.9 [−7.3, −2.4] s) (certainty of evidence: very low) (Figure 3D).

(A) Risk of bias assessment of RCTs

Study	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall bias
Jain2004	Low risk	Some concerns	Low risk	Low risk	Some concerns	High risk
Moura2006	Some concerns	Some concerns	Low risk	Some concerns	Some concerns	High risk
Saboo2013	Low risk	Some concerns	Low risk	Low risk	Some concerns	High risk
Murphy2020	Low risk	Some concerns	Low risk	Low risk	Low risk	Some concerns

(B) Risk of bias assessment for proportion based meta-analysis and meta-analysis of means

Study	Confounding (All characteristics of patients known to affect the outcome reported: Birth weight, Gestational age, upper airway anomaly, setting where intubation was performed) (★ If Minimum 3 Are Reported)	Deviation from intended interventions (Study design) (★ If Prospective)	Missing data (★ If Not significant)	Overall Assessment: ★★★ - Low risk ★★ – Moderate risk ★ Or None – High risk
Hancock1992	★	★	★	Low risk
Moura2006	★	★	★	Low risk

FIGURE 2 (A) Risk of bias assessment of andomized controlled trials (RCTs). (B) Risk of bias assessment for proportion-based meta-analysis and meta-analysis of means [Color figure can be viewed at wileyonlinelibrary.com]

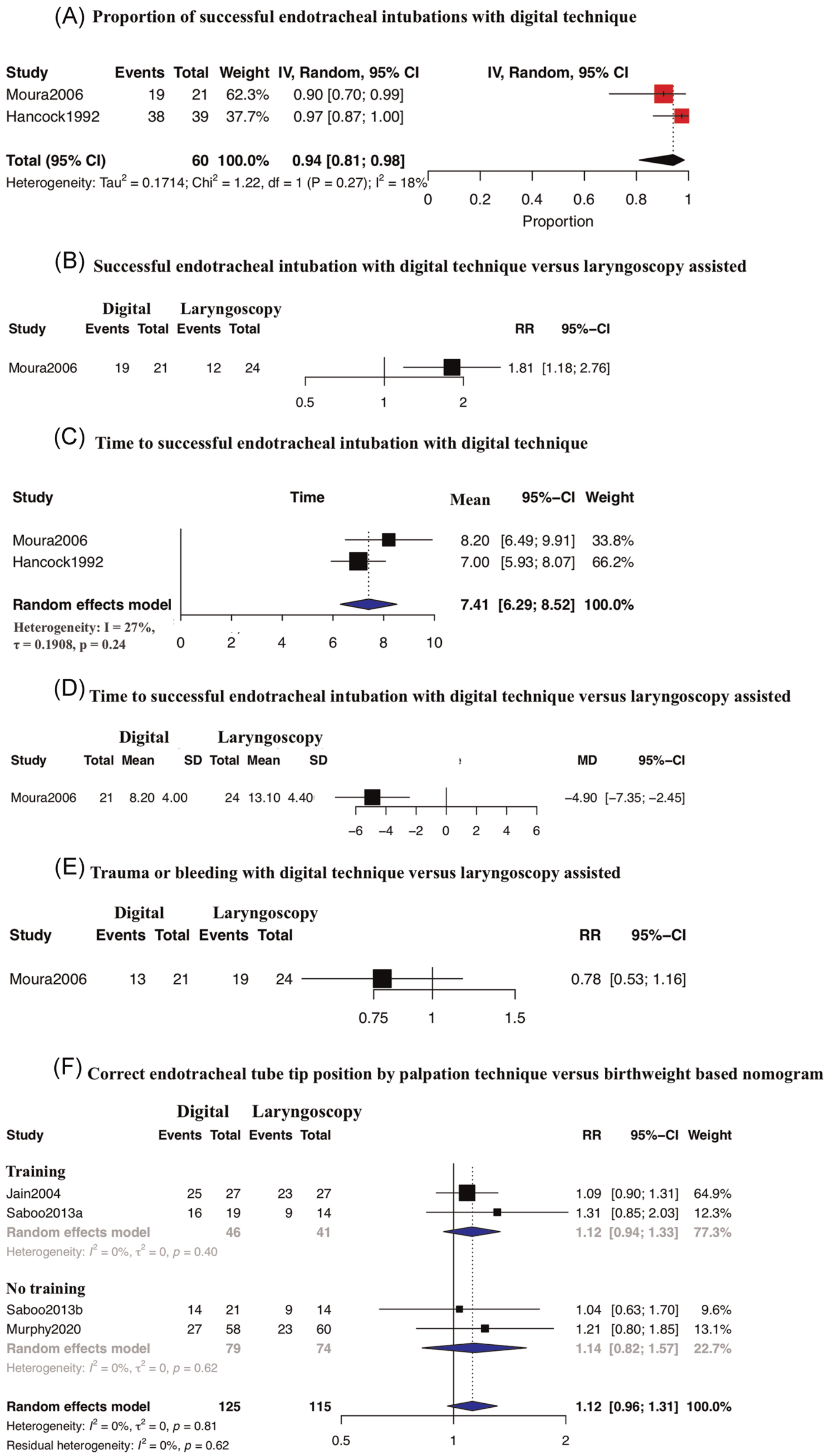

FIGURE 3 (A) Proportion of successful endotracheal intubations with digital technique. (B) Successful endotracheal intubation with digital technique versus laryngoscopy assisted. (C) Time to successful endotracheal intubation with digital technique. (D) Time to successful endotracheal intubation with digital technique versus laryngoscopy assisted. (E) Trauma or bleeding with digital technique versus laryngoscopy assisted. (F) Correct endotracheal tube tip position by palpation technique versus birth weight-based nomogram [Color figure can be viewed at wileyonlinelibrary.com]

3.2.3 | Incidence of trauma or bleeding

One RCT reported no differences between DTI and laryngoscope-assisted TI for the outcome trauma or bleeding (RR 95% CI: 0.78 [0.53; 1.16]) (certainty of evidence: very low) (Figure 3E).

3.2.4 | Proportion of correct ETT position

Meta-analysis of three RCTs indicated that there was a trend towards a higher proportion of correct ETT position with finger palpation technique when compared to weight-based formula alone (RR 95% CI: 1.12 [0.96; 1.31]) (certainty of evidence: very low). Finger palpation for ETT tip, when performed by personnel who had no prior hands-on training, had a similar proportion of optimal ETT tip position when compared to birth weight-based formula alone (RR 95% CI: 1.14 [0.82; 1.57]) (Figure 3F).

The certainty of the evidence for all the outcomes is given in Tables S2 and S3.

4 | DISCUSSION

Our search revealed only one RCT and an observational study evaluating DTI.[11,12] Low certainty of evidence from these studies indicate that the success rates of digital intubation is 94% and that DTI could be performed within a mean time of 7.4 s. The only RCT that had evaluated DTI versus laryngoscopy-assisted TI had reported that DTI is relatively faster and is associated with improved success rates in the first attempt.[11] Two case reports have also mentioned the utility of DTI in neonates with difficult upper airway anatomy such as Pierre Robin syndrome, where conventional laryngoscopy assisted TI had failed.[27,28] Lingappan et al. in their Cochrane review had reported that the mean time to successful TI in neonates was more than 50 s even with the aid of a video laryngoscope.[4] The National Emergency Airway Registry for Neonates (NEAR4NEOS) from the USA had reported that the first attempt success rate of TI using a laryngoscope was only 49%.[29] It should be noted that while personnel who performed DTI in the two included studies were well experienced, the NEAR4NEOS had included data on TI performed by professionals with varying background of skills including residents, neonatal fellows, respiratory therapists, and nurse practitioners.[29]

There are many aspects of DTI that need further evaluation. Xue et al. had described the use of a light-wand guided DTI in neonates in their correspondence to the Editor.[30] This could be further explored in future trials. The learning curve for DTI is unknown. The potential adverse effects associated with the procedure need to be evaluated further. Furthermore, its feasibility in extremely low gestational age neonates might be doubtful due to the small oral aperture.[12] Finally, the effect of the use of premedication during DTI has not been studied. The utility of DTI in low-resource settings also needs to be evaluated in future studies. Most of the neonatal resuscitation training programs tailored to teach health professionals in low resource settings such as HBB do not include advanced airway management such as TI.[13] Though a majority of the neonates do not require this step, the feasibility of training personnel on DTI which does not require any additional equipment needs to be studied. A recent RCT conducted in Uganda evaluating the use of a LMA for providing positive pressure ventilation (PPV) when compared to the routinely used face mask found that LMA might have a lower likelihood of treatment failure and might be a better rescue strategy when face mask PPV fails.[31] Studies on such low-cost innovative interventions are the need of the hour in low resource settings, which have a huge burden of perinatal asphyxia and its associated morbidity and mortality.

The evaluation of ETT tip position is as important as that of placing the ETT successfully in the trachea. Though weight-based nomograms or formulas are used to calculate the lip-to-tip distance, a chest radiograph is routinely used to confirm the actual position of the ETT tip.[17] Portable radiograph machines might not be available in low-resource settings. In such scenarios, the use of finger palpation to confirm whether ETT is in the trachea as well as to determine the position of the ETT tip would be of immense benefit. Very low certainty of evidence from three RCTs included in this review showed that there was a trend towards the more correct placement of ETT tip when finger palpation is used. Also, studies that had trained the operators extensively showed better efficacy of the palpation technique when compared to those in which operators had limited prior training. Razak et al. had similarly evaluated different methods of estimating the depth of ETT such as using weight and gestational age-based nomogram and finger palpation.[32] Although Razak et al.'s review had looked at the accuracy of these methods based on the different gestational ages of neonates studied, we had added further information on the effect of training on the success rate of the palpation technique. Also, our review was intended to look at the feasibility of using DTI along with finger palpation to confirm the correct positioning of ETT as two sequential steps in neonates in LMICs. In view of the very low certainty of the evidence, we suggest adequately powered RCTs to evaluate the efficacy of the finger palpation technique.

There were several limitations to our review. Firstly, a very limited number of studies had evaluated DTI or finger palpation to ascertain ETT tip position. Secondly, surrogate outcomes such as success rates and time to successful completion of procedure were reported instead of important clinical outcomes. Thirdly, the evaluated studies included a widely heterogenous population of term and preterm neonates of varying gestational ages. Finally, the certainty of the evidence for the outcomes was low to very low.

5 | CONCLUSION

Low certainty of evidence suggests that DTI in neonates is feasible, might be faster, and is associated with improved success rates in experienced hands when compared to laryngoscopy-assisted TI. Furthermore, very low certainty of evidence showed that finger palpation to ascertain the position of ETT tip might be a promising adjunct to the routinely utilized birth weight-based formula. As there are many unanswered questions in relation to DTI and given the fact that it might be of relevance in the resuscitation of neonates in low resource settings, we suggest future studies evaluating its learning curve and relative efficacy when performed by newly trained personnel.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Viraraghavan Vadakkencherry Ramaswamy: conceptualization (lead); formal analysis (lead); methodology (lead); writing original draft (lead); writing review & editing (equal). **Thangaraj Abiramalatha**: data curation (equal); formal analysis (equal); methodology (equal); writing review & editing (equal). **Tapas Bandyopadhyay**: data curation (equal); formal analysis (equal); validation (equal); writing review & editing (equal). **Abdul Kareem Pullattayil**: data curation (supporting); investigation (supporting); methodology (equal); resources (lead); writing review & editing (equal). **Daniele Trevisanuto**: conceptualization (equal); formal analysis (equal); writing original draft (equal); writing review & editing (lead).

IMPACT STATEMENT

- Digital tracheal intubation might be a promising technique in neonates for faster intubation and with a higher success rates in experienced hands when compared to laryngoscopy-guided tracheal intubation.
- Due to the low certainty of evidence and its potential to improve neonatal care in low resource settings, future trials on digital tracheal intubation with large sample sizes is emphasized.

DATA AVAILABILITY STATEMENT

All the data included are from published trials. Data related to this systematic review is available on request.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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