Title: Video Versus Direct Laryngoscopy For Urgent Tracheal Intubation In Neonates: A Systematic Review And Meta-Analysis

Keywords: Intubation, neonate, videolaryngoscope

Authors: Niall Donaldson[1], Colm PF O'Donnell[2,3], Charles C Roehr[4,5,6], Eleri Adams[7], David Bartle[8], Lucy E Geraghty[2, 3], Robert Tinnion[9], Joyce E O'Shea[1,10, 11].

Authors' Affiliations: Royal Hospital for Children[1], Glasgow; National Maternity Hospital, Dublin[2]; University College Dublin, Dublin[3]; Women's and Children's Division, Southmead Hospital, North Bristol NHS Trust, Bristol[4]; Faculty of Health Sciences, University of Bristol, Bristol[5]; National Perinatal Epidemiology Unit, Oxford Population Health, University of Oxford[6]; Oxford University Hospitals, NHS Foundation Trust[7], Royal Devon and Exeter Hospital, Exeter[8]; Newcastle upon Tyne University Hospitals, Newcastle[9]; Scotstar Neonatal Transport, Glasgow[10]; University of Glasgow, Glasgow[11].

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Corresponding Author: Joyce O'Shea

Email: Joyce.oshea2@nhs.scot

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ABSTRACT

Intubation is most often performed electively by anaesthetists in controlled conditions in operating theatres. In neonates, however, it is most often performed by neonatologists or paediatricians in urgent circumstances in the neonatal intensive care (NICU) or delivery room (DR). Neonatal intubation is a difficult skill to learn and maintain, and success rates are sub-optimal both in the NICU and DR. Video laryngoscopy (VL) has the potential to increase intubation success and safety as it may offer a better view of the airway, which can be shared by the intubator and other clinicians.

Objectives:

To compare the efficacy and safety of using VL to direct laryngoscopy (DL) for intubation of neonates in the NICU and DR.

Search Methods:

We searched the Cochrane Central Register of Controlled Trials, MEDLINE, Embase and CINAHL up to August 2024 without language restrictions.

Selection Criteria:

Randomised controlled trials (RCTs), quasi-RCTs, cluster-RCTs, or cross-over trials that compared VL to DL for intubation of neonates outside of the neonatal operating theatre.

Main Results

VL improves first attempt intubation success rates, (RR 1.46, 95%CI 1.21 – 1.75), with a number needed to treat (NNT) of 6.

Conclusions

VL should be the standard of care for neonatal intubations in the NICU and DR

BACKGROUND

Adults and children are most commonly intubated electively by anaesthetists in controlled conditions in operating theatres, with high success rates. Neonates however, are most often intubated by paediatricians or neonatologists, advanced neonatal nurse practitioners (ANNPs) or respiratory therapists. Neonatal intubations are usually performed in urgent circumstances in the neonatal intensive care unit (NICU) or delivery room (DR). In both of these settings, the need for intubation can arise with little warning. The DR can be particularly challenging as space, staff and equipment are often limited. Success rates are around 50% and even lower for inexperienced or infrequent intubators.[1,2] Multiple attempts are frequently required and the risk of adverse events (including hypoxia; trauma to the upper airways, pharynx and larynx; pneumothorax; interventricular haemorrhage and death) increases with each attempt.[3,4,5] By the third attempt the risk of adverse events increases ten-fold.[3]

Changes in clinical practice in neonatology in recent years (e.g. cessation of routine intubation of neonates born through meconium-stained liquor and increased use of non-invasive breathing support) have resulted in a dramatic reduction in the number of intubations. There has also been a steady increase in the numbers of clinicians (doctors, nurse practitioners, respiratory therapists) trying to learn the skill. With decreasing opportunity to practice, success rates have fallen, and it is more challenging to achieve and maintain proficiency.

Traditionally, clinicians intubate a neonates by looking directly into their mouth using a standard laryngoscope (direct laryngoscopy, DL). The supervision that can be provided to inexperienced operators is limited, as the trainer cannot share the view

of the airway to guide successful intubation. Their ability to point out the anatomy and correct errors is limited. A review of unsuccessful intubations performed by novice intubators found that lack of intubation success was mostly associated with failure to recognise the anatomy.[6]

The use of video laryngoscopes (VL), which display a magnified image of the airway on a monitor for clinicians to view (indirect laryngoscopy) is increasingly being used. The magnified view may be advantageous not only to the intubator, but also the supervisor and other members of the intubation team, as the images are available for all to see, allowing real time changes in technique and position, to achieve successful intubation.

In adults,[7,8], its use has been shown to improve intubation success and safety. [7,8] A large recent adult study (sample size 1417) comparing VL to DL in urgent intubations of critically unwell adults found improved first attempt successful intubation on the first attempt with VL (85% v 71%, 95% CI, 9.9 to 18.7; P<0.001).[8] Within the paediatric population, VL is increasingly being used also. Two large studies using VL compared to DL for elective intubation of children by anaesthetists have recently been published. Garcia-Marcinkiewicz included 564 intubations and found first attempt success rates were higher with VL, (93% compared to 88%(adjusted absolute risk difference 5·5% [95% CI 0·7 to 10·3]; p=0·024)).[9] Riva et al included 250 intubations and found the first-attempt tracheal intubation success rate with no desaturation was higher with VL (89% compared to 79% (adjusted absolute risk difference of 9·5% (0·8 to 18·1; p=0·033)). [10] A 2017 Cochran review of VL in children included 12 studies of elective intubation by anaesthetists in operating theatres. The sample

sizes of these studies were small (range 34 – 203, only one study included more than 100 children.) The first attempt success rates in both groups was high generally greater than 90% and not different between them. [11]

As VL has the potential to improve intubation success and safety, it should be considered for routine care in neonates. However, there should be evidence of benefit to justify the costs associated with introducing VL (equipment and training). A Cochrane review of VL for neonatal intubation showed a small beneficial effect of VL. However, this review included studies of infants undergoing elective surgery who were intubated by anaesthetists, in addition to studies where neonates were intubated in urgent circumstances in NICU and DR.[12] As the clinical scenarios and personnel who perform urgent intubation in these settings are quite different, we felt it clinically relevant to only include studies that enrolled neonates intubated in the NICU and DR in this review and meta-analysis.

OBJECTIVES

To perform a systematic review and meta-analysis of the use of VL for urgent intubation of neonates in the NICU and DR.

METHODS

Criteria for Considering Studies for this Review

Types of Studies

Randomised controlled trials (RCTs), quasi-RCTs, cluster-RCTs, or cross-over trials performed in the NICU or DR were included. Studies conducted outside these

settings (e.g. in operating theatres, anaesthetic rooms or paediatric intensive care units) were excluded.

Type of Participants

Neonates in whom intubation was attempted were included. The intubations were carried out by either paediatric trainees or consultants, neonatal trainees or consultants, advanced neonatal nurse practitioners or respiratory therapists.

Types of Interventions

The comparison of VL to DL for intubation. Any model of VL was accepted.

Types of Outcome measures

Primary and secondary outcomes were assessed either during or immediately after the intubation attempt.

Primary Outcomes

- Intubation success at first attempt (measured by one or a combination of; exhaled carbon dioxide detection, chest wall movement, chest auscultation, misting of tube, improvement in clinical condition and position on first chest x-ray)
- Overall intubation success rate (confirmed by the same methods)

Secondary Outcomes

- Lowest oxygen saturation (SpO_2) recorded
- Lowest heart rate (HR) recorded
- Number of bradycardic/ desaturation episodes
- Time taken at intubation attempt

- Number of intubation attempts
- Airway related adverse events e.g. mucosal trauma, bleeding, lacerations

Subgroup analyses:

- Level of experience of the operator – trainee, experienced clinician

Search Methods for Identification of Studies

Electronic Search

We searched the Cochrane Central Register of Controlled Trials, MEDLINE, Embase and CINAHL up to August 2024. We searched clinical trials databases for ongoing and recently completed trials and did not apply language restrictions. We used the search strategy: Video laryngoscopy OR Video laryngoscope AND direct AND intubation AND Neonate or Neonatal.

Data Collection and Analysis

We used the Cochrane method for conducting a review.[13] We extracted the following information from each of the papers selected; blinding, randomisation, single vs multi centre, intervention and stratification. Data was collected regarding each of the outcomes outlined in the papers selected.

Selection of Studies

We reviewed the titles of all papers identified by the electronic searches and removed duplicates. We then read the abstracts and included the papers in the review if they met our inclusion criteria. Full versions of the texts of selected papers were obtained and authors were contacted directly, if the outcomes we sought weren’t reported in the papers.

Data Extraction from Selected Studies

We collected the following data from each of the studies;

- Title, authors and date when published
- Single vs multi centre, location of study
- Randomisation process and blinding
- Type of video laryngoscope used
- Inclusion and exclusion criteria
- Primary and secondary outcomes and sub-group analyses
- Results of primary and secondary outcomes and sub-group analyses

Assessment of Risk of Bias of Included Studies

We assessed each of the included studies in the following domains using the Cochrane Risk of Bias Tool;

- Sequence generation (selection bias)
- Allocation concealment (selection bias)
- Blinding of participants and personnel (performance bias)
- Blinding of outcome assessment (detection bias)
- Incomplete outcome data (attrition bias)
- Selective reporting (reporting bias)
- Any other bias

Measures of treatment effect

We analysed the results of included studies using the statistical package Review Manager software (RevMan 5.4 2020). We used the standard method of the

Cochrane Neonatal Review Group and applied a fixed-effect model for meta-analysis.[13]

RESULTS

Results of Search

Six studies fulfilled our inclusion criteria - O'Shea 2015, Moussa 2016, Volz 2018, Bartle 2019, Tippmann 2023 and Geraghty 2024.[14-19] The characteristics of study participants are presented in Table 1.

	Video Laryngoscope				**Direct Laryngoscope**			
	Birth Weight (grams)	Gestational Age (Weeks)	Weight at Intubation (grams)	Corrected Gestational Age at Intubation (Weeks)	Birth Weight (grams)	Gestational Age (Weeks)	Weight at Intubation (grams)	Corrected Gestational Age at Intubation (Weeks)
O'Shea	1091 *(795-1799)*	28 *(26-32)*	1173 *(819-1884)*	29 *(27-32)*	1027 *(757-1562)*	28 *(26-30)*	1125 *(816-1569)*	29 *(27-32)*
Moussa	1080 *(838-1910)*	29 *(26-32)*	1410 *(1035-2200)*	31 *(28-35)*	1315 *(953-2284)*	29 *(27-34)*	1603 *(1155-2580)*	32 *(29-36)*
Volz			1870 *(±972 SD)*	32.8 *(±5 SD)*			1847 (±1020 SD)	32.4 (±5 SD*)*
Bartle			2620 *(Mean)*				2040 *(Mean)*	
Tippmann			1220 *(815-1695)*	29 *(27-33)*			1077.5 *(755.5-1760.5)*	29 *(26-33.5)*
Geraghty	1340 *(755-2400)*	29.6 *(26.6-34.1)*			1250 *(810-2460)*	28.4 *(26.3-34.7)*		

Table 1: Characteristics of study participants

Included Studies

We identified six randomised controlled trials, including one feasibility study (Bartle), for inclusion in this review.[17] These studies reported a total of 863 intubations.

Five studies were single centre and one (Bartle) was multi-centre. The studies were conducted in Australia, Canada, Germany, Ireland, United Kingdom and United States of America.

The studies included neonates of either sex and a wide range of weights and gestations, in whom intubation was attempted in the NICU or DR. The intubations were carried out by paediatric trainees, neonatal trainees, advanced neonatal nurse practitioners or neonatologists. All studies included a VL with a modified Miller blade.

O'Shea 2015 included paediatric trainees with less than six months of tertiary neonatal experience. All intubations were oral and performed in NICU or DR using the LaryFlex VL, (Acutronic, Hirzel, Switzerland). The VL was used to perform direct laryngoscopy in all infants, while random assignment determined whether the screen was visible to other clinicians or covered during the attempt. All intubations were supervised in a controlled manner. The sample size was 206 intubations. The primary outcome was successful intubation at the first attempt. Secondary outcomes were lowest heart rate and oxygen saturations recorded during attempt and the duration of the attempt. [14]

Moussa 2016 randomised paediatric residents (Years 1-3) to learn to intubate using either C-MAC (Karl Storz, Tuttlingen, Germany) VL for indirect laryngoscopy or DL. In the second phase of the study, the experimental arm crossed over to perform DL. Nasal and oral intubations within NIU were included, and all intubations were supervised by a senior clinician. The sample size was 213 intubations. The primary outcome was successful intubation within three attempts. Secondary outcomes were time to successful intubation, number of bradycardic episodes, lowest SpO_2 during attempt, mucosal trauma, number of failures and reason for intubation failure.[15]

Volz 2018 randomised paediatric trainees to either use C-MAC VL to perform direct laryngoscopy within NICU while being coached by a supervisor or DL. Forty-eight trainees were included in the study, with 101 oral intubations being analysed. The primary outcome was successful intubation within two attempts. Secondary outcomes were intubation success rates by training year, success on first and second attempts and adverse events.[16]

Bartle 2019 conducted a feasibility study. Oral intubations within the NICU were randomised to using either a C-MAC VL or DL. The intubators were paediatric trainees who were supervised by a senior colleague. The sample size was 40 intubations. The primary outcome was successful intubation within three attempts. Secondary outcomes were number of attempts to successful intubations and trainee and trainer satisfaction.[17]

Tippmann 2023 randomised neonates who were being nasally intubated to indirect laryngoscopy using Infant View VL (Acutronic Medical Systems AG, Switzerland) or DL. The sample size was 89 intubations. Intubations were performed by trainees and consultants (24%) and took place within NICU and DR. The primary outcome was successful intubation at the first attempt. Secondary outcomes were rate of adverse events, episodes of moderate or severe bradycardias and desaturations, number of attempts until successful and frequency of cross over to the alternative method.[18]

Geraghty 2024 randomised neonates within NICU or DR settings being orally intubated, to either indirect laryngoscopy with a C-MAC VL or DL. The sample size was 214 intubations. Intubators were all levels of trainees and consultant neonatologists (5%). The primary outcome was successful intubation at the first attempt. Secondary outcomes were lowest SpO_2 during attempt, lowest HR, number

of attempts to successful intubation, duration of successful intubation attempts and cross over to alternative device.[19]

Risk of Bias

The risk of bias table is presented in Figure 1

Figure 1: Risk of bias in included studies

Allocation

The six studies included in the review were judged at low risk of bias at randomisation.

Five of the six studies were judged to be low risk for allocation concealment, one study (Volz) was judged to be unclear as no details were given.

Blinding

The risk of performance bias was judged to be high in all six studies. Due to the nature of the interventions it was not possible to blind the participants nor outcome assessors. The participants knew what device they used during the procedure and the trainee/ supervisor knew whether a screen was visible during the intervention.

The outcome assessors were not reported to be blinded. However, given that the primary outcomes were measured using objective outcomes such as exhaled carbon dioxide detection, we judged that this risk was low.

Incomplete data

In Volz's study, 24 of the 61 intubations (39%) in the VL group were performed using DL, because the infants were <1000 g, considered too small for the VL. The results

were reported as intention to treat but this high degree of crossover may reduce the effect of the intervention. The success rates by method of intubation used is not presented.

Selective Reporting

The risk of reporting bias was judged to be low in all six studies, as outcomes were reported for all participants.

Primary Outcomes

Successful Intubation at first attempt was reported by four studies and the remaining authors were contacted and provided data on this outcome for the remaining studies. Meta-analysis of this outcome (figure 2) included 849 intubations. The use of VL compared to DL showed an increased first attempt success rate (RR 1.45, 95%CI 1.21 – 1.75), with a number needed to treat (NNT) of 6. A forest plot of overall success at first attempt intubation is presented in figure 2.

Figure 2 : Success at first intubation attempt

Overall intubation success rate was reported by three studies (Volz, Bartle, Moussa) but number of attempts allowed varied, so meta-analysis was not performed. Volz and Moussa showed a significant effect of VL at overall intubation success (Volz 57% vs. 33%, P < 0.05; Moussa 75% vs 63%, P 0.03). Bartle also showed effect but with the smaller sample size of the feasibility study, this did not reach statistical significance (Bartle 76% vs 56%, P 0.86).

Secondary Outcomes

It was not possible to perform meta-analysis on the secondary outcomes as there was too much heterogeneity between the studies. Lowest SpO_2 recorded was reported by three studies (O'Shea, Moussa and Geraghty) and lowest HR recorded was reported by two studies (O'Shea and Geraghty). Number of bradycardic/ desaturation episodes were reported by three studies (Moussa, Volz and Tippmann). There were no differences in these outcomes.

Time taken at intubation attempt was reported by four studies (O'Shea, Moussa, Volz and Geraghty). O'Shea and Volz reported no difference, Moussa and Geraghty reported that the time taken to intubate with DL was slightly shorter than with VL.

The median number of intubation attempts was reported by three studies (Bartle, Tippmann and Geraghty). Bartle and Geraghty found a reduction in the median number of attempts in the VL group, Tippmann found no difference.

Airway related adverse events e.g. mucosal trauma, bleeding, lacerations was reported for three studies (Moussa, Volz and Tippmann). Moussa found slightly more mucosal trauma in the DL group, Volz and Tippmann found no difference.

Subgroup Analysis of First Attempt Success Rate by Trainee Doctors

Participants were intubated by trainees in all six studies (816 intubations). The use of VL compared to DL among trainees showed an increased success rate at first intubation attempt (RR 1.45 95%CI 1.21 – 1.75), with a NNT of 6. Only two studies included consultant neonatologists with a total of 33 intubations (Geraghty,

Tippmann). A forest plot of success at first attempt intubation among trainees is presented in figure 3.

Figure 3. Success at first intubation attempt among trainees

DISCUSSION

The use of VL by neonatal and paediatric clinicians performing urgent intubation in the NICU or DR resulted in a higher rate of successful intubation at the first attempt (NNT = 6). The use of VL did not see an increase in adverse events, compared to DL.

Success rates have been reported as less than 25% amongst trainees.[20-22] A study of 40 neonatal trainees in the US reported that less than half achieved intubation proficiency (defined as an 80% success rate within two intubations) during their 2-3 years of fellowship training. Those that achieved proficiency required a median of 18 (range 8 – 46) intubation attempts to do so, while some never reached proficiency despite 50 intubation attempts.[23] Potential for harm is greatest with low success rates, thus finding an intervention to improve success is mandatory.

The lack of opportunities to acquire and practice intubation in neonates presents a major challenge for training paediatricians and neonatologists. Studies in anaesthesia report that clinicians need to perform 40 or more intubations to become proficient.[24] Paediatric and neonatal trainees are very unlikely to have this number of opportunities to intubation neonates.[25]

Failure to recognise the anatomy and inability to obtain an adequate view of the airway are common reasons for intubation failure in this population.[6] A benefit of

neonatal VL is the ability to share the view between intubator and supervisor, allowing the anatomy to be highlighted and errors to be corrected. Moussa showed that residents taught to intubate with VL reached proficiency sooner than those initially taught with DL, and they maintained their skills when they crossed over to intubating with DL.[15] VL was appreciated and well received by novice intubators.[26] DeMeo showed that early successful intubations improve confidence of trainees and shorten the learning curve to proficiency.[27] The use of VL can contribute to the Human Factors approach in medicine, by creating an intubation environment which allows the team to visualise the airway and adapt in real time and promote learning. Many VLs can record, allowing for retrospective review of the intubation event for education purposes.

One of the challenges to date for the use of VL within neonatology is the availability of suitable VL. Ideally, a VL would be readily available, cheap, quick and easy to set up, have a long-lasting internal battery, the ability to record images and have disposable or easily cleaned blades that come in suitable sizes for even the tiniest of infants. Experienced neonatologists will generally have learned to intubate with DL in a previous era when intubations were more frequent. Some early models of neonatal VLs had blades that were different in size, shape and feel to DL blades.[28] These differences made experienced clinicians reluctant to embrace the technology and may explain the findings of a survey of 169 UK neonatal units in 2021 - 63% of units stocked a VL but only 31% used them as first line for intubations.[29] Fortunately there are a growing number of VLs on the market and the quality and availability of the technology is improving steadily. The shape differences between VL and DL blades have reduced and there are now several models that include smaller blades for the extremely preterm and extremely low birth weight populations.

It is well described that neonatal intubation success rates particularly for inexperienced operators are sub-optimal and few evidence based interventions to improve this have been found. VL has consistently been shown to improve intubation success rates.

CONCLUSIONS

VL should be the standard of care for neonatal intubation in both the neonatal unit and delivery room particularly when the intubator is inexperienced.

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