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| Question | |
| NLS 5350 - Exhaled CO2 to guide non-invasive ventilation at birth | |
| **Population:** | Newborn infants receiving intermittent positive pressure ventilation (IPPV) by any non-invasive interface at birth |
| **Intervention:** | Use of exhaled CO2 monitor in addition to clinical assessment, pulse oximetry and/or electrocardiogram (ECG) |
| **Comparison:** | Clinical assessment, pulse oximetry and/or ECG only |
| **Main outcomes:** | The pre-specified primary outcome was endotracheal intubation in the delivery room. The secondary outcomes were divided as follows: 1) Resuscitation outcomes at birth: survival to neonatal intensive care unit (NICU) admission (critical); time to heart rate >100 bpm (important); duration of IPPV (important); use of IPPV corrective actions (important); and use of chest compressions (important); 2) Other major morbidity: survival to hospital discharge (critical); bronchopulmonary dysplasia (BPD), severe intraventricular hemorrhage (IVH) and periventricular leukomalacia (all three important) in infants born at <34 weeks’ gestation; and unexpected admission to special or intensive care unit (important) in infants born at ≥34 weeks’ gestation. |
| **Setting:** | Delivery room |
| **Perspective:** | Individual patients, their families, health care providers and health service providers. |
| **Background:** | Exhaled CO2 application immediately after birth has been reviewed by ILCOR with the focus on the correct placement of an endotracheal tube {ILCOR 2006 e-978; Perlman 2010 S516; Perlman 2015 S204}. In 2010, ILCOR reviewed the use of colorimetric CO2 detection to assess ventilation in non-intubated, bradycardic neonates and made the following treatment recommendation: there is insufficient evidence to recommend routine use of colorimetric exhaled CO2 detectors during mask ventilation of newborns in the delivery room {Perlman 2010 S516}.  However, quantitative, and qualitative analysis of exhaled CO2 is being used in some centers to guide mask ventilation of preterm infants at birth {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Hawkes 2017 74; Kakkilaya 2019 e20180201; Kong 2013 104}. The rationale for this use is that exhaled CO2 may provide useful information related to potential airway obstruction {Finer 2009 865; Leone 2006 e202} or problems with lung aeration {Hooper 2013 e70895}, but there are concerns related to the dead space and increased resistance introduced into the ventilatory circuit {Brown 2016 1003}, and the reliability of colorimetric devices {Blank 2014 1568}. The impact on the resuscitation team, such as potential distraction when using an exhaled CO2 monitor, is unknown.  In this context, a search for evidence for utilizing exhaled CO2 to guide non-invasive positive pressure ventilation immediately after birth was prioritized by the Neonatal Life Support Task Force. |
| **Conflict of interests:** | None |

# Assessment

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| Problem Is the problem a priority? | | | |
| Judgement | Research evidence | Additional considerations |
| ○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know | Over 140 million babies are born annually worldwide {United Nations - Population Division 2022}. It is estimated that up to 5% of newborns receive intermittent positive-pressure ventilation (IPPV) at birth {Wyckoff 2020 185}. The use of exhaled CO2 may be relevant to infants receiving IPPV at birth. | Exhaled CO2 may provide useful information on the effectiveness of mask ventilation. The absence of exhaled CO2 may indicate airway obstruction, failure of lung aeration or cardiac compromise, and its presence may precede an increase in heart rate (HR) in bradycardic infants who are being adequately ventilated {Cereceda-Sanches 2019 358; Hawkes 2014 1315; Leone 2006 e202; Sankaran 2021 2580; Williams 2021 3148}. Quantitative and qualitative analysis of exhaled CO2 is being used in some centers to guide mask ventilation of infants at birth {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Kong 2013 104; Hawkes 2017 74; Kakkilaya 2019 e20180201}. However, there are concerns related to the dead space introduced into the ventilatory circuit {Brown 2016 1003}, the reliability of colorimetric devices {Blank 2014 1568}, and the distraction of the resuscitation team when using the exhaled CO2 monitor in the delivery room. |

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| Desirable Effects How substantial are the desirable anticipated effects? | | | |
| Judgement | Research evidence | | Additional considerations |
| ○ Trivial ○ Small ○ Moderate ○ Large ○ Varies ● Don't know | Eligible studies were not found. Based on the narrative review, exhaled CO2 monitoring during IPPV with facemask immediately after birth was available to providers in eight studies {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Hawkes 2017 74; Kang 2014 e102729; Kong 2013 104; Mizumoto 2015 186; Ngan 2017 F525}, but no study had a comparator group of infants receiving IPPV without exhaled CO2 monitoring. Six of these studies {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Kang 2014 e102729; Mizumoto 2015 186; Ngan 2017 F525} reported some possible benefits:  1. Exhaled CO2 and detection of airway obstruction:   * Finer et al {Finer 2009 865} reviewed data from 18 infants with GA <32 weeks that received IPPV by facemask from a trial that randomly assigned patients to resuscitation with room air or 100% oxygen. Colorimetric CO2 detectors were used to assist with IPPV in all patients. The interventions to correct the obstruction included repositioning of the head (n=10), checking the mask seal (n=5), a new operator (n=2), and increasing the pressure (n=1). The authors concluded that the use of a colorimetric detector provides the resuscitation team with a visible signal that can indicate airway patency. * Blank et al {Blank 2014 1568} reviewed the data of 41 preterm infants with bradycardia receiving PPV with T-piece and facemask at birth and were monitored with colorimetric CO2 detectors. The interventions that were performed in response to colorimetric monitoring included increasing the inspiratory pressure (37%) and readjusting the position of the infant’s airway or the position of the mask (24%).   2. Exhaled CO2 to assess lung aeration:   * Kang et al {Kang 2014 e102729} studied 51 infants <37 weeks’ gestation and found that those on CPAP (n=31) had higher exhaled CO2 values with lower tidal volumes compared to infants who received IPPV by T-piece and facemask (n=20). The authors concluded that exhaled CO2 monitoring confirms that infants maintained on CPAP achieve better gas exchange (resulting from sufficient lung aeration) than infants requiring IPPV. * Ngan et al {Ngan 2017 F525} randomized infants <33 weeks’ gestation to IPPV (n=86) or a 20-second sustained inflation (n=76) with facemask at birth. Exhaled CO2 increased more rapidly after the sustained inflation. The authors concluded that sustained inflation resulted in better lung aeration compared with IPPV. * Blank {Blank 2018 1} used exhaled CO2 to determine lung aeration prior to umbilical cord clamping in 44 infants >32 weeks’ gestation. A T-piece with facemask was applied in infants needing respiratory support and the exhaled CO2 was used as an indicator of pulmonary gas exchange. The authors concluded that it is feasible to provide resuscitation and monitor infants during delayed cord clamping using physiologic targets to indicate when the infant is ready for umbilical cord clamping.   3. Exhaled CO2 as a predictor of increase in HR in initially bradycardic infants:   * Blank et al {Blank 2014 1568} reviewed the data of 41 preterm infants with bradycardia receiving IPPV with T-piece and facemask at birth. All infants were monitored with colorimetric CO2 detector. The authors observed that colorimetric CO2 detection during mask IPPV at birth precedes a significant increase in HR. * Mizumoto et al {Mizumoto 2015 186} evaluated seven infants ventilated with flow-inflating bag and facemask. They found that an exhaled CO2 >15mmHg preceded a HR increase to >100 bpm by 8-73 seconds.   Among the eight studies with exhaled CO2 monitoring during IPPV with facemask immediately after birth available to providers (none of them with a comparator group of infants receiving IPPV without exhaled CO2 monitoring), two evaluated the effect of exhaled CO2 monitoring at birthon the partial pressure of CO2 (pCO2) at NICU admission. Kong et al {Kong 2013 104} reported that guiding delivery room ventilation with exhaled CO2 measurement did not result in more preterm infants having admission pCO2 within the recommended range. Hawkes et al {Hawkes 2017 74} compared preterm infants receiving IPPV by T-piece and facemask monitored by quantitative or qualitative exhaled CO2. Due to the lack of differences between study groups in primary or secondary outcomes, the authors concluded that the use of either form of exhaled CO2 monitoring should be considered during newborn stabilization. | | In a study by Linde et al {Linde 2018 1}, measured exhaled CO2 data by a sidestream quantitative sensor were retrospectively assessed. Higher expired CO2 (as % of expired air) was noted in infants receiving IPPV by facemask with self-inflating bag who survived vs. those who died (2.8 vs. 1.7%, respectively, p=0.001), possibly reflecting better CO2 exchange in surviving newborns. Tidal volumes in both groups were within the recommended range. Because CO2 data were retrospectively obtained after the resuscitation, the impact of real time CO2 monitoring to the providers to guide ventilatory actions could not be assessed.  Kakkilaya et al {Kakkilaya 2019 e20180201} implemented a resuscitation bundle, including the exhaled CO2 detector, to optimize facemask IPPV in infants ≤29 weeks’ gestation at birth. Comparing pre- (n=180) vs. post- (n=134) quality improvement cohorts, the latest had lower intubation rate in the delivery room, lower need for mechanical ventilation, lower rates of BPD and severe retinopathy of prematurity. It is not possible to know the effectiveness of the individual components of the bundle. |
| Undesirable Effects How substantial are the undesirable anticipated effects? | | | |
| Judgement | Research evidence | | Additional considerations |
| ○ Large ○ Moderate ○ Small ○ Trivial ○ Varies ● Don't know | Based on the narrative review, there are some concerns with the use of exhaled CO2 to guide IPPV by facemask at birth. As noted by van Vonderen {van Vonderen 2015 F514}, several factors can make interpreting exhaled CO2 data at birth complicated. These factors include the following 1) Leak is frequent during mask ventilation and may decrease the CO2 concentration in the sensor, underestimating the exhaled CO2; 2) A poor correlation between the expired tidal volume and the exhaled CO2 could be due to a closed glottis (while volume is measured due to pressurization of the upper respiratory tract, very little exhaled CO2 will be measured); and 3) It is possible that dead-space ventilation of the mask, oropharynx and trachea causes insufficient renewal of the expired volume causing an overestimation of exhaled CO2 levels.  The exhaled CO2 monitors may also be inadequate to detect periods of adequate ventilation during low pulmonary blood flow and/or low cardiac output after lung inflation {Blank 2014 1568}, i.e., CO2 detection may not distinguish between resuscitations that are not going well because the lungs are not being aerated and those in which the lungs are not being perfused.  Even in the absence of airway obstruction, exhaled CO2 may be low in infants born at <29 weeks’ gestation maybe due to insufficient inflation pressures to overcome the resistance of fluid filled small airways and the absence of fully vasodilated pulmonary circulation {Hunt 2019 17}.  The reliability of colorimetric devices may be affected by contamination with gastric contents and medication {Blank 2014 1568; Muir 1990 41}. | | Attention to the device may distract the resuscitators from paying attention to the newborn infant during resuscitation. The potential harms associated with any monitoring that may distract the resuscitation team have not been explored.  Adverse effects of exhaled CO2 monitoring may depend on the training and expertise of health care providers, but this issue has not been explored. |
| Certainty of evidence What is the overall certainty of the evidence of effects? | | | |
| Judgement | Research evidence | | Additional considerations |
| ○ Very low ○ Low ○ Moderate ○ High ● No included studies | The systematic search found 2370 references. Full text review was conducted for 23 papers. No studies were identified which addressed the PICOST question. | |  |
| Values Is there important uncertainty about or variability in how much people value the main outcomes? | | | |
| Judgement | Research evidence | | Additional considerations |
| ○ Important uncertainty or variability ○ Possibly important uncertainty or variability ● Probably no important uncertainty or variability ○ No important uncertainty or variability | The valuation of the main outcomes is consistent with the values assigned by the ILCOR NLS task force and a larger group of neonatal resuscitation experts {Strand 2020 328}. | |  |
| Balance of effects Does the balance between desirable and undesirable effects favor the intervention or the comparison? | | | |
| Judgement | | Research evidence | Additional considerations |
| ○ Favors the comparison ○ Probably favors the comparison ○ Does not favor either the intervention or the comparison ○ Probably favors the intervention ○ Favors the intervention ○ Varies ●  Don't know | | We have considered the lack of appropriate studies to support the decision to use or not use exhaled CO2 monitors to guide IPPV with non-invasive interfaces, such as facemasks, supraglottic airways, and nasal cannulae, immediately after birth. |  |
| Resources required How large are the resource requirements (costs)? | | | |
| Judgement | | Research evidence | Additional considerations |
| ○ Large costs ○ Moderate costs ○ Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ● Don't know | | There are no published cost data on exhaled CO2 monitoring to guide IPPV with non-invasive interfaces, such as facemasks, supraglottic airways and nasal cannulae, in newborns immediately after birth. | Given that about 5% of all newborns receive IPPV at birth {Wyckoff 2020 185}, the cost of using or not using exhaled CO2 monitoring to guide IPPV with non-invasive interfaces is an important consideration.  The use of exhaled CO2 monitoring may add costs related to equipment, maintenance, supplies, and training of personnel. Qualitative CO2 detectors are disposable and the use of capnography or capnometry requires specific monitors with related costs.  Balancing this, Blank et al {Blank 2014 1568} speculated that colorimetric CO2 monitoring may be helpful to indicate ineffective ventilation when other monitors, such as pulse oximeter and ECG, are unavailable. It should be noted that the colorimetric CO2 detector requires no electricity. |
| Certainty of evidence of required resources What is the certainty of the evidence of resource requirements (costs)? | | | |
| Judgement | | Research evidence | Additional considerations |
| ○ Very low ○ Low ○ Moderate ○ High ● No included studies | | No data available. |  |

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| Cost effectiveness Does the cost-effectiveness of the intervention favor the intervention or the comparison? | | |
| Judgement | Research evidence | Additional considerations |
| ○ Favors the comparison ○ Probably favors the comparison ○ Does not favor either the intervention or the comparison ○ Probably favors the intervention ○ Favors the intervention ○ Varies ● No included studies | No data available. | Although there are no published cost-effectiveness data, it could be speculated that monitoring of exhaled CO2 may decrease costs if it is effective to guide IPPV with non-invasive interfaces, lowering endotracheal intubation rates and adverse effects associated with invasive ventilation at birth, especially in preterm infants. |
| Equity What would be the impact on health equity? | | |
| Judgement | Research evidence | Additional considerations |
| ○ Reduced ○ Probably reduced ○ Probably no impact ○ Probably increased ○ Increased ○ Varies ● Don't know | No data available. | The cost of equipment and training resources may be significantly more limiting in low-resource settings, so health equity may be potentially reduced and the gap between well-resourced and resource-limited environments may therefore become larger.  Balancing this, Blank et al {Blank 2014 1568} speculated that colorimetric CO2 monitoring may be helpful to indicate ineffective ventilation when other monitors, such as pulse oximeter and ECG, are unavailable. It should be noted that the colorimetric CO2 detector requires no electricity. |
| Acceptability Is the intervention acceptable to key stakeholders? | | |
| Judgement | Research evidence | Additional considerations |
| ○ No ○ Probably no ● Probably yes ○ Yes ○ Varies ○ Don't know | No data available. | The narrative review suggests that the intervention is accepted by providers in the delivery room of high resource settings:  Hawkes et al {Hawkes 2017 74}, in UK, compared sidestream capnography with a colorimetric device and described that “exhaled CO2 detection during facemask IPPV has been used regularly in our delivery room during the stabilization of preterm infants over the last 2 years.”  Kakkilaya et al {Kakkilaya 2019 e20180201}, in USA, implemented a resuscitation bundle, including a colorimetric exhaled CO2 detector, to optimize facemask IPPV in 134 preterm infants at birth. The authors described that the use of the colorimetric CO2 detector was easily incorporated by the team.  Possibly, colorimetric exhaled CO2 detectors would be more widely accepted by providers than quantitative devices, which need more resources and training to be implemented and used. Also, colorimetric exhaled CO2 detectors are already recommended to verify endotracheal tube position during resuscitation at birth {Perlman 2015 S204}. |

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| Feasibility Is the intervention feasible to implement? | | |
| Judgement | Research evidence | Additional considerations |
| ○ No ○ Probably no  ○ Probably yes ○ Yes ● Varies ○ Don't know | The eight studies with exhaled CO2 monitoring during IPPV with facemask immediately after birth available to providers (none of them with a comparator group of infants receiving IPPV without exhaled CO2 monitoring) show that exhaled CO2 monitoring by quantitative or qualitative devices is feasible {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Hawkes 2017 74; Kang 2014 e102729; Kong 2013 104; Mizumoto 2015 186; Ngan 2017 F525}.  A review evaluated the feasibility of capnography use with facemask ventilation {Cereceda-Sanchez 2019 258} and concluded that, in newborn infants, exhaled CO2 monitoring at birth is feasible. | Feasibility is likely to be device dependent. Colorimetric exhaled CO2 devices are already used in several delivery rooms to verify endotracheal tube position. However, the use of quantitative devices to guide facemask IPPV has only been verified in small clinical trials {Hawkes 2017 74; Kang 2014 e102729; Kong 2013 104; Mizumoto 2015 186} and the feasibility outside the research settings is unknown. |

Summary of judgements

|  | **Judgement** | | | | | | |
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| **Problem** | No | Probably no | Probably yes | **Yes** |  | Varies | Don't know |
| **Desirable Effects** | Trivial | Small | **Moderate** | **Large** |  | Varies | **Don't know** |
| **Undesirable Effects** | Large | Moderate | Small | Trivial |  | Varies | **Don't know** |
| **Certainty of evidence** | Very low | Low | Moderate | High |  |  | **No included studies** |
| **Values** | Important uncertainty or variability | Possibly important uncertainty or variability | **Probably no important uncertainty or variability** | No important uncertainty or variability |  |  |  |
| **Balance of effects** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **Don't know** |
| **Resources required** | Large costs | Moderate costs | Negligible costs and savings | Moderate savings | Large savings | Varies | **Don't know** |
| **Certainty of evidence of required resources** | Very low | Low | Moderate | High |  |  | **No included studies** |
| **Cost effectiveness** | Favors the comparison | Probably favors the comparison | Does not favor either the intervention or the comparison | Probably favors the intervention | Favors the intervention | Varies | **No included studies** |
| **Equity** | Reduced | **Probably reduced** | Probably no impact | Probably increased | Increased | Varies | **Don't know** |
| **Acceptability** | No | Probably no | **Probably yes** | Yes |  | **Varies** | Don't know |
| **Feasibility** | No | Probably no | Probably yes | Yes |  | **Varies** | Don't know |

**Type of recommendation**

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| Strong recommendation against the intervention | Conditional recommendation against the intervention | **Conditional recommendation for either the intervention or the comparison** | Conditional recommendation for the intervention | Strong recommendation for the intervention |
| ○ | ○ | **●** | ○ | ○ |

# Conclusions

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| Recommendation |
| There is insufficient evidence to suggest for or against the use of exhaled CO2 to guide IPPV with non-invasive interfaces, such as facemasks, supraglottic airways, and nasal cannulae, in newborns immediately after birth. |

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| Justification |
| In making this recommendation for newborns receiving non-invasive IPPV in the delivery room, the Task Force considered that there were no studies reporting outcomes comparing active CO2 monitoring to guide IPPV with non-invasive interfaces to a group not using CO2 monitoring. Therefore efficacy, effectiveness, and safety of exhaled CO2 monitoring when being used via non-invasive devices could not be assessed.  The eight studies that reported data on infants receiving IPPV by facemask with exhaled CO2 information available to the resuscitation team suggest that exhaled CO2 monitoring may help recognize airway obstruction and inadequate tidal volume delivery/lung aeration during IPPV. The detection of exhaled CO2 may precede an increase in HR in bradycardic neonates during IPPV with facemask {Blank 2014 1568; Blank 2018 1; Finer 2009 865; Hawkes 2017 74; Kang 2014 e102729; Kong 2013 104; Mizumoto 2015 186; Ngan 2017 F525}. Despite these findings, monitoring of exhaled CO2 immediately after birth did not result in more infants having admission pCO2 within the recommended range {Hawkes 2017 74; Kong 2013 104}. Survival was not assessed in any of these eight studies. In a study by Linde et al {Linde 2018 1}, measured exhaled CO2 data by a sidestream quantitative sensor were retrospectively assessed. Higher expired CO2 (as % of expired air) was noted in infants receiving IPPV by facemask with self-inflating bag who survived vs. those who died (2.8 vs. 1.7%, respectively, p=0.001), possibly reflecting better CO2 exchange in surviving newborns. Tidal volumes in both groups were within the recommended range. Because CO2 data were retrospectively obtained after the resuscitation, the impact of real time CO2 monitoring to the providers to guide ventilatory actions could not be assessed.  In a quality improvement effort, Kakkilaya et al {Kakkilaya 2019 e20180201} implemented a resuscitation bundle, including an exhaled CO2 detector to optimize facemask IPPV in infants ≤29 weeks’ gestation at birth. Comparing pre- vs. post- (n=180 *vs*. n=134) quality improvement intervention cohorts, the latter had lower intubation rate in the delivery room (58 vs. 37%), lower administration of mechanical ventilation (85 vs 70%), lower rates of BPD (26 vs 13%), and severe retinopathy of prematurity (14 vs 5%). Despite these results, it is not possible to know the effectiveness of the isolated components of the bundle.  There are some potential concerns with the use of exhaled CO2 to guide IPPV by facemask at birth. It is possible that dead-space ventilation of the mask, oropharynx, and trachea causes insufficient renewal of the expired volume, causing an overestimation of exhaled CO2 levels {van Vonderen 2015 F514}. The exhaled CO2 monitors may also be inadequate to detect periods of adequate ventilation during low pulmonary blood flow and/or low cardiac output {Blank 2014 1568}. Even in the absence of airway obstruction, exhaled CO2 may be low in infants born at <29 weeks’ gestation maybe due to insufficient inflation pressures to overcome the resistance of fluid filled small airways and the absence of fully vasodilated pulmonary circulation {Hunt 2019 665}.  The reliability of colorimetric devices may be affected by contamination with gastric contents and medications {Blank 2014 1568; Muir 1990 41}. The potential harms of exhaled CO2 monitoring could include distraction from other important aspects of observing the infant and other monitoring devices, or anchoring bias (over-dependence on one observed value rather than consideration of all clinically important information). Furthermore, the implications for training and implementation of introducing CO2 monitoring devices into routine practice have not been sufficiently explored.  In making the treatment recommendation, the Task Force noted the lack of studies to support the decision to use or not use exhaled CO2 monitors to guide IPPV with non-invasive interfaces, such as facemasks, supraglottic airways and, nasal cannulae, immediately after birth. |
| Subgroup considerations |
| No data was found on the pre-specified subgroups: methods of exhaled CO2 evaluation; types of non-invasive interface used in IPPV; indications of IPPV, and gestational age. |
| Implementation considerations |
| We anticipate that implementing exhaled CO2 monitoring into routine clinical practice would require training and costs. In addition, there are human factor issues that need to be addressed should exhaled CO2 monitoring become more widespread (see Research Priorities section below). |
| Monitoring and evaluation |
| If exhaled CO2 monitoring during IPPV using non-invasive interfaces immediately after birth is implemented the following short and long term clinical outcomes should be carefully monitored: 1) Resuscitation outcomes at birth: endotracheal intubation in the delivery room, survival to NICU admission; time to HR >100 bpm; duration of IPPV; use of IPPV corrective actions; and use of chest compressions ; 2) Other major morbidity: survival to hospital discharge; BPD, severe IVH and PVL in infants <34 weeks’ gestation; and unexpected admission to special or intensive care unit in infants ≥34 weeks’ gestation. Also, possible harms associated with exhaled CO2 monitoring as well as reliability issues of the different devices should be continuously evaluated. |
| Research priorities |
| In order to make evidence-based recommendations on the use of exhaled CO2 to guide non-invasive positive pressure ventilation immediately after birth, it is important that research covers the following knowledge gaps:   * Efficacy and effectiveness of CO2 monitoring to guide IPPV with non-invasive interfaces in newborns immediately after birth, considering the different methods of measurement and the different non-invasive interfaces * Efficacy and effectiveness of CO2 monitoring to guide IPPV with non-invasive interfaces in newborns immediately after birth with different indications of IPPV, such as apnea/irregular respirations or bradycardia/asystole, and different gestational ages, such as <280/7; 280/7 -336/7; and 340/7 or more weeks * Potential risk due to undetected exhaled CO2 in newborns with absent or insufficient circulation during effective IPPV * Impact of cord management strategies on exhaled CO2 detection * Impact of the presence of gastric reflux, other secretions, blood, meconium, or medications on the reliability of colorimetric CO2 detection * Potential harm due to the distraction of attention of resuscitation providers by exhaled CO2 monitors * Cost-effectiveness of the use of exhaled CO2 monitors |
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