Dissertation

Quality of neonatal resuscitation and impact of interdisciplinary and interprofessional in situ simulation training

submitted by

Dr.med.univ. Lukas Peter MILEDER

for the Academic Degree of

Doctor of Medical Science
(Dr. scient. med.)

at the

Medical University of Graz

executed at the

Division of Neonatology,
Department of Paediatrics and Adolescent Medicine

under the supervision of

Univ.-Prof. Dr. Berndt URLESBERGER

2024

Declaration of Academic Integrity

I hereby declare that this doctoral thesis is my own original work and that I have fully acknowledged by name all of those individuals and organisations that have contributed to the research for this thesis. Due acknowledgement has been made in the text to all other material used. Throughout this doctoral thesis and in all related publications I followed the “Standards of Good Scientific Practice and Ombuds Committee at the Medical University of Graz“.

Graz, February 26th, 2024 Dr. Lukas Peter Mileder eh.

Disclosures

These articles, which have been published before finalization of the dissertation, are partly included in this doctoral thesis:

1) Mileder LP, Derler T, Baik-Schneditz N, Schwaberger B, Urlesberger B, Pichler G. Optimizing noninvasive respiratory support during postnatal stabilization: video-based analysis of airway maneuvers and their effects. *J Matern Fetal Neonatal Med*. 2022;35(20): 3991-3997. doi: 10.1080/14767058.2020.1846176.
2) Mileder LP, Urlesberger B, Schwaberger B. Use of Intraosseous Vascular Access During Neonatal Resuscitation at a Tertiary Center. *Front Pediatr*. 2020;8: 571285. doi: 10.3389/fped.2020.571285.
3) Mileder LP, Gressl J, Urlesberger B, Raith W. Paramedics' Newborn Life Support Knowledge and Skills Before and After a Targeted Simulation-Based Educational Intervention. *Front Pediatr*. 2019;7: 132. doi: 10.3389/fped.2019.00132.

The second and third article were published in *Frontiers in Pediatrics* under an Open Access agreement (Creative Commons CC BY 4.0 license: https://creativecommons.org/licenses/by/4.0/#), and both Taylor & Francis, which holds the copyright for the first article, and Frontiers gave permission to include the articles in my dissertation (see Appendix).

For the first article, Taylor & Francis asked to include the following statement: “This is an Accepted Manuscript of an article published by Taylor & Francis Group in *The Journal of Maternal-Fetal & Neonatal Medicine* on November 10th, 2020, available online: https://www.tandfonline.com/doi/full/10.1080/14767058.2020.1846176.”

All co-authors have agreed to the inclusion of their published data in this doctoral thesis.

Graz, February 26th, 2024 Dr. Lukas Peter Mileder eh.

Acknowledgements

First of all, I would like to express my sincere gratitude to my advisor and scientific mentor Univ.-Prof. Dr. Berndt Urlesberger, who has introduced me to the unique discipline and scientific field of neonatology, and who always guided me with his remarkable knowledge, clinical and scientific experience, spirit, enthusiasm, and vision.

I also would like to thank the other two members of my dissertation committee, Assoc.Prof. Priv.-Doz. Dr. Georg Schmölzer and Research Prof. Priv.-Doz. Mag.rer.nat. Dr.rer.nat. Alexander Avian, for their patience, enduring support, and expert advice.

This study would not have been possible without the time, effort, and expertise of the two video assessors, Assoc.Prof. Priv.-Doz. Dr. Georg Schmölzer and OA Dr. Peter Wöckinger – thank you very much to both of you!

I want to thank the Doctoral School “Sustainable Health Research”, in which I had the privilege to conduct this doctoral thesis.

I deeply appreciate the support, help, and academic challenge provided by OÄ^{in} Dr.^{in} Jasmin Pansy, Priv.-Doz.^{in} DDr.^{in} Nariae Baik-Schneditz, Priv.-Doz.^{in} Dr.^{in} Mirjam Ribitsch, Priv.-Doz. DDr. Bernhard Schwaberger, Priv.-Doz. Dr. Wolfgang Raith, and Evelyn Ziehenberger. Especially, I want to thank Univ.-Prof. Priv.-Doz. Dr. Gerhard Pichler for the chance to contribute to our remarkable research group, but even more for all the motivating and stimulating discussions and his invaluable guidance by example.

Finally, I gratefully acknowledge and wholeheartedly thank my wonderful family:
To my parents Eva and Peter as well as to my sisters Maria and Lena, I cannot thank you enough for your love, constant encouragement, and unwavering support!
To my beloved partner and my best friend Ines, and to our amazing son Johannes – you are my motivation, my inspiration, my source of joy, and my pillars of strength – I love you!

Table of Contents

List of Abbreviations

ANTS	Anaesthetists' Non-Technical Skills
$crSO_2$	cerebral regional tissue oxygen saturation
ECG	electrocardiogram
ERC	European Resuscitation Council
g	gram(-s)
HR	heart rate
i.e.	id est (“that is”)
IO	intraosseous
IQR	interquartile range
kg	kilogramme(-s)
mCPAP	mask continuous positive airway pressure
min	minute(-s)
ml	millilitre(-s)
mmHg	millimetre(-s) of mercury
mPPV	mask positive pressure ventilation
NIRS	near-infrared spectroscopy
pCO_2	partial pressure of carbon dioxide
PEARLS	Promoting Excellence and Reflective Learning in Simulation
PEEP	positive end-expiratory pressure
pO_2	partial pressure of oxygen
PPV	positive pressure ventilation
s	second(-s)
SBME	simulation-based medical education
SMART	Standardized Measurement of Airway Resuscitation Training
SpO_2	arterial oxygen saturation
°C	degree(-s) of Celsius

List of Figures

List of Tables

Zusammenfassung

Einleitung: Die erweiterte Stabilisierung und Reanimation von Neugeborenen nach der Geburt ist selten erforderlich, geht jedoch mit einem hohen Risiko einher, weshalb sich diese klinische Situation ausgezeichnet für simulationsbasiertes Teamtraining eignet. In situ-Simulationstraining, also Training im tatsächlichen klinischen Arbeitsumfeld, bietet zusätzliche Vorteile, jedoch wurde bislang nur für wenige medizinische Fachgebiete wissenschaftlich belegt, ob es tatsächlich hilft Patient*innenversorgung und -Outcome zu verbessern. Das Ziel dieser Studie war daher, an einer neonatologischen Intensivstation (i) die Qualität der postnatalen Stabilisierung und Reanimation zu erheben und (ii) den Einfluss von in situ-Simulationstraining auf patient*innenrelevante Qualitätsindikatoren zu untersuchen.

Material und Methoden: Nach Zustimmung der lokalen Ethikkommission führten wir eine prospektive Beobachtungsstudie an der Klinischen Abteilung für Neonatologie, Medizinische Universität Graz, durch. Inkludiert wurden darin angestellte Ärzt*innen und neonatologische Pflegepersonen auf freiwilliger Basis nach deren Aufklärung und Zustimmung. Die Aus-/Weiterbildungsmaßnahme umfasste einen Zeitraum von vier Monaten, während dem in situ-Simulationstraining regelmäßig für Studienteilnehmer*innen in interdisziplinären und interprofessionellen Teams durchgeführt wurde. Die Trainings erfolgten mithilfe eines hochrealistischen Neugeborenensimulators, die Trainingsszenarien fokussierten auf die häufigsten neonatalen Krankheitsbilder und die Trainings wurden jeweils von strukturierten Debriefing-Einheiten gefolgt.

Während zweier, jeweils zweimonatiger Beobachtungsphasen vor (Prä-Training) und nach der Aus-/Weiterbildungsmaßnahme (Post-Training) (i) wurde das Niveau der nicht-technischen Fertigkeiten und des Teamwork während tatsächlicher postnataler Neugeborenen-versorgungen und -reanimationen beurteilt, (ii) wurden klinische Patient*innendaten von Neugeborenen, die an der Klinischen Abteilung für Neonatologie Graz an einer von der Ethikkommission genehmigten klinischen Studie teilnahmen, gesammelt und (iii) wurde das individuelle Wissen der Trainingsteilnehmer*innen über Neugeborenenreanimationsleitlinien mittels Fragebögen erhoben. Die primäre Zielgröße der Studie war die Qualität der nicht-technischen Fertigkeiten und der Teaminteraktion während tatsächlicher postnataler Neugeborenenversorgungen und -reanimationen, welche anhand von Videoaufzeichnungen im Kreißsaal durch zwei externe, verblindete Neonatologen unter Verwendung des Anaesthetists' Non-Technical Skills (ANTS)-Score beurteilt wurde.

Ergebnisse: Insgesamt wurden 41 in situ-Simulationstrainings durchgeführt. Beim Vergleich der 12 Teamvideos der Prä- und der 13 Teamvideos der Post-Trainingsphase zeigte sich im ANTS-Score bereits vor der Einführung des in situ-Simulationstrainings ein hohes Niveau an nicht-technischen Fertigkeiten und Teaminteraktion, welches nicht weiter zunahm. Es fand sich jedoch eine signifikante Zunahme im Teamwork-Ereignis „Evaluation von Plänen" nach der Durchführung der in situ-Simulationstrainings (0,5 [Interquartilsabstand 0,0-1,0] versus 1,0 [1,0-2,0], p=0,049). Das individuelle Wissen der Trainingsteilnehmer*innen über Neugeborenenreanimationsleitlinien war nach den in situ-Simulationstrainings ebenfalls signifikant verbessert, während sich keine Unterschiede in der Zeit bis zur Auskultation der Herzfrequenz und bis zum ersten Beatmungshub, Anzahl der endotrachealen Intubationsversuche, arteriellen Sauerstoffsättigung und Herzfrequenz, Körpertemperatur, den Apgar-Scores, Pneumothorax-Inzidenz, Krankenhausaufenthaltsdauer und Mortalität zeigten.

Konklusion: Ein in situ-Simulationstrainingsprogramm wurde erfolgreich über vier Monate implementiert und durchgeführt. Während es keine Verbesserungen bei klinischen Outcome-Parametern in der Post-Trainingsphase gab, so unterstreicht die Zunahme eines Teamwork-Ereignisses, welche eine der primären Studienzielgrößen waren, nicht nur die Effektivität der Aus-/Weiterbildungsmaßnahme, sondern auch das Potential von in situ-Simulationstraining zur Verbesserung von Patient*innenversorgung und -Outcome.

Abstract

Introduction: Advanced stabilization and resuscitation of newly born infants after birth is a high-risk, low-occurrence event, which lends itself well to simulation-based team training. In situ simulation training, i.e. training in the real healthcare environment, offers added benefits, but it has only been shown for a few medical disciplines if it actually improves healthcare delivery and patient outcome. Therefore, the aim of this study was to (i) assess the quality of postnatal stabilization and resuscitation and (ii) evaluate the impact of in situ simulation training on quality indicators of patient care at a neonatal intensive care unit.

Materials and Methods: After approval by the local Ethics Committee, we performed a prospective observational study at the Division of Neonatology, Medical University of Graz, including employed physicians and neonatal nurses on a voluntary basis after informed consent. The educational intervention consisted of a period of four months, during which in situ simulation training was delivered regularly for study participants in interdisciplinary and interprofessional teams. Using a high-fidelity neonatal simulator, training scenarios focused on main neonatal diseases, and structured debriefings were held after each training session.

During two two-month observational phases before (pre-training) and after the educational intervention (post-training), we (i) assessed the level of non-technical skills and teamwork during actual events of postnatal stabilization and resuscitation, (ii) collected clinical patient data of neonates who participated in one of the Ethics Committee approved clinical studies at the Division of Neonatology Graz, and (iii) investigated individual knowledge of neonatal resuscitation guidelines among training participants using a questionnaire. The primary study outcome was the quality of non-technical skills and team interaction during actual postnatal stabilization and resuscitation, which was analysed from delivery room video recordings by two external, blinded neonatologists using the Anaesthetists' Non-Technical Skills (ANTS) score.

Results: A total of 41 in situ simulation trainings were delivered. When comparing 12 team videos from the pre- and 13 team videos from the post-training period using the ANTS score, there was an already high level of non-technical skills and team interaction before the implementation of in situ simulation training, which did not further improve. Still, there was a significant increase in the teamwork event “evaluation of plans” following the delivery of in situ simulation training (0.5 [IQR 0.0-1.0] versus 1.0 [1.0-2.0], p=0.049). Training participants' knowledge of neonatal resuscitation guidelines was also significantly improved after in situ simulation training, while there were no differences in time to heart rate auscultation and first ventilation breath, number of endotracheal intubation attempts, arterial oxygen saturation and heart rate, body temperature, Apgar scores, incidence of pneumothorax, length of hospitalization, and mortality.

Conclusion: An in situ simulation training program has been successfully implemented and delivered over a period of four months. While there were no improvements in clinical outcome parameters in the post-training period, the observed improvement in one teamwork event, which was among this study's primary outcome parameters, emphasizes not only the effectiveness of the educational intervention, but also the potential of in situ simulation training to improve healthcare delivery and patient outcome.

1. Introduction

1.1 Perinatal transition

The transition from intra- to extrauterine life is a complex and dynamic physiological process that involves substantial pulmonary, respiratory, cardio-circulatory, haemodynamic, thermoregulatory, endocrine, and metabolic changes, requiring "*rapid, complex and well-orchestrated steps*". (1) The major adaptive processes during this sensitive period, and their implications for postnatal stabilization and neonatal resuscitation after birth, will be discussed in the following chapters.

1.1.1 Pulmonary development and respiratory transition

As early as at the 26th post-conceptional day, the right and left lung buds can be identified as individual pouches of the primitive foregut. (2) Foetal lung development occurs in five stages, i.e. embryonic, pseudoglandular, canalicular, saccular, and alveolar. (3)

Beginning with organogenesis in the fourth week of foetal life, these stages of lung maturation are not happening in strict sequence, but they are rather overlapping because lung development begins in central parts of the developing organ and then progresses into its periphery. (2) The canalicular stage of lung development from weeks 16 to 26 is of special importance to the discipline of neonatology, as (i) first air-blood barriers develop in future alveolar ducts and saccules through convergence of the alveolar epithelium with mesenchymal blood vessels and (ii) surfactant production by type II epithelial cells (pneumocytes) begins. (2) These essential developmental processes of the foetus define the limit of viability – also referred to as 'grey zone' (4) – in the care of extremely preterm neonates, which is usually considered between 22 and 24 weeks of gestation. (5,6)

The saccular stage spans weeks 24 to 38 of intrauterine development and is characterized by an expansion of future airspaces. (2) Lung fluid is a main driving force of foetal lung growth and maturation, (7,8) as the associated intrapulmonary pressure keeps the lungs constantly expanded. (9) Active chloride transport has been identified as the central mechanism of foetal lung fluid secretion. (1,10)

Beginning during the 36th week, alveolarization occurs by new septa lifting off immature, pre-existing parenchymal septa, which contain a double-layered capillary network, thus further dividing the foetal airspaces. (2) It has been known for decades that the number of alveoli increases from a range of zero to 50 million to more than 300 million alveoli in adult lungs. (11) However, it was generally believed that the process of alveolarization stops after approximately two to three years of age; novel imaging methods, however, have shown that neo-alveolarization occurs even through childhood and adolescence. (12) Furthermore, "catch-up alveolarization" has been suggested in former extremely preterm neonates, based on comparable alveolar sizes at an age of ten to fourteen years between those and former term born children. (13)

First foetal breathing movements can already be observed at ten weeks of gestation. (1) They are essential for normal foetal lung growth, as they counteract lung recoil. (14) Foetal breathing movements origin from neuronal activities in the respiratory centre located in the brainstem, (15) they are intermittent and related to foetal cycles of rest and activity and, thus, change as the central nervous system matures over time. (14) At 24 to 28 weeks of gestation, foetuses show breathing movements about 14% of the time, increasing to about 30% until weeks 32 to 40. (16,17) Factors inhibiting foetal breathing movements are hypoxaemia (both acute and chronic [18]), hypoglycaemia, maternal alcohol consumption, maternal smoking, amniotic infections, and maternal consumption of sedative or narcotic drugs, (1,14) while hyperoxaemia, hypercapnia, hyperglycaemia, aminophylline, and betamethasone have been recognized as stimulants of foetal breathing movements. (1,17,19) Foetal breathing movements also have an effect on lung maturation, as the complete lack thereof is associated with disturbed differentiation of type II pneumocytes, resulting in impaired synthesis, storage, and secretion of surfactant. (15)

For uncomplicated adaption to postnatal life, lungs must be cleared from fluid and expanded by establishing and maintaining functional residual capacity. (8) Before spontaneous vaginal birth, the secretion of chloride and lung fluid by the lung endothelium decreases, mediated by cortisol, adrenaline, and thyroid hormones. (20) Furthermore, at term age sodium is being absorbed via epithelial surface sodium channels, effectively removing lung fluid from the alveoli into the epithelial cells. (20,21) In addition, spontaneous breathing efforts also contribute significantly to fluid removal and lung aeration, as Siew et al. (22) showed in near-term rabbit pups that they generated a functional residual capacity of 16.2 ± 1.2ml/kg over the first five breaths and that 94.8 ± 1.4% of lung aeration occurred during inspiration.

Accordingly, 16 out of 17 neonates were able to establish a functional residual capacity after the first spontaneous breath in the study by Milner et al. (23), who used oesophageal balloons and a reverse plethysmograph for their measurements. Braked expiration, by either crying, grunting or an expiratory hold, has been identified as a mechanism of postnatal lung recruitment in both term and preterm neonates due to the high compliance of the chest wall. (24) First breaths after birth are characterized by high flow levels during inspiration, short inspiration times of around 0.3 seconds, and long expiration times of around one second. (24) In neonates born at term, an increase in median respiratory rates from 45 over 50 to 60 breaths per minute has been demonstrated at one, two, and five minutes after birth, respectively. (25)
While the majority of term and preterm neonates present with spontaneous breathing efforts after birth, (1) the trigger factors for the change from periodic foetal breathing to continuous postnatal breathing are still not completely understood. (19) Hypercapnia is a powerful stimulant for postnatal breathing, but physical stimuli such as light, noise, lower ambient temperatures, and obstetrical handling during birth probably contribute to the onset of breathing as well. (18-20) Chemosensitivity to hypoxaemia continues to develop postnatally, (26) which may explain why neonates are rather insensitive to hypoxaemia shortly after birth. (19) The "vaginal (or thoracic) squeeze", describing the passive compression of the foetal thorax when passing through the birth canal, only plays "*a very minor role*" in lung fluid clearance. (8,19)

Foetal oxygen saturation is as low as 45-65%, (19) resulting in the metaphor of "*Mount Everest in utero*". (27) In foetuses of 39.5 ± 1.3 weeks of gestation during the first stage of labour with suspicious or pathologic foetal heart rates, Goffinet et al. (28) reported even lower values with a median arterial oxygen saturation (SpO_2) of 42% (10th and 90th percentile: 30% and 53%, respectively).
After birth, reference ranges for SpO_2 in respiratory stable neonates showed a wide range between 29% and 92% (3rd and 97th percentile, respectively), and a median time of 7.9 minutes (interquartile range [IQR] 5-10 minutes) to reach an SpO_2 of above 90%. (29) Neonates delivered by Caesarean section or those born prematurely have lower SpO_2 levels and require a longer time to reach values of 85% or above. (29-31)

1.1.2 Cardiac development and cardio-circulatory transition

The heart develops from the primary heart tube to its four-chambered structure between 20 and 44 days of gestation. (32) Approximately at the 22nd post-conceptional day, the first heart beat occurs. (1) Foetal circulation is mainly characterized by:

- gas exchange occurring via the placenta,
- right-to-left shunts via the Foramen ovale and Ductus arteriosus, ensuring maximal oxygen supply to the developing brain and heart via the carotid and coronary arteries, respectively,
- Ductus venosus flow providing the majority of left-ventricular output
- inferior and superior Vena cava flow providing most of right ventricular output, and
- high pulmonary resistance and consecutive low pulmonary blood flow. (1,33)

In the placenta, a concentration gradient allows for oxygen transfer from the placental space into villi, which contain capillary vessels that ultimately form the umbilical vein. (1) Median partial pressure of oxygen (pO_2) in umbilical venous blood is around 27.4mmHg (25th and 75th percentile: 20.5mmHg and 33.8mmHg, respectively), which has a median oxygen saturation of 56% (25th and 75th percentile: 35% and 72%, respectively). (34) Around 50% of the blood flow in the umbilical vein bypasses the liver through the Ductus venosus and collects deoxygenated blood from the hepatic veins and the inferior Vena cava before entering the right atrium. (20,33) Due to the higher pressure in the right atrium, the rather well oxygenated blood from the Ductus venosus mainly flows into the left atrium via the Foramen ovale, from where it is ejected by the left ventricle into the ascending aorta. (8,33) The remaining venous blood flow to the right atrium, especially from the inferior and superior Vena cava, is directed at the right ventricle and the pulmonary artery. Relative foetal hypoxia causes vasoconstriction of the pulmonary arteries (20) and, therefore, only 10 to 25% of the right ventricular output reaches the lungs, while most of the poorly oxygenated blood flows across the Ductus arteriosus into the descending aorta. (33) The amount of pulmonary blood flow increases over time, (20) but it still remains around 28% of the total blood flow in the main pulmonary artery (74ml/kg/minute out of 261ml/kg/minute) in late-gestation foetuses. (35)

A decrease in pulmonary vascular resistance leading to an increase in pulmonary blood flow, an increase in systemic vascular resistance, and the reversal and, later, closure of right-to-left shunts are essential for uncomplicated cardio-circulatory transition at birth. (8,19)

During the first breaths after births, pulmonary vascular resistance decreases significantly due to the aeration of the lungs, the increase in oxygenation and vasodilation of the pulmonary arteries. (1,20) The pressure decrease in the right atrium and the rapidly increased blood flow from the pulmonary veins to the left atrium reverse the atrial pressure gradient, leading to the physiological closure of the Foramen ovale. (8) The postnatal increase in arterial pO_2 leads to vasoconstriction of the Ductus arteriosus and the umbilical arteries, while the decreased blood flow causes a collapse of the umbilical vein and Ductus venosus. (1,8) In healthy term neonates, Ductus arteriosus shunting usually changes from right-to-left to a predominant left-to-right shunt within 10 minutes after birth. (36) Systemic vascular resistance increases primarily due to the loss of the high-flow, low-resistance system of the placenta by clamping of the umbilical cord, (19) but other factors also contribute to this important physiological process, such as an increase in thromboxane 2 and vasopressin levels. (37)

Clamping of the umbilical cord after aeration of the lungs has been proven beneficial for postnatal transition. Bhatt et al. (38) showed in preterm lambs that clamping of the umbilical cord before ventilation resulted in a significant decrease in heart rate (HR) and right ventricular output, which was reversed by ventilation. Conversely, if umbilical cord clamping was delayed for three to four minutes after initiation of ventilation, HR was not affected and the decrease in right ventricular output was less pronounced. (38) Accordingly, a higher incidence of death or hospital admission has been described in healthy term born neonates if umbilical card clamping was performed prior to initiation of spontaneous breathing. (39) Therefore, this "*physiological sequence*" (40) of delaying clamping of the umbilical cord until after successful lung aeration has been widely adopted.

1.1.3 Thermoregulatory transition

In utero, temperature exchange between mother and foetus occurs via the placenta, the uterus and the amniotic fluid. (41,42) Gilbert et al. (43) illustrated that 84.5% of heat exchange takes place in the placenta via circulation. As the foetal metabolic rate is rather high, foetal temperature is 0.3-0.5°C above the mother's body temperature. (41) Foetal temperature is closely related to maternal body temperature, but Laburn et al. (44) showed in sheep that maternal fever was associated with a significant increase in the foeto-maternal temperature gradient, suggesting compromised foetal heat loss.

After birth the neonate must rapidly adapt to lower environmental temperatures. Mechanisms involved in postnatal thermoregulation are non-shivering thermogenesis through lipolysis in brown adipose tissue, and, to a lesser degree, piloerection and shivering thermogenesis. (45) Brown adipose tissue, which has been recognized as a “thermogenic organ” (45) with many mitochondria and fat vacuoles, is typically found in the neck, axillae, back, mediastinum, abdomen, and thighs, constituting around 5% of neonatal body weight. (46) Preterm and growth-restricted neonates possess less brown adipose tissue and are, therefore, more prone to cold stress and hypothermia after birth. (20)

Generally, their high body surface-to-volume ratio and wet skin due to amniotic fluid place neonates at significant risk of postnatal hypothermia. (42,47) Evaporation of amniotic fluid is the main mechanism of heat loss after birth, but convection due to lower ambient temperatures, conduction, and radiation also are contributing factors. (48) Heat loss is most pronounced during the first 30 minutes after birth, (48) and un-dried neonates cared for at a room temperature of 25°C may even lose 2.1°C in rectal body temperature during this short time span. (49)

Postnatal hypothermia, defined as a body temperature below 36.5°C, (48) is a significant risk factor for neonatal morbidity and mortality. Laptook et al. (50) reported a relative increase in mortality of 28%, and in the incidence of late-onset sepsis in 11%, for each degree of Celsius decrease in low-birth-weight-infants’ body temperature at admission. Correspondingly, hypothermia is associated with significantly increased risks of mortality, intraventricular haemorrhage, bronchopulmonary dysplasia, sepsis, and retinopathy of prematurity in very-low-birth-weight infants. (51) Nonetheless, incidences of neonatal hypothermia remain high even in specialized perinatal centres, (52,53) especially among preterm neonates, those born with a low birth weight, and neonates requiring resuscitation. (54)

Hyperthermia after birth has been defined as a body temperature above 37.5°C. (48) It can be caused by elevated maternal body temperature due to factors such as epidural analgesia, chorioamnionitis, prolonged rupture of membranes, or overheated delivery rooms. (42) In addition, “*over-enthusiastic thermal care*” (42) may also render a proportion of neonates, especially those born before 30 weeks of gestation, hyperthermic. (55) The risk associated with postnatal hyperthermia must not be underestimated, as Lyu et al. (56) reported a significant association between their defined composite outcome, i.e. severe neurological injury, severe retinopathy of prematurity, necrotizing enterocolitis, bronchopulmonary dysplasia, and nosocomial infection, and elevated admission body temperature in preterm neonates below 33 weeks of gestation.

1.2 Postnatal stabilization and resuscitation

The majority of term born neonates will undergo perinatal transition without requiring medical support. (57) Nonetheless, in the study by Bjorland et al. (58) 6.2% of 4693 neonates required interventions beyond drying and tactile stimulation in the first minutes after birth, including positive pressure ventilation (PPV) (3.6%), endotracheal intubation (0.4%), chest compressions (0.2%), and adrenaline administration (0.1%). Several ante- and intrapartum risk factors for the need for delivery room intubation, chest compressions, and/or emergency medications have been identified, among them intrauterine growth restriction, meconium-stained amniotic fluid, chorioamnionitis, delivery by forceps or vacuum extraction, maternal general anaesthesia, and foetal bradycardia. (59)

Although neonatal mortality, i.e. death within the first 28 days after birth, has decreased significantly since 1990, the estimated global number of neonatal deaths is still as high as 2.5 million neonates per year. (60) Perinatal asphyxia is among the main causes of neonatal mortality, (61) and it may account for up to 61% of early neonatal death within the first 24 hours after birth. (62)

1.2.1 Postnatal clinical assessment

In 1953, Virginia Apgar published a report where she described the standardized assessment of neonates one minute after birth based on five, easily to determine clinical parameters: HR, respiratory effort, reflex irritability, muscle tone, and skin colour. (63) Her motivation for establishing such a scoring system was "*to predict survival, to compare several methods of resuscitation which were in use at the time, and through the infant's responsiveness after delivery, to compare perinatal experience in different hospitals*". (64) She suggested to score each parameter with either zero (if absent), one, or two (if present) points and reported from her initial experience at the Sloane Hospital for Women, New York, United States of America, that neonates scored with eight to ten points, i.e. the maximum score, were in good clinical condition, while those receiving zero to two points were in poor condition with death rates ranging from 9 to 14%. (63) In a larger study in 15348 neonates, Apgar et al. (65) again showed a significant difference in mortality between neonates receiving zero to two and those being scored with ten points at one minute after birth (15% versus 0.13%, respectively). Accordingly, Crawford et al. (66) demonstrated a significant correlation between HR, respiratory effort, reflex irritability, and muscle tone, but not skin colour, and pH values, partial pressure of carbon dioxide (pCO_2), and base excess in umbilical artery blood.

Since the first description, the scoring system suggested by Virginia Apgar has developed into the gold standard for postnatal assessment of neonates' condition and "*today an Apgar score is assigned to virtually every baby born in a hospital*". (67) Even 60 years after Apgar's groundbreaking first report, (63) the scoring system named after her is being recognized as valuable in predicting death within one year after birth. (68)

Nonetheless, the Apgar score also has significant limitations. Perinatal anaesthesia and the presence of congenital malformations may negatively influence the score. (69) The applicability of the Apgar score in preterm neonates has been questioned, as muscle tone and breathing, for example, are related to physical and physiological maturity. Correspondingly, birth weight and gestational age positively correlate with Apgar scores. (70,71) Furthermore, despite its standardized design, Apgar scoring is subjective and, therefore, interrater variability is high. O'Donnell et al. (72) found a mean difference of 2.4 points when medical and nursing staff retrospectively reviewed delivery room videos, with the lowest interobserver reliability (0.30) for the evaluation of skin colour. To correct for prematurity and the need for medical interventions after birth, modifications of the initial Apgar score have been developed. Rüdiger et al. (73) combined the "Specified-Apgar", which describes a neonate's condition irrespective of gestational age or required medical interventions, and the "Expanded-Apgar", which accounts for resuscitative interventions that are required to achieve a certain clinical condition. They found that the "Combined-Apgar" allowed for a more accurate evaluation of preterm neonates' condition, suggesting its use in extremely and very preterm neonates. (73)

The Apgar score was not intended to predict or decide upon postnatal resuscitation. (74) Nonetheless, current neonatal resuscitation guidelines recommend assessing HR, respiratory rate, and muscle tone immediately after birth to identify neonates at risk, who will most probably require medical interventions. (74,75)

Already in her first report, Apgar (63) identified HR as "*the most important diagnostic and prognostic*" scoring parameter, hence suggesting to give a score of two points if the HR was 100-140 beats per minute. Since then, initial HR after birth and its response to PPV have been identified as significant predictors of the 24-hour outcome, with the risk of death decreasing by 2% for every additional heart beat per minute. (76) Accordingly, prolonged bradycardia below 100 beats per minute for two or more minutes is associated with higher odds of hospital mortality in preterm neonates below 32 weeks of gestation. (77)

However, there are no absolute thresholds for neonatal HR that ultimately demand medical interventions. Current neonatal resuscitation guidelines recommend a heart of or above 100 beats per minute as satisfactory, (75) but such cut-off values are arbitrary. (78) Dawson et al. (79) reported a median HR of 96 beats per minute (IQR 65-127) in neonates with a mean gestational age of 38 weeks, which increased to a median of 163 beats per minute (IQR 146-175) at minute 5 after birth, showing that a relevant proportion of healthy neonates has a HR below 100 beats per minute one minute after birth. In contrast, term neonates after vaginal delivery with delayed cord clamping had a median HR of 175 beats per minute (IQR 57-189) at 61 seconds after birth, which slowly decreased from thereon. (80)

HR can be assessed by palpation of arterial pulses or the umbilical cord, by cardiac auscultation or by continuous monitoring provided by pulse oximetry or electrocardiogram (ECG), among other technologies. Palpating femoral or brachial pulses has been proven unreliable for the correct detection of neonatal HR. (81) Apgar (63) postulated that "*palpation of the cord about two inches from the umbilicus is the most satisfactory method for determining the heart rate quickly*", but pulsations cannot be detected in all neonates (82) and HR by umbilical cord palpation may only be accurate in 55% of neonates. (81) Cardiac auscultation using a stethoscope is an inexpensive and almost ubiquitously available technique to assess HR in neonates after birth – furthermore, HR assessment by auscultation can be performed rather quickly within a median of 14 seconds, but it generally underestimates continuous HR monitoring via ECG by a mean of nine beats per minute. (83) Pulse oximetry can accurately measure neonatal HR, (84) but peripheral hypoperfusion, movement artefacts, cardiac arrhythmias, and interference by light can significantly reduce the quality of pulse oximetry (75) and low signal quality leads to underestimation of HR. (85) Furthermore, HR assessment is significantly faster with ECG monitoring in comparison to pulse oximetry. (86) Therefore, current neonatal resuscitation guidelines suggest ECG "*to* *provide a rapid and accurate estimation of heart rate*" in the delivery room. (75) In addition, the use of ECG is recommended in cases where cardiopulmonary resuscitation is required in neonates after birth. (74) Importantly, in depressed neonates with a HR above 60 beats per minute, pulseless electric activity should be ruled out by pulse oximetry, cardiac auscultation, and/or palpation of pulses. (74,87,88)

1.2.2 Airway management and non-invasive respiratory support after birth

In those neonates with "incomplete" or even "poor or failed" transition, based on heart rates below 100 or below 60 beats per minute, inadequate breathing or apnoea, and reduced or floppy muscle tone, current neonatal resuscitation guidelines recommend to clamp the umbilical cord immediately, to dry, stimulate and wrap the neonate in a warm towel, and to establish and/or maintain an open airway. (75)

Techniques to open the upper airway include placing the neonate in supine position with the head in a neutral position. (75) Other recommendations include placing the neonatal head in a "sniffing" position, defined as "*neck flexion with upper cervical extension*", (89) which is characterized by a mean angle of 90.5 ± 5.7° between a virtual line through the subnasal region and the centre of the upper contour of the external auditory canal and a line parallel to the mattress, respectively. (90) Lifting the neonate's chin and/or applying the jaw thrust manoeuvre, i.e. moving the jaw in an upward and anterior position with both hands at the mandibular angles, may further help achieving upper airway patency. (89,91)

Airway obstruction after birth can also be caused by amniotic fluid, whether clear or meconium-stained, blood, mucus, or vernix caseosa. However, the emphasis of postnatal resuscitation in apnoeic or inadequately breathing neonates is on establishing pulmonary ventilation as soon as possible and, therefore, routine airway suctioning is not recommended in non-vigorous neonates after birth. (75) Inspection of the mouth and pharynx and suctioning, in case of visible obstruction, should only be performed after initial ventilation attempts have failed. (75)

There is a high incidence of so-called difficult airways among neonates and children, with an incidence of 5.8% among 5609 patients with a mean gestational age of 38 weeks at the time of their respective anaesthesia in the NECTARINE study. (92) Difficult neonatal airways can be categorized as anatomically difficult (e.g. due to small airway diameters or congenital anomalies), as physiologically difficult (due to cardiorespiratory instability, e.g. as in neonates with pulmonary hypertension), and as both anatomically and physiologically difficult, as in extremely preterm neonates. (93) Based on the clinical situation, the available preparation time, the local expertise, and the available resources, management options for difficult airways differ – they include utilization of oro- or nasopharyngeal airways, supraglottic airways, video laryngoscopy, tracheal tube introducers and stylets, fiberoptic or bronchoscopic intubation, premedication such as muscle relaxants, apnoeic oxygenation, and establishing surgical airways. (93,94)

If airway patency has been ensured in non-vigorous neonates after birth, yet breathing efforts are still ineffective or missing, initiating PPV is now of utmost importance, "*ideally within 60 s of birth*". (75) This aims at supporting respiratory transition, which is a three-phased process: (i) clearance of lung fluid and lung aeration, (ii) maintaining gas exchange despite air-liquid surface tension and increased perialveolar interstitial tissue pressure, and (iii) gas exchange and metabolic homeostasis after fluid clearance from interstitial tissue. (95) Effective lung aeration depends on numerous factors, among them airway patency, the total amount of lung fluid, airway diameters, alveolar surface, peak inspiratory pressure, and pressure duration. (95,96)

Given this manifold influencing factors, which are further affected by gestational age, mode of delivery, and pre-existing conditions such as sex and birth weight, it is not surprising that recommendations how to deliver PPV in neonates after birth vary. The European Resuscitation Council (ERC) recommends delivering five inflations with inspiratory times of two to three seconds, followed by short inflations at a rate of 30 per minute in case of an increase in HR and visible chest rise, (75) while the American Heart Association advocates delivering PPV at a rate of 40-60 inflations per minute with inspiratory times of no longer than one second. (74) Regardless of these different recommendations, both guidelines emphasize the importance of initiating respiratory support in apnoeic neonates or those suffering from respiratory distress immediately, as the risk of death or prolonged hospital admission increases by 16% for every 30-second delay in PPV. (97) Conversely, effective mask ventilation in apnoeic near-term and term neonates leads to a median increase in HR of 60 beats per minute after only 23 seconds of ventilation. (98)

Besides an increase in HR, bilateral chest rise by visual assessment suggests effective ventilation. However, there is a poor correlation between clinical estimation and actual tidal

volumes, and delivered tidal volumes are often underestimated by treating physicians in the delivery room. (99,100) Measuring exhaled carbon dioxide levels as an indicator of lung aeration may help guiding respiratory support, (95,101) although a randomized controlled trial did not find an improvement in pCO_2 levels through end-tidal carbon dioxide monitoring in the delivery room. (102)
By displaying inflation parameters such as peak inspiratory pressure, positive end-expiratory pressure (PEEP), tidal volume, gas flow, and face mask leak, respiratory function monitoring may help individualized, targeted and, thus, safe PPV. (95,103) While Schmölzer et al. (104) found significantly reduced face mask leak and a lower number of endotracheal intubations in the delivery room in a group with a visible respiratory function monitor, a multi-centre randomized controlled trial did not report an improvement in targeted tidal volume delivery through availability of respiratory function monitoring. (105) The latter finding may at least in part be attributed to difficulties in visual assessment of respiratory waveforms, with low interrater reliability especially in regard to positive pressure inflations. (106)

Self-inflating ventilation bags are commonly used to deliver PPV to neonates after birth, as they are available at low cost and do not require constant gas flow. (107) However, in comparison to T-piece resuscitators, self-inflating ventilation bags are associated with more excessive peak inspiratory pressures during PPV in the delivery room. (108) Furthermore, delivery of peak inspiratory pressure and PEEP, which supports the generation of functional residual capacity during ventilation especially in the preterm population, (109) is most accurate and consistent with T-piece resuscitators in comparison to flow-inflating and self-inflating ventilation bags. (110) A meta-analysis of four randomized controlled trials including 1247 patients revealed shorter duration of PPV and a reduced risk of bronchopulmonary dysplasia when using a T-piece resuscitator compared to a self-inflating bag. (111) Therefore, using a T-piece resuscitator is being recommended in the delivery room depending on availability. (75)

Plastic face masks are the most commonly used interfaces to deliver non-invasive respiratory support in the delivery room. (107) There is no difference in face mask leak between anatomically shaped and round ones, (112) and mask hold technique (“two-point top hold” versus “spider hold” versus “two-handed hold”) does also not alter face mask leak. (113)

However, as delivery of PPV via a face mask is challenging even in the hands of experienced healthcare providers, laryngeal mask airways have come into focus as potential primary ventilation interfaces. Trevisanuto et al. (114) reported higher rates of effective PPV in neonates ventilated with laryngeal mask airways in comparison to conventional face masks. In contrast, a large phase 3 trial did not find a difference in the primary outcome (death within seven days or admission to the neonatal intensive care unit with moderate-to-severe hypoxic ischaemic encephalopathy) when comparing delivery of PPV either via a laryngeal mask airway or face mask. (115) Therefore, laryngeal mask airways may be used in term and preterm neonates equal to or above 34+0 weeks of gestation, especially if conventional PPV using a face mask fails. (75,116)

Face mask leak and airway obstruction are common challenges when delivering respiratory support to neonates after birth, even for experienced healthcare professionals. Schmölzer et al. (117) reported significant face mask leak in 51% of preterm neonates receiving PPV and airway obstruction in 26%, whereas Kaufman et al. (118) found median face mask leak between 24% and 59% during PPV in the delivery room. Corrective interventions comprise repositioning the airway, opening and/or suctioning the mouth and oropharynx, and increasing peak inspiratory pressure, among others. (95) The Neonatal Resuscitation Program® by the American Academy of Pediatrics has summarized ventilation correcting measures using the acronym "MR SOPA": **m**ask adjustment, **r**eposition head, **s**uction mouth and nose, **o**pen mouth, **p**ressure increase, and **a**lternative airway. (119)

1.2.3 *"Optimizing noninvasive respiratory support during postnatal stabilization: video-based analysis of airway maneuvers and their effects"* (120)

For this study, "*we retrospectively analysed data of two prospective observational studies, which were performed in neonates delivered by Caesarean section between September 2009 and January 2015 at the Division of Neonatology, Medical University of Graz, Austria. Both studies were approved by our local ethics committee (EK 25-342 ex 12/13 and EK 23-403 ex 10/11). Written parental consent was obtained prior to study inclusion.*

We included male and female preterm and term neonates in whom video recordings were performed as part of the studies and who required mCPAP and/or mPPV during the first 15 min after birth. We excluded patients with congenital cardio-pulmonary malformations, *primary endotracheal intubation during postnatal stabilization or insufficient quality of video recording.*

Postnatal stabilization and resuscitation was performed by a neonatologist or an experienced paediatric resident and a neonatal nurse according to current European recommendations. All neonates were placed in supine position under a radiant warmer. Extremely preterm neonates were covered with a polyethylene wrap during postnatal stabilization. Respiratory support was delivered using a T-piece system (Neopuff Infant Resuscitator, Fisher & Paykel Healthcare, New Zealand) with a round silicone face mask (Laerdal Medical, Norway). Vital signs were measured by pulse oximetry (IntelliVue MP30 Monitor, Philips, The Netherlands) with a probe on the right hand or wrist, and near-infrared spectroscopy (NIRS) was measured with the NIRO 200-NX (Hamamatsu Photonics, Japan) or Invos 5100 device (Somanetics, United States of America) using a neonatal sensor on the left fronto-parietal head. Face mask leak was measured using the Florian respiratory function monitor (Acutronic Medical Systems, Switzerland). Video recordings and measurements were performed during the first 15 min after birth. All data including video recordings were stored digitally in a polygraphic data management system (Alpha-Trace digital MM, BEST Medical Systems, Austria).

Demographic data were obtained from our electronic patient management system, including mode of delivery and maternal anaesthesia, sex, gestational age, birth weight, Apgar scores, and umbilical artery pH. Videos were analysed in regard to mode of respiratory support (mCPAP/mPPV), duration of respiratory support (mCPAP/mPPV), and manoeuvres to improve respiratory support, including:

- *Repositioning of the face mask, defined as complete removal from the face, unless the face mask was removed with the intention to perform suctioning*
- *Oropharyngeal suctioning*
- *Change between one- and two-hand mask hold*
- *Respiratory support provided by another healthcare professional*
- *Change of face mask, defined as another type or size of face mask*
- *Change of head position*

Furthermore, we collected data of SpO_2 *and HR, both measured by pulse oximetry, cerebral regional tissue oxygen saturation (*$crSO_2$*) measured by NIRS, and face mask leak, which was calculated by the respiratory function monitor as mean value over a period of 60 s."* (120)

"Between 1 September 2009 and 31 January 2015, video recordings were available for 653 neonates, 143 of whom (21.9%) required mCPAP and/or mPPV after birth. Nine videos (6.3%) had to be excluded due to insufficient recording quality.

Median gestational age of the 134 included neonates (76 preterm/58 term neonates; m:f = 60:74) was 35.7 weeks of gestation (28.8-40.6). The median birth weight was 2580g (466-4670). All neonates were delivered by Caesarean section, 85.1% (114/134) had maternal spinal anaesthesia and 14.9% (20/134) had maternal general anaesthesia.

We analysed the first 15 min after birth in all 134 neonates, resulting in 2010 min of video material. Seventy-two neonates (53.7%) received only mCPAP, while the other 62 neonates (46.3%) were treated with mCPAP and intermittent mPPV. Respiratory support was delivered for a total of 1028.6 min, with 896.7 min (87.2%) of mCPAP (661.1 min in preterm/235.6 min in term neonates) and 131.9 min (12.8%) of mPPV (85.7 min in preterm/46.2 min in term neonates). Prior to initiation of respiratory support, oropharyngeal suctioning was performed in 20 of 76 preterm neonates (26.3%) and in seven of 58 term neonates (12.1%).

Of the 134 neonates included in this analysis, 105 (78.4%) received at least one manoeuvre to improve non-invasive respiratory support. In these 105 neonates a total number of 427 manoeuvres was observed, with a median of 2 (0-22) manoeuvres per neonate. The most common manoeuvre was face mask repositioning (n=243/427, 56.9%), followed by oropharyngeal suctioning (n=111/427, 26.0%), change between one- and two-hand mask hold (n=33/427, 7.7%), change of respiratory support delivering personnel (n=26/427, 6.1%), change of face mask (n=10/427, 2.3%), and change of head position (n=4/427, 0.9%).

Of the 427 manoeuvres, 287 (67.2%) occurred in preterm and 140 (32.8%) in term neonates. We observed a median of three manoeuvres (0-22) in preterm and a median of two manoeuvres (0-13) in term neonates (p=0.01), thus preterm neonates required adjustment manoeuvres significantly more often. There were no relevant differences in the choice of respiratory support improving interventions between preterm and term neonates.

Complete 60-s recordings for SpO_2 *and HR before and after the first respiratory support improving manoeuvre were available for 37 preterm and 43 term neonates, respectively. Mean HR was 134 ± 35 before and 140 ± 22 beats per minute after the first manoeuvre (p=0.28).* SpO_2 *increased non-significantly from a mean of 72.0 ± 16.2% to 74.3 ± 16.0% (p=0.16).* $crSO_2$ *data were available for 30 neonates (13 preterm/17 term neonates), showing a statistically significant increase after the first manoeuvre (37.3 ± 22.0% versus 45.4 ±*

21.5%, p=0.001). Face mask leak was 45.2 ± 36.1% before and 36.7 ± 26.2% after the first airway manoeuvre in 25 neonates (p=0.27)." (120)

The high incidence of corrective steps in this study underline the challenges that are regularly encountered during postnatal airway management and non-invasive respiratory support after birth. The finding of face mask repositioning being the most common airway manoeuvre is not surprising, given the significant face mask leak during non-invasive ventilation after birth which has been reported by several studies. (117,118)

1.2.4 Oxygen administration during non-invasive respiratory support after birth

According to current neonatal resuscitation guidelines, respiratory support of term and preterm neonates equal to or above 35+0 weeks of gestation should be initiated using room air, i.e. a fraction of inspired oxygen of 0.21. (74,75) Pre-ductal measurement of SpO_2 by pulse oximetry should guide further oxygen titration, aiming at targets of 65%, 85%, and 90% at two, five, and ten minutes after birth, respectively. (75)

Initiating respiratory support after birth with room air in comparison to 100% of oxygen results in a 27% relative reduction in short-term mortality in term and late preterm neonates. (121) On the other hand, in neonates suffering from pulmonary disease such as meconium aspiration syndrome, using low concentrations of inspired oxygen may cause hypoxaemia. (122) Especially in neonates with perinatal asphyxia and pulmonary pathology, titrating the fraction of inspired oxygen to reach pre-defined targets, as currently recommended, seems to constitute the optimal strategy to ensure cardiopulmonary stability. (123)

1.2.5 Cardiopulmonary resuscitation after birth

Cardiopulmonary resuscitation, characterized by alternating chest compressions with PPV with a fraction of inspired oxygen of 1.0, should be initiated in case of persistent bradycardia after birth (i.e. HR below 60 beats per minute) after at least 30 seconds of effective ventilation. (74,75) For this purpose, a ratio of three chest compressions followed by one inflation breath is being recommended, with the goal of providing 30 inflations and 90 chest compressions every minute. (74,75) A recent multi-centre, cluster cross-over randomized trial, which was stopped prematurely, compared continuous chest compressions superimposed by sustained inflations with this 3:1 ratio, but could not identify a difference in return of spontaneous circulation or neonatal mortality. (124)

Using a two-handed technique for delivery of chest compressions is being recommended (75) and the two-thumb encircling hands technique is more effective in terms of compression depth, correct hand position, and provider fatigue than the two-finger technique. (74,125) Furthermore, in their animal study using a piglet model of neonatal asphyxia, Bruckner et al. (126) described improved carotid blood flow and left ventricular contractile function associated with the two-thumb technique and with the over-the-head two-thumb-technique.

Regarding the compression depth, the chest should be compressed by one third of its anterior-posterior diameter, with adequate time after each compression for chest recoil. (127) This compression depth of one third of the anterior-posterior thorax diameter has been shown to be more effective than one fourth, and to be safer than one half of the chest depth. (128)

Administration of adrenaline is indicated if "*effective ventilation and chest compressions have failed to increase the heart rate above 60 min*$^{-1}$" after 30 seconds of cardiopulmonary resuscitation. (75) Adrenaline is an adrenergic receptor agonist, which causes vasoconstriction through stimulation of α_1 and α_2 receptors, increasing coronary arterial blood pressure and blood flow, and increased cardiac output via stimulation of β_2 receptors. (129) Adrenaline further increases HR, velocity of cardiac conduction, cardiac contractility, as well as myocardial relaxation. (130) Adverse effects of adrenaline include increased myocardial oxygen demand, respiratory and metabolic acidosis, and hypertension or tachycardia after return of spontaneous circulation. (130)

Intravascular, i.e. intravenous or intraosseous (IO), administration of adrenaline is preferred over endotracheal instillation, (74,75) as the endotracheal route requires higher doses (131) and is associated with a significantly longer time until return of spontaneous circulation. (132) Recommended intravascular doses of adrenaline for postnatal resuscitation are 0.01-0.03mg/kg, administered repetitively every three to five minutes if the HR remains below 60 beats per minute. (74,75,129) An experimental study in asphyxiated newborn lambs found the highest rate of return of spontaneous circulation after administration of 0.03mg/kg epinephrine, followed by a flush of 3ml/kg of normal saline. (133)

The other recommended drugs during cardiopulmonary resuscitation after birth include volume expander, glucose, and sodium bicarbonate. Administration of a volume expander such as 0.9% sodium chloride or group 0 Rhesus-negative blood is required in case of suspected or proven hypovolaemia or anaemia, respectively. (74,75) Glucose should be administered "*in a prolonged resuscitation*" (75) in order to prevent hypoglycaemia, as glucose is the major substrate for cellular metabolism and hypoglycaemia may cause neurological symptoms including seizures, systemic hypoperfusion, cyanosis, and right-to-left shunting. (134) Although a Cochrane review did not identify benefits in mortality before discharge or pathological neurological findings at discharge, (135) the ERC guideline recommends to consider sodium bicarbonate "*in a prolonged unresponsive resuscitation with adequate ventilation to reverse intracardiac acidosis*". (75)

Umbilical venous catheterization is the primarily recommended strategy to gain intravascular access during postnatal resuscitation. (74,75) Experimental studies suggest that peripheral venous cannulas can be used for emergency umbilical venous access (136) and that placement of an "emergency umbilical button cannula", either by standard approach or lateral umbilical cord incision, is faster in comparison to a standard umbilical venous catheter. (137)

Depending on local expertise and resources, or if umbilical venous access has failed, IO access has been recognized as an alternative vascular access route for administration of drugs. (74,75) Although some severe complications related to IO puncture have been described by case reports, (138) a 91% success rate has been recently reported among 161 neonates, with only 6% of potentially severe complications. (139) Hence, a systematic review recommended availability of IO access on neonatal intensive care units and to consider it "*for early use in neonates where other access routes have failed*". (140)

1.2.6 *"Use of Intraosseous Vascular Access During Neonatal Resuscitation at a Tertiary Center"* (141)

For this study, we surveyed medical personnel of our neonatal intensive care unit and performed a retrospective patient chart review based on survey responses:

"The Division of Neonatology at the Department of Paediatrics and Adolescent Medicine, Medical University of Graz, Austria, is a tertiary 47-bed neonatal intensive care unit covering 8,000 births a year, 3,500 of them being inborn patients. Post-natal stabilization and neonatal

resuscitation is being performed according to current guidelines. For administration of emergency drugs during neonatal resuscitation, either umbilical venous catheterization, peripheral venous puncture or IO access is being used, depending on patients' gestational age, birth weight, and the treating physicians' individual decision.
A battery powered IO access device (Arrow EZ-IO, Teleflex Medical Europe Ltd., Ireland) has been in use since April 1st, 2015. Since its introduction, frequent simulation-based practical trainings regarding its utilization have been delivered to physicians and nurses.
For this purpose, we composed an electronic eight-question questionnaire. A paediatric resident and a neonatal nurse, who were both not involved in study design and data analysis, tested the first draft of the questionnaire for clarity of language and content. Finalized questionnaires were sent by e-mail to all paediatric residents, paediatricians, and neonatologists with clinical duties at our institution between April 1st, 2015, and April 30th, 2020. Participation was voluntary. If there was no response after 2 weeks, we contacted colleagues personally.
Based on the answered questionnaires, we identified patients from electronic medical records and retrospectively collected demographic data as well as indications and complications of IO puncture. We defined success with IO access by (i) correct local puncture and (ii) successful administration of medication and/or fluid, based on questionnaire reports and patient chart review." (141)

"*All 41 forwarded questionnaires (100%) were answered and returned. During the study period of 61 months, nine of the 41 physicians (22.0%) had attempted IO access 15 times in a total of 12 neonates. Six of the 15 IO access attempts (40%) had been undertaken by residents and nine (60%) by fellows and neonatologists, respectively. All punctures were attempted at the proximal tibia. Eight of the 12 patients were term neonates, three were preterm neonates, and one former extreme preterm neonate received IO access at a post-menstrual age of 42 weeks. Ten of the 12 neonates (83.3%) required IO access during postnatal transition in the neonatal resuscitation suite, while the other two patients (16.7%) had IO access established at the neonatal intensive care unit.*" (141)

"*Eight of the nine physicians (88.9%) had previously trained IO access using simulation-based methods. IO access could be successfully gained in nine of 12 patients (75.0%). In six* *of the 12 neonates (50.0%) IO access was successful on the first attempt, while in three further neonates (25.0%) it was successful on the second attempt. In the remaining three patients (25.0%) an alternative vascular access route was used after one unsuccessful attempt.*

IO access was attempted during post-natal resuscitation in 11 neonates (91.7%). In eight of the 12 neonates (66.7%) IO access was attempted after unsuccessful peripheral venous puncture and in four patients (33.3%) it was attempted primarily. IO access was used to administer adrenaline (n=5), fluid and/or blood (n=3), and emergency sedation after intubation (n=1). Minor short-term complications (paravasation, local skin reactions and/or local soft tissue infections) were reported in three of nine successful IO punctures (33.3%)." (141)

These findings are comparable to other studies and in line with current treatment recommendations. (74,75,140) The primary indication for IO access was postnatal resuscitation and it was mainly attempted after failure of other vascular access routes. While the success rate was lower than reported elsewhere, (139) we did not observe any severe complications related to IO puncture.

1.3 Simulation-based education and training in healthcare

High-reliability industries such as aviation, aerospace programs, nuclear power, and the military, but also business management, have implemented simulation rigorously not only to improve operational safety, but also to train and evaluate professionals in their respective fields. (142,143) Through these examples, these industries provided "*a benchmark safety record for medicine to emulate*". (144)

In the context of education and training, simulation has been defined as "*a technique - not a technology - to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner*". (145) Anaesthesiologists were the first to implement simulation into healthcare, (146,147) leading to the development of simulation-based medical education (SBME). As early as in 1978, Gosling et al. (148) described the concept and design of a simulation-based neonatal umbilical vessel catheterization model, which was quickly followed by the development of neonatal and infant intubation trainers. (149) Ultimately, this led to dedicated simulation-based neonatal team trainings programs and centres such as the Center for Advanced Pediatric and Perinatal Education at Packard Children's Hospital, Stanford University, United States of America. (150,151)

Several arguments support the structured utilization of SBME, among them the recognition that junior doctors may not be sufficiently prepared for clinical duties, working time restrictions impairing bedside learning, increased emphasis on patient safety, and development of medicine into a multidisciplinary and multiprofessional team effort requiring effective communication and collaboration among healthcare professionals. (152,153) Furthermore, patient harm as a result of medical error is a common and serious burden, (154,155) and medical error has been identified as the third leading cause of death in the United States of America. (156) These alarming findings resulted in a paradigm change, (154,155) and SBME has been recognized as one measure to effectively improve patient safety. (154,157-159)

SBME offers several advantages over traditional instructional methodologies. Neuroscience shows that adult learning is most effective when trainees are actively engaged, (160,161) supporting the implementation of regular hands-on simulator practice for cognitive, technical, and behavioural skills acquisition. SBME provides opportunities for immediate active experimentation and allows for "*cementing of new knowledge and long-term changes in practice*". (162) Furthermore, SBME establishes a safe, supportive educational environment where errors can be committed and discussed without punishment, it facilitates training of both common medical situations and rare emergencies, provides on-demand learning and repetitive, deliberate practice of cognitive, psychomotor, and non-technical skills, and allows for individual and team performance to be evaluated objectively. (151-153,163) In addition, by providing real-time quantitative feedback through monitoring devices, SBME offers advantages over traditional feedback delivery which is solely based on trainer experience and observation. (164,165) Hence, SBME may be an effective "growth mindset intervention" (166) and should be considered a powerful tool in neonatology faculty development. (167)

An increasing amount of studies from different disciplines and specialties such as emergency medicine, paediatrics, and neonatology show that SBME constantly improves learners' knowledge, technical proficiency, and (clinical/professional) behaviour. (168-171) These effects have been shown both in the simulation "laboratory" and for actual patient care. (172) Besides improving the quality of medical practice, SBME is ultimately associated with improved patient outcomes, which has been reported for emergency medicine, airway management, and cardiopulmonary resuscitation both in adults and neonates. (170,173-176) In addition, SBME may also yield a return on financial investment through a reduction of medical complications, (177) less intensive care admissions and shorter hospital stays, (178) and a lower number of medical malpractice claims. (179)

1.3.1 “Paramedics' Newborn Life Support Knowledge and Skills Before and After a Targeted Simulation-Based Educational Intervention” (180)

In this prospective observational study, the *“primary outcome was theoretical knowledge of current ERC guidelines; secondary outcomes were practical ventilation skills measured by face mask leakage [%] and incidence of substantial mask leakage, defined as >75%, during non-invasive bag-valve-mask ventilation of a neonatal manikin. Parameters were assessed before and after a 1-day simulation-based educational intervention.*

Active paramedics from the Red Cross division in Nestelbach near Graz, Austria, were recruited for the study during an in-house training. Participation was voluntary without financial compensation.

Theoretical knowledge was assessed using a self-composed questionnaire, consisting of a general part asking for demographic information and 20 single-choice questions. Questions referred to all aspects of neonatal resuscitation with a particular focus on out-of-hospital care. Wording was directly taken from the ERC guidelines’ official German translation. The questionnaire was pretested by two medical students and two physicians of the Medical University of Graz, Austria, for clarity of language and content.

Participating paramedics were presented with the questionnaire between February 24, 2017, and April 8, 2017. They were given a maximum of 30 minutes to answer it individually and under supervision. Cognitive aids were not allowed.

Quality of bag-valve-mask ventilation was assessed using a respiratory function monitor for training purposes (Standardized Measurement of Airway Resuscitation Training [SMART], GM Instruments Ltd., United Kingdom). This consists of a control unit connected to a flow sensor (F10L screen pneumotachograph, GM Instruments Ltd., United Kingdom) and a term neonatal manikin with leak-free airway and an integrated neonatal test lung (Draeger, Drägerwerk AG & Co. KGaA, Germany). For each inflation, peak inspiratory pressure, air flow, tidal volume and face mask leakage are displayed on a connected personal computer.

For assessment of paramedics' ventilation proficiency, the manikin was placed in supine position on a table with an anti-slip mat. Each participant was asked to "ventilate the neonate for 90 s effectively." For this, we provided participants with the 500-ml self-inflating ventilation bag (Laerdal Silicone Resuscitator paediatric model, Laerdal Medical, Norway) and the round face mask (Neonatal Face Mask size 1, Laerdal Medical, Norway) that are used at the studied Red Cross division. Neither a PEEP valve nor a manometer was attached to the ventilation bag, while the pop-off valve was activated. No external gas flow was connected to the ventilation bag.

During assessment, participants were neither able to see the computer screen nor received any kind of instruction or feedback. The computer screen was filmed using a digital camera on a tripod to record and later manually transfer data into a Microsoft Excel database, as the first series of the SMART system does not allow direct data storage and extraction. As paramedics underwent assessment on a random basis no identifying information was stored, ensuring confidentiality of data, and anonymity of participants.

Training took place on April 8th, 2017, in two seminar rooms at the Red Cross headquarter in Nestelbach near Graz and was executed by the corresponding author for a total duration of seven hours. It began with a 45-minute lecture on neonatal resuscitation according to current ERC guidelines. Then, the first group of six people participated in a practical technical skills training on "Initial assessment and airway management" (excluding ventilation training), while the second group underwent ventilation assessment in a separate room as described above. After 30 minutes, groups were switched.

After lunch, the whole group participated in a 60-minute bag-valve-mask ventilation training, during which direct visual feedback from the SMART system was used for deliberate simulator practice. During the subsequent 90-minute algorithm training, realistic out-of-hospital neonatal resuscitation scenarios were practiced in teams of three using a low-fidelity newborn manikin (Newborn Anne, Laerdal Medical, Norway). Finally, all participants were asked to answer the questionnaire again and underwent ventilation skills assessment in the same setting as before." (180)

"*Forty-one out of 68 paramedics (60.3%) took part in the initial survey (median age 24 years [19-74]; m:w = 29:12). Of those, seven (17.1%) had been involved in an out-of-hospital birth. None had practical experience in neonatal resuscitation. Seven paramedics (17.1%) had* *additional medical education as midwife, nurse, nurse assistant or paramedic with advanced emergency competence, and one (2.4%) was a medical student at the time of assessment. In the initial assessment of knowledge prior to the intervention, a median of 62.1% (IQR 37.5-77.4) of the 20 single-choice questions were answered correctly.*

Twelve of the participating 41 paramedics (29.3%) underwent the 1-day simulation-based training and answered the second questionnaire. Two paramedics (16.7%) had experienced an out-of-hospital birth and, again, none had been involved in neonatal resuscitation. One of the 12 paramedics (8.3%) had received training as a nurse assistant or midwife. In the second knowledge assessment, 91.7% (IQR 83.3-100.0) of questions were answered correctly (p<0.001). Highest improvements occurred for questions related to oxygen saturation targets after birth, intervals of heart rate assessment and indication for emergency drugs.

For assessment of practical (ventilation) skills, we analysed a total of 1,332 inflations (691 before and 641 after training, respectively). Each participant delivered a median of 55.5 (IQR 48.0-70.0) inflations before and 53 (IQR 48.0-59.0) after training. There was no difference in median face mask leakage when comparing pre- and post-training data: 17.0% (IQR 0.0-55.0%) before vs. 18.0% (IQR 6.0-34.0%) after training (p=0.414). Nevertheless, there was a significant reduction in the incidence of substantial face mask leakage >75% after the educational intervention (median 15.8 vs. 6.1%; p<0.001)." (180)

The results of this study are similar to previous ones, (168-170,173,174) as the initially moderate knowledge level of participating paramedics was significantly improved following the simulation-based educational intervention. Furthermore, hands-on bag-valve-mask ventilation training with respiratory function monitoring was associated with a significant decrease in substantial face mask leak, which – if transferred to actual patient care – would be of major importance.

1.3.2 In situ simulation training

SBME delivered in the clinical environment is being referred to as in situ simulation. (181) Literature offers several reasons why in situ simulation training should be preferred to "traditional" SBME being delivered in dedicated training centres. In situ simulation training promotes experiential learning which is closely aligned with healthcare providers' actual work, while offering the advantage of more efficient training both for learners and their institutions. (181) It has also been used to successfully analyse and improve quality of patient care and to identify latent safety threats in actual healthcare environments. (182-186) Identification of latent hazards and knowledge gaps, and opportunities for clinical teams to rehearse infrequent and/or high-risk scenarios may be the most valuable benefits of in situ simulation training. (181)

However, although in situ simulation training is being increasingly utilized in healthcare, there are only few studies investigating its impact on organizational performance and patient health. (187) Therefore, the aim of this study was to assess the quality of postnatal stabilization and resuscitation and to evaluate the impact of in situ simulation training on quality indicators of patient care at a neonatal intensive care unit.

2. Materials and Methods

We performed a prospective observational study at the Division of Neonatology, Department of Paediatrics and Adolescent Medicine, Medical University of Graz. The study was approved by the Ethics Committee at the Medical University of Graz (27-014 ex 14/15). All employed physicians and nurses at the Division of Neonatology were invited to participate in the study on a voluntary basis and informed consent was obtained from every participant prior to study participation. The maximum number of participants was arbitrarily set at 40.

2.1 Intervention

Over a period of four months unannounced in situ simulation training was delivered, with the goal of at least three training opportunities for each study participant. Training was scheduled according to clinical workload in order to not interfere with patient care.

In situ simulation training was conducted using a wireless, highly realistic (high-fidelity) neonatal simulator (Gaumard Newborn HAL S3010, Gaumard Scientific Company Inc., Miami, United States of America) in the resuscitation room and clinical area of the Division of Neonatology. Training was delivered by an experienced simulation trainer (Dr. Lukas Mileder) with substantial experience in designing and delivering simulation-based educational interventions. Scenarios were focused on main neonatal diseases and challenges of postnatal management and required training participants to act according to the individual case descriptions and the “clinical” development of the simulated patients, whose appearance and vital signs were adapted based on team performance and medical interventions.

Each training session lasted for 15-20 minutes, involved an interprofessional team comprising physicians and members of the nursing staff, and was followed by 15-30 minutes of structured debriefing, with a reactions, description, analysis, and application and/or summary phase. (188) Debriefings focused on the learning objective of the respective scenario and aimed at improving participants’ knowledge, technical proficiency, awareness of human factors, and crisis resource management skills. (188,189) To ensure psychological safety during debriefings, several implicit and explicit strategies such as circular seating, empathy, inclusivity, and confidentiality were employed. (190) For specific medical aspects of the scenarios, a paediatrician and/or neonatologist was present during every training session.

2.2 Evaluation

In order to assess the potential impact of the intervention, two two-month observational phases were conducted before (pre-training) and after the educational intervention (post-training). During both observational phases we assessed the quality of non-technical skills and teamwork during postnatal stabilization and resuscitation, collected clinical patient data and investigated individual knowledge of neonatal resuscitation guidelines among training participants (see 2.3 Outcome measures).

All preterm and term neonates, whose parents had decided to participate in one of the Ethics Committee approved clinical studies at the Division of Neonatology, were included in this study. As part of the respective study protocols, postnatal stabilization and resuscitation was video-recorded and clinical and demographic patient data of these neonates were collected. For study purposes, a second mobile camera was installed to record the team and to allow for post-hoc analysis of team behaviour during postnatal stabilization and resuscitation. In addition, study participants were asked to individually and anonymously answer a standardized cognitive knowledge test focusing on neonatal resuscitation guidelines, (127,191) which has been developed by the ERC for its Newborn Life Support provider courses.

As part of the clinical studies at the Division of Neonatology, clinical patient data obtained during postnatal stabilization and resuscitation (respiratory parameters measured by a respiratory function monitor, SpO_2 and HR measured by pulse oximetry and/or ECG) are stored in a polygraphic system (Alpha-Trace digital MM, B.E.S.T. Medical Systems, Vienna, Austria). These data were collected together with additional patient information from our hospital's electronic patient data management system and from patient charts.

Video recordings were analysed by two external neonatologists with extensive experience in neonatal resuscitation, non-technical skills, and team performance. Outcome measures included (i) individual task performance (time to HR auscultation, time to first ventilation breath), and (ii) quality of non-technical skills and teamwork, (192,193) as there is a significant correlation between technical and non-technical skills especially under stressful conditions. (194,195) Videos from the pre- and post-training periods were reviewed in random order to ensure blinding of assessors. Video analyses focused on team performance rather than individual proficiency, and videos were exclusively used for scientific purposes. To protect data privacy, videos will be deleted after finalization of the project.

The cognitive knowledge tests were distributed before and after the educational intervention. The principal investigator performed the evaluation anonymously.

2.3 Outcome measures

The primary study outcome was the quality of non-technical skills and team interaction during actual postnatal stabilization and resuscitation. This was assessed objectively using the Anaesthetists' Non-Technical Skills (ANTS) score (192) with its four categories and 15 elements (Table 1; scoring: 4 = good, 3 = acceptable, 2 = marginal, 1 = poor, n = not observed) and compared between the pre- and post-training period. Furthermore, the number of teamwork events ("sharing information, inquiry, assertion, teaching/advising, and evaluation of plans") (193) was determined from video review and compared.

Categories	Elements
Task Management	• Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilising resources
Team Working	• Co-ordinating activities with team members • Exchanging information • Using authority and assertiveness • Assessing capabilities • Supporting others
Situation Awareness	• Gathering information • Recognising and understanding • Anticipating
Decision Making	• Identifying options • Balancing risks and selecting options • Re-evaluating

Table 1. Categories and elements of the Anaesthetists' Non-Technical Skills (ANTS) score (192).

The following clinical patient data were collected and analysed as secondary outcome measures:

- time from arrival of the neonate at the resuscitation table to HR auscultation [seconds] (video analysis)
- time from arrival of the neonate at the resuscitation table to first ventilation breath [seconds] (video analysis)
- number of endotracheal intubation attempts and frequency of successful endotracheal intubation during postnatal stabilization and resuscitation
- face mask leak during delivery of non-invasive respiratory support after birth [%], from the first inflation breath for a period of two minutes, based on analysis of data from the Florian respiratory function monitor (Acutronic Medical Systems, Hirzel, Switzerland)
- SpO_2 and HR five minutes after arrival of the neonate at the resuscitation table [% and beats per minute, respectively]
- rectal body temperature during/immediately after postnatal stabilization and resuscitation [°C]
- Apgar scores (minutes 1, 5, and 10)
- post-resuscitation complications (i.e. development of pneumothorax within 24 hours after birth)
- length of hospitalization [days]
- mortality.

In addition, the numbers of correct answers of the standardized cognitive knowledge test on neonatal resuscitation guidelines were compared between the two two-month observational periods.

2.4 Sample size calculation and statistical analyses

Thomas et al. (193) studied the effect of teamwork training on teamwork behaviour during neonatal resuscitation. They compared a control group receiving standard neonatal resuscitation training with an intervention group receiving additional teamwork training, and found 9.0 ± 2.1 teamwork events in the control group. In the intervention group, 12.8 ± 3.4 teamwork events were observed. Assuming comparable differences as in the study by Thomas et al. (193) between the pre- and post-training observational phases and using the standard deviation of 3.4, the same effect could be detected in our study with 30 events of postnatal stabilization and resuscitation using a t-test for independent samples with a power of 98%.

Data are presented as frequencies, absolute and relative values, mean ± one standard deviation or median (IQR), as appropriate. Data were tested for normal distribution using Shapiro-Wilk and Kolmogorov-Smirnov test. Sex, the need for respiratory support after birth (oropharyngeal suctioning, oxygen supplementation, mCPAP, mPPV, endotracheal intubation), rates of hypothermia, and development of pneumothorax within 24 hours after birth were compared between the two patient groups (pre- and post-training) using either Chi-Square test or Fisher's Exact Test. Results of the standardized cognitive knowledge test were compared between the pre- and post-training period using the Wilcoxon signed rank test. Depending on data distribution, t-test for independent samples or Mann-Whitney-U test were used to compare the remaining outcome measures between both groups; although the study design warrants statistical analysis using paired samples t-test, t-test for independent samples or Mann-Whitney-U test had to be used, as outcome measures were analysed anonymously for the whole cohort and not for individual resuscitations. A p-value of <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics 28 (Armonk, United States of America).

3. Results

3.1 Delivery of in situ simulation training

Over a four-month period (October 2015 – January 2016), a total of 41 in situ simulation trainings were delivered at the Neonatal Intensive Care Unit, Medical University of Graz. This number corresponds to a mean of 2.6 trainings per week (when excluding two weeks of Christmas holidays). The number of trainings per month during the intervention period is depicted in Figure 1.

Each of the training sessions involved a median of two physicians (residents and/or fellows; 1-3) and a median of two neonatal nurses (2-3). A total of 21 physicians and 27 nurses took part in those 41 simulation trainings, slightly exceeding the planned maximum of 40 training participants. When assuming a number of four participants per training, this would correspond to participation in a mean of 3.4 trainings for each study participant.

From a medical standpoint, the simulation scenarios focused on main diseases and challenges of postnatal management and included peri- and postnatal asphyxia (n=11), meconium aspiration syndrome (n=9), respiratory distress including the management of a preterm neonate (n=8), bacterial infection/sepsis (n=4), congenital cardiac malformation (n=3), seizures (n=3), difficult airway (n=2), and pneumothorax (n=1). Besides the cognitive and technical skills required to deal with these situations, the training sessions also focused on participants' non-technical skills such as communication, leader-/followership, decision making, situational awareness, and task management.

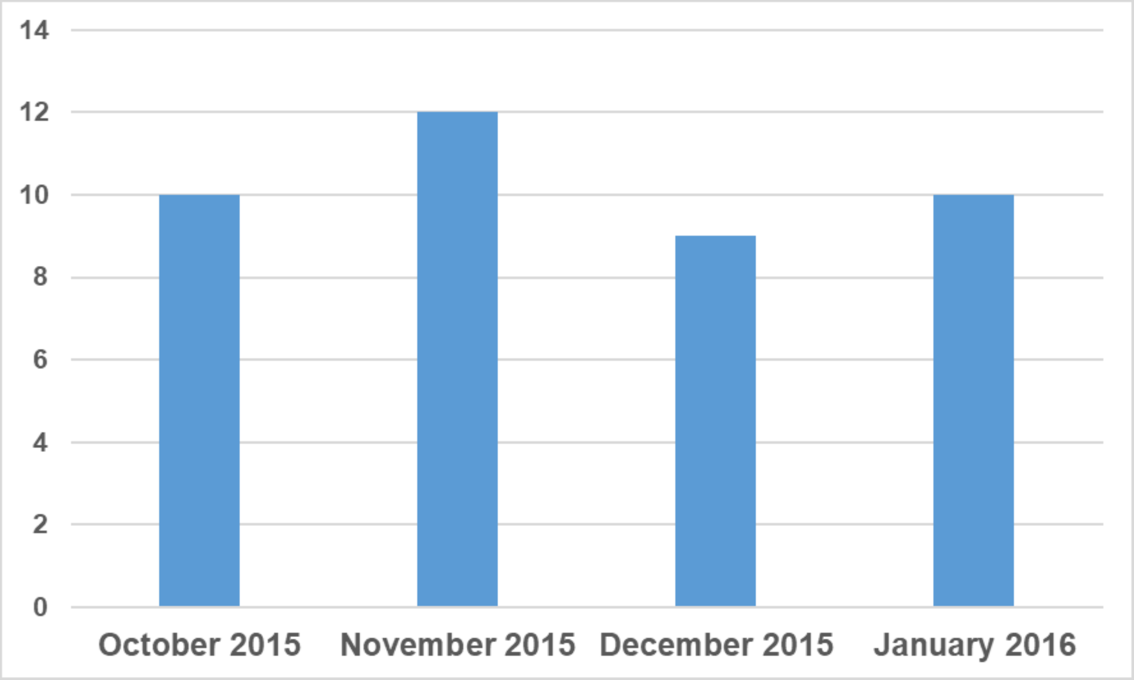


Figure 1. Number of simulation trainings per month during the educational intervention.

3.2 Patients (pre- and post-training periods)

During the pre-training period of the study, 20 preterm neonates, whose parents had decided to participate in one of the Ethics Committee approved clinical studies at the Division of Neonatology Graz, were included in this study. Of these 20 neonates, 15 (75%) required respiratory support after birth and intensive care treatment.

Twenty-five preterm neonates were video-recorded as part of clinical studies after the delivery of in situ simulation training, and could thus be included in the analysis. Thirteen (52%) of these 25 neonates required respiratory support after birth and received intensive care treatment.

These 28 neonates (15 before and 13 after the educational intervention, respectively), who required respiratory support after birth as well as intensive care treatment, were included in this analysis and their demographic data are shown in Table 2. Neonates who were included in this study after the delivery of in situ simulation training had a lower birth weight (p=0.043), but there were no differences in gestational age or sex between the groups. All 28 neonates were delivered by Caesarean section.

	All neonates (n=28)	**Neonates before simulation training (n=15)**	**Neonates after simulation training (n=13)**	**p-value**
Gestational age [weeks]	30.4 ± 3.6	31.5 ± 3.7	29.2 ± 3.3	p=0.101
Male sex [%]	16 (57.1)	9 (60)	7 (53.8)	$\chi^2(1)=0.108$, p=0.743
Birth weight [grams]	1441 ± 672	1678 ± 744	1168 ± 469	p=0.043*

Table 2. Demographic data of the included 28 neonates, who required respiratory support after birth as well as intensive care treatment (absolute and relative values or mean ± one standard deviation, as appropriate). *(* = p<0.05)*

3.3 Primary study outcome

Among those 15 preterm neonates who were included before the delivery of in situ simulation training, 12 team videos (80%) were available for analysis. For the post-training period, 13 team videos (100%) were available and could be analysed. There were no differences in the median duration of team videos between the pre- and post-training period (15 [10.25-15.0] versus 15 [15.0-15.0] minutes, p=0.393).

The first video reviewer rated the four ANTS categories Task Management, Team Working, Situation Awareness, and Decision Making with a median of 3.5 (3-4), 4 (3-4), 4 (3-4), and 4 (4-4) before and with a median of 3 (3-4), 3 (3-4), 4 (3-4), and 4 (3.5-4), respectively, after the delivery of in situ simulation training (Figure 2). There were no differences in those categories between the pre- and post-training period (Task Management: p=0.742; Team Working: p=0.190; Situation Awareness: p=0.547; Decision Making: p=0.659).

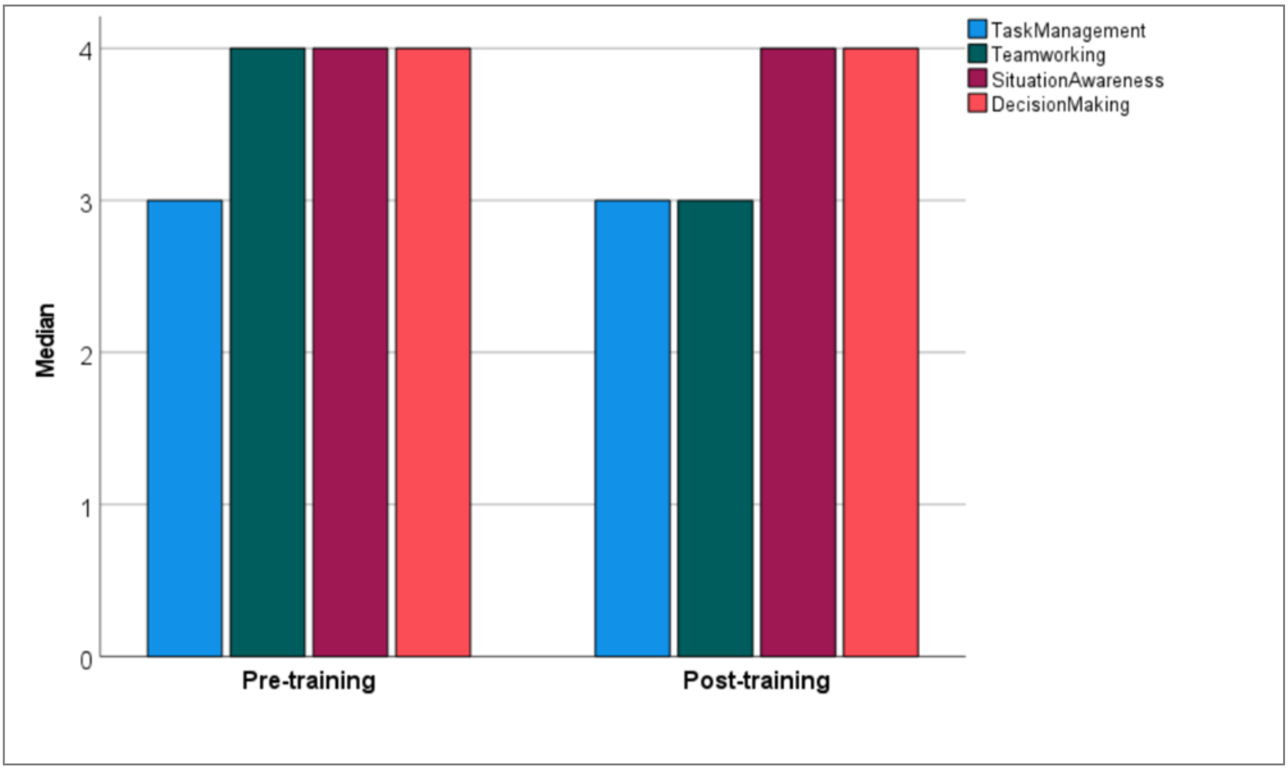


Figure 2. ANTS categories before (left) and after (right) the delivery of in situ simulation training, based on the rating from the first video reviewer (4 = good, 3 = acceptable, 2 = marginal, 1 = poor).

The ratings of the 15 individual ANTS elements by reviewer 1 are presented in Table 3. There were no differences between individual ANTS element scores before and after the delivery of in situ simulation training (Table 3).

ANTS elements	Pre-training	Post-training	p-value
Planning and preparing	2.5 (2.0-3.0)	(no scoring)	-
Prioritising	3.0 (2.75-4.0)	4.0 (2.0-4.0)	p=0.832
Providing and maintaining standards	4.0 (4.0-4.0)	4.0 (3.0-4.0)	p=0.207
Identifying and utilising resources	3.0 (2.0-3.0)	4.0 (2.0-4.0)	p=0.392
Co-ordinating activities with team members	3.0 (2.0-4.0)	4.0 (2.0-4.0)	p=0.494
Exchanging information	2.0 (2.0-3.0)	4.0 (2.0-4.0)	p=0.093
Using authority and assertiveness	3.0 (1.0-4.0)	3.0 (2.5-4.0)	p=0.649
Assessing capabilities	3.0 (2.0-4.0)	3.0 (2.5-4.0)	p=0.531
Supporting others	3.0 (1.0-4.0)	3.0 (1.0-4.0)	p=0.865
Gathering information	3.0 (1.0-3.0)	3.0 (2.0-4.0)	p=0.531
Recognising and understanding	3.0 (2.0-4.0)	3.0 (2.0-4.0)	p=0.820
Anticipating	2.5 (1.75-4.0)	2.0 (2.0-4.0)	p=0.738
Identifying options	3.0 (1.75-3.0)	3.0 (2.0-4.0)	p=0.376
Balancing risks and selecting options	2.0 (2.0-3.0)	3.0 (2.0-4.0)	p=0.303
Re-evaluating	3.0 (2.0-4.0)	3.0 (3.0-4.0)	p=0.733

Table 3. Median scores (IQR) of individual ANTS elements before and after the delivery of in situ simulation training, based on the rating from the first video reviewer (4 = good, 3 = acceptable, 2 = marginal, 1 = poor).

The four ANTS categories Task Management, Team Working, Situation Awareness, and Decision Making were rated with a median of 3 (3-4), 4 (3-4), 4 (3-4), and 4 (3-4) before and with a median of 3 (3-4), 3 (3-4), 4 (3-4), and 4 (3.75-4), respectively, after the delivery of in situ simulation training by the second reviewer (Figure 3). Again, there were no differences in those categories between the pre- and post-training period (Task Management: p=0.436; Team Working: p=0.623; Situation Awareness: p=1.000; Decision Making: p=0.693).

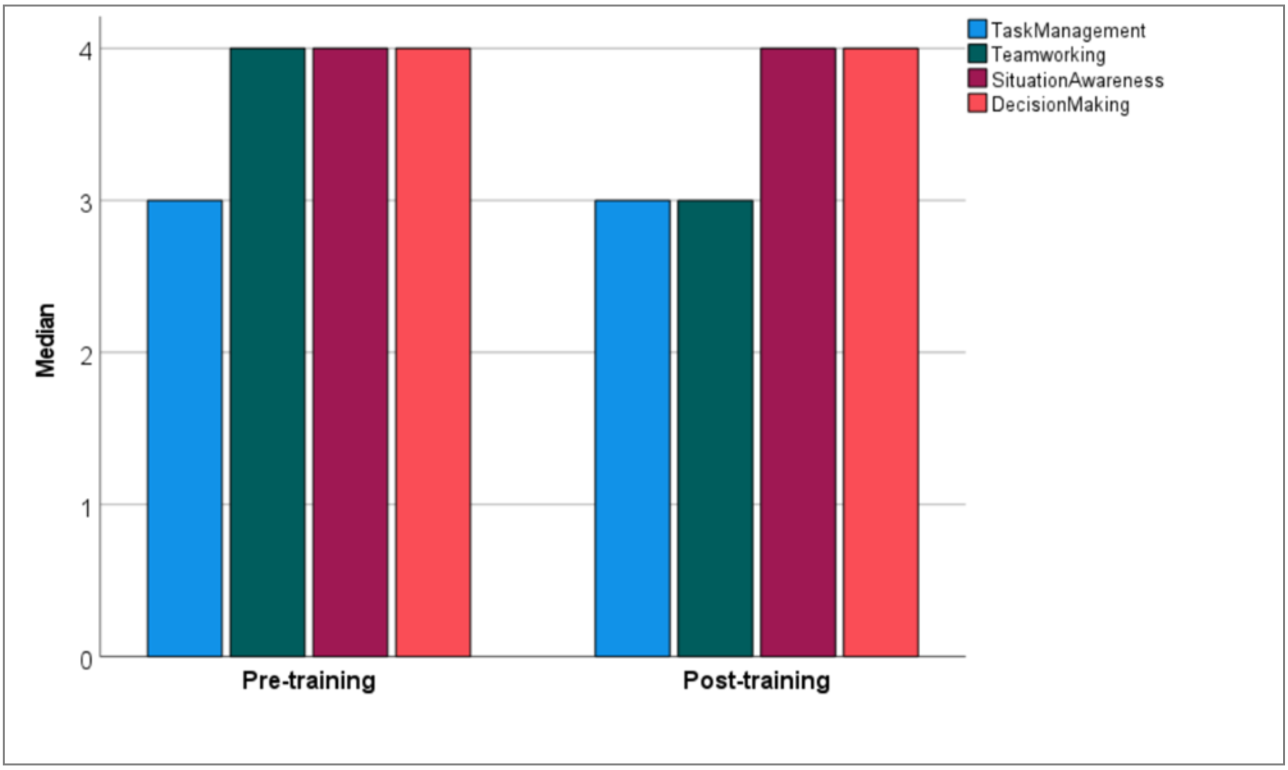


Figure 3. ANTS categories before (left) and after (right) the delivery of in situ simulation training, based on the rating from the second video reviewer (4 = good, 3 = acceptable, 2 = marginal, 1 = poor).

Table 4 presents the ratings of the 15 individual ANTS elements by reviewer 2. There were no differences between individual ANTS element scores before and after the delivery of in situ simulation training (Table 4).

ANTS elements	Pre-training	Post-training	p-value
Planning and preparing	4.0 (2.25-4.0)	3.0 (2.0-4.0)	p=0.695
Prioritising	4.0 (3.0-4.0)	4.0 (2.0-4.0)	p=0.400
Providing and maintaining standards	4.0 (3.0-4.0)	4.0 (2.0-4.0)	p=0.743
Identifying and utilising resources	4.0 (3.5-4.0)	4.0 (2.0-4.0)	p=0.731
Co-ordinating activities with team members	4.0 (3.0-4.0)	4.0 (2.5-4.0)	p=0.303
Exchanging information	4.0 (3.0-4.0)	4.0 (3.0-4.0)	p=0.605
Using authority and assertiveness	4.0 (3.0-4.0)	4.0 (3.0-4.0)	p=1.000
Assessing capabilities	4.0 (4.0-4.0)	4.0 (3.5-4.0)	p=0.481
Supporting others	4.0 (3.0-4.0)	4.0 (4.0-4.0)	p=0.691
Gathering information	4.0 (3.5-4.0)	4.0 (4.0-4.0)	p=0.602
Recognising and understanding	4.0 (3.0-4.0)	4.0 (3.25-4.0)	p=0.422
Anticipating	4.0 (3.25-4.0)	4.0 (3.75-4.0)	p=0.897
Identifying options	4.0 (4.0-4.0)	4.0 (3.5-4.0)	p=0.529
Balancing risks and selecting options	4.0 (3.25-4.0)	4.0 (4.0-4.0)	p=0.686
Re-evaluating	4.0 (4.0-4.0)	4.0 (3.25-4.0)	p=0.524

Table 4. Median scores (IQR) of individual ANTS elements before and after the delivery of in situ simulation training, based on the rating from the second video reviewer (4 = good, 3 = acceptable, 2 = marginal, 1 = poor).

Table 5 summarizes the five teamwork events as defined by Thomas et al. (193), i.e. sharing information, inquiry, assertion, teaching/advising, and evaluation of plans. While there was an increase in absolute numbers from the pre- to the post-training period for all five teamwork events, this did only reach statistical significance for “evaluation of plans” (0.5 [0.0-1.0] versus 1.0 [1.0-2.0], p=0.049). When adding together the numbers of all teamwork events, there was again an increase following the delivery of in situ simulation training (15.0 [10.0-24.25] versus 18.0 [13.5-30.5]), which almost reached statistical significance (p=0.056; Figure 4).

	Pre-training	Post-training	p-value
Sharing information [n]	5.5 (4.0-10.75)	9.0 (6.0-17.5)	p=0.102
Inquiry [n]	4.0 (1.5-7.5)	6.0 (5.0-8.0)	p=0.088
Assertion [n]	0.0 (0.0-1.0)	1.0 (0.0-2.0)	p=0.129
Teaching/advising [n]	1.0 (1.0-3.5)	2.0 (0.0-2.5)	p=0.911
Evaluation of plans [n]	0.5 (0.0-1.0)	1.0 (1.0-2.0)	p=0.049*

Table 5. Median number (IQR) of teamwork events per neonate before and after the delivery of in situ simulation training. *(* = p<0.05)*

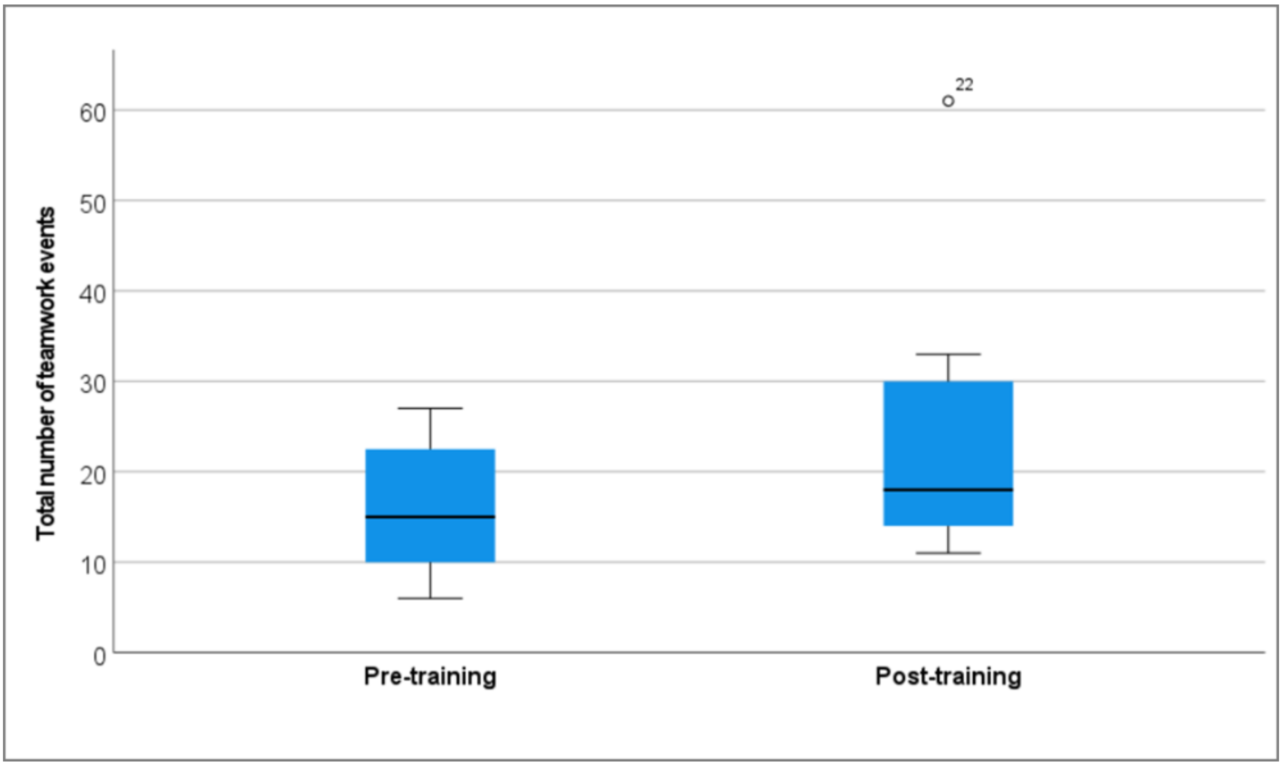


Figure 4. Total number of teamwork events per neonate before (left) and after (right) the delivery of in situ simulation training (p=0.056).

3.4 Secondary study outcomes

Based on video analysis, median time from arrival at the resuscitation table to HR assessment by auscultation was 9.5 (3.0-22.75) seconds in the pre- and 10.0 (5.25-21.75) seconds in the post-training group (p=0.715). Auscultation of the heart could be clearly identified by video review in 12 out of the 15 neonates (80%) in the pre-training period and in ten out of the 13 neonates (76.9%) in the post-training period.

In those neonates who did not breath or who did not breathe sufficiently, median time from arrival at the resuscitation table to first ventilation breath was 27.0 (16.5-43.0) seconds before and 30.0 (14.0-49.0) seconds after the delivery of in situ simulation training (p=0.871). As the first ventilation breath was not clearly visible in every video, data were available for five out of nine neonates (55.6%) who required PPV in the pre-training period and for seven out of ten neonates (70%) who required PPV in the post-training period.

Measures of respiratory support are summarized and compared between the groups in Table 6. There were no differences in either of the respiratory support interventions. In the 11 neonates who required intubation there was a median of two (1-3) intubation attempts, with a median of two (1.25-2.75) in the pre-training group and of two (1-3) in the post-training group, respectively (p=0.920).

	All neonates (n=28)	**Neonates before simulation training (n=15)**	**Neonates after simulation training (n=13)**	**p-value**
Oropharyngeal suctioning [%]	22 (78.6%)	12 (80.0%)	10 (76.9%)	p=1.000
Oxygen supplementation [%]	25 (89.3%)	14 (93.3%)	11 (84.6%)	p=0.583
Mask CPAP [%]	28 (100%)	15 (100%)	13 (100%)	-
Mask PPV [%]	19 (67.9%)	9 (60.0%)	10 (76.9%)	p=0.435
Intubation [%]	11 (39.3%)	4 (26.7%)	7 (53.8%)	$\chi^2(1)=2.157$, p=0.142

Table 6. Measures of postnatal respiratory support of the included 28 neonates.

As another secondary outcome parameter, we aimed at analysing face mask leak during delivery of mPPV after birth. However, due to technical problems with the Florian respiratory function monitor (Acutronic Medical Systems, Hirzel, Switzerland) this analysis could not be performed as intended.

Median SpO_2 and HR five minutes after arrival of the neonate at the resuscitation table were 78.5% (72.25-86.25) and 137.5 (128.5-147.0) beats per minute in the pre-training group and 76% (62-84) and 144 (93-152) beats per minute in the post-training group, respectively. There were no statistical differences between both groups, neither in SpO_2 (p=0.406) nor in HR (p=0.732). SpO_2 and HR data were available for ten neonates (66.7%) in the pre-training period and for seven neonates (53.8%) in the post-training period.

Rectal body temperature during/immediately after postnatal stabilization and resuscitation was 36.8 ± 0.2°C before and 36.6 ± 0.7°C after the implementation of in situ simulation training (p=0.394). More neonates had a body temperature below 36.5°C in the post-training group (5/13 [38.5%] versus 1/15 [6.7%]), however this difference was not statistically significant (p=0.069). All neonates who suffered from hypothermia after birth were extremely preterm neonates between 24+1 and 29+4 weeks of gestation, with birth weights ranging from 550 to 1214g.

Median Apgar scores at minutes one, five, and ten were 7 (5-8), 8.5 (8-9), and 9 (9-9) for all 28 neonates. For those 15 neonates who were included before the delivery of in situ simulation training, Apgar scores were 7 (6-8), 9 (8-9), and 9 (9-9), respectively. Apgar scores of the 13 neonates who were included after in situ simulation trainings were 6 (4.5-8), 8 (7-9), and 9 (9-9), respectively.
The 5-minute Apgar score was significantly lower in the post-training group (p=0.045), but there were no differences in the Apgar scores at one and ten minutes after birth (p=0.421 and p=0.697, respectively; Figure 5). If the three deceased neonates (one in the pre- and two in the post-training period, respectively) were removed from the analysis, there was no significant difference in the 5-minute Apgar score (9 [8-9] versus 8 [8-9], p=0.191).

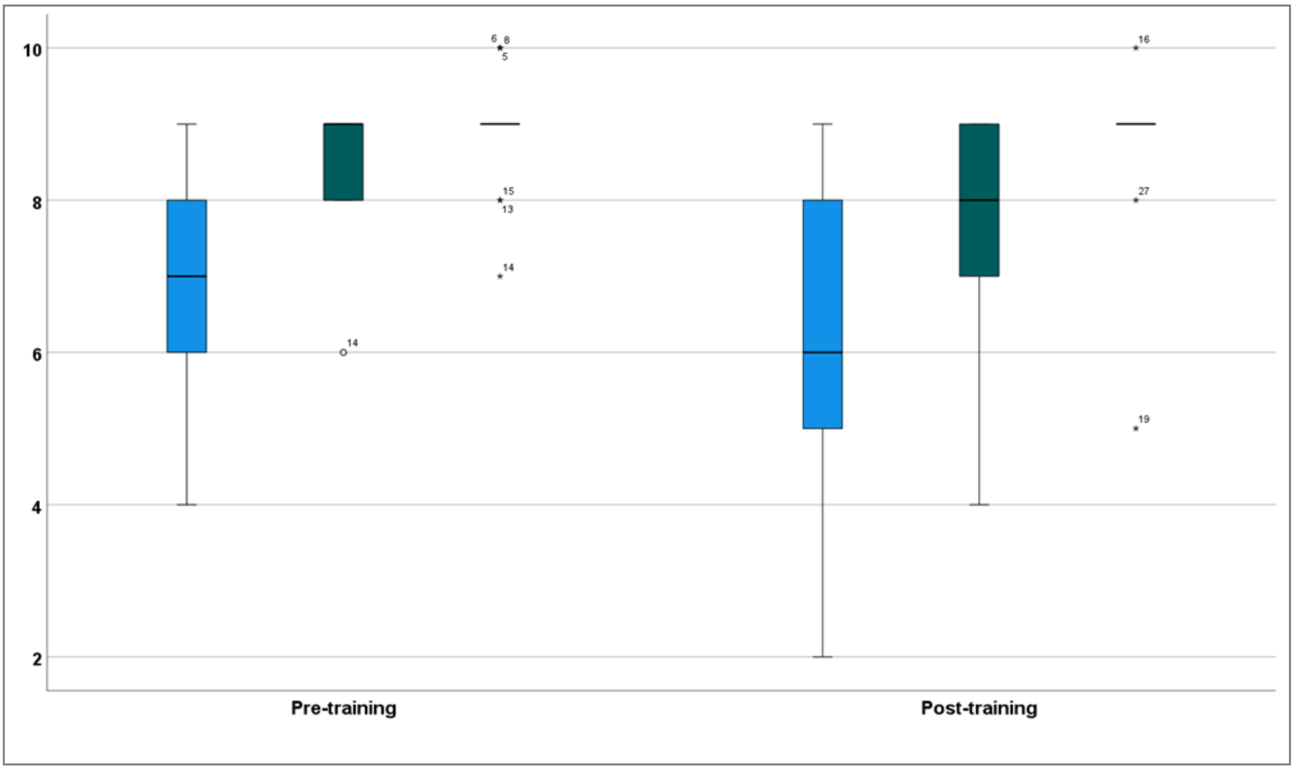


Figure 5. Apgar scores at one (blue), five (green), and ten minutes after birth before (left) and after (right) the delivery of in situ simulation training. *(p=0.045 for 5-minute Apgar scores)*

As a surrogate parameter for post-resuscitation complications, we collected the number of peumothoraces within 24 hours after birth. One neonate (6.7%) developed a pneumothorax during the pre-training period, while there was no pneumothorax during the post-training period (p=1.000).

All 28 neonates were hospitalized for a median of 34 (16.5-66.75) days. Neonates who were included before the delivery of in situ simulation training were hospitalized for 28 (16-57) days, while hospitalization was 41 (15-75.5) days in the post-training group (p=0.447). Even when removing the three deceased neonates from the analysis, there was no difference in length of hospitalization (29 [17.5-60.25] versus 51 [21-78] days, p=0.267).
Mortality was 1/15 (6.7%) before and 2/13 (15.4%) after the educational intervention, with no significant difference between the groups (p=0.583). Deceased neonates were all born between 24+1 and 26+5 weeks of gestation and died between days four and nine after birth.

	Pre-training	**Post-training**	**p-value**
Time from arrival at the resuscitation table to HR auscultation [seconds]	9.5 (3.0-22.75)	10.0 (5.25-21.75)	p=0.715
Time from arrival at the resuscitation table to first ventilation breath [seconds]	27.0 (16.5-43.0)	30.0 (14.0-49.0)	p=0.871
Number of endotracheal intubation attempts [n]	2 (1.25-2.75)	2 (1-3)	p=0.920
SpO_2 five minutes after arrival at the resuscitation table [%]	78.5 (72.25-86.25)	76 (62-84)	p=0.406
HR five minutes after arrival at the resuscitation table [beats per minute]	137.5 (128.5-147.0)	144 (93-152)	p=0.732
Rectal body temperature [°C]	36.8 ± 0.2	36.6 ± 0.7	p=0.394
Apgar at 1 minute	7 (6-8)	6 (4.5-8)	p=0.421
Apgar at 5 minutes	9 (8-9)	8 (7-9)	p=0.045*
Apgar at 10 minutes	9 (9-9)	9 (9-9)	p=0.697
Pneumothorax within 24 hours after birth [n]	1/15	0/13	p=1.000
Length of hospitalization [days]	28 (16-57)	41 (15-75.5)	p=0.447
Mortality [n]	1/15	2/13	p=0.583

Table 7. Summary of secondary study outcomes before and after the delivery of in situ simulation training (absolute values, mean ± one standard deviation or median (IQR), as appropriate). *(* = $p<0.05$)*

Twenty-nine training participants, i.e. 60.4% of all trained healthcare professionals, answered the standardized cognitive knowledge test before and after the delivery of in situ simulation training. A median of 15 (13-15.5) questions were answered correctly during the pre-training period, while this number increased to 18 (17-19) after training delivery ($p<0.001$; Figure 6).

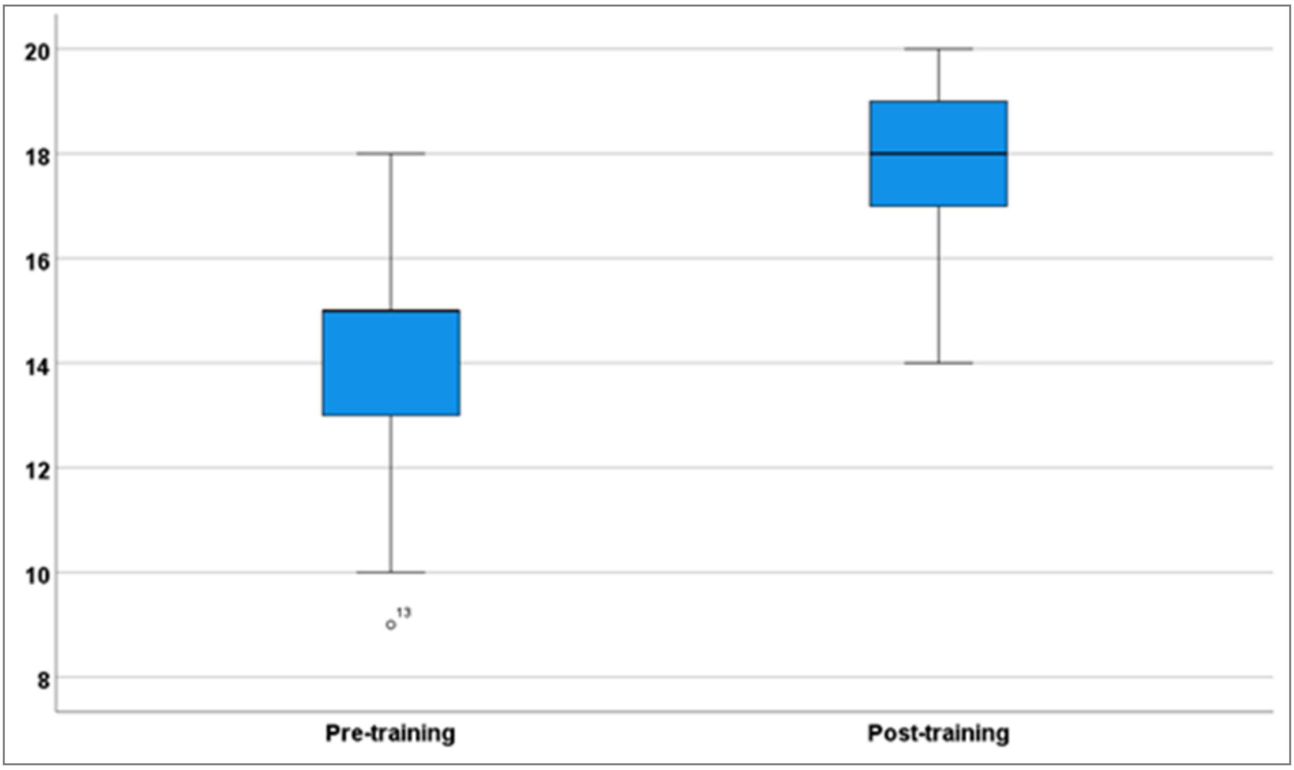


Figure 6. Numbers of correct answers from the 20-question standardized cognitive knowledge test before (left) and after (right) the delivery of in situ simulation training ($p<0.001$).

4. Discussion

Postnatal stabilization and resuscitation requires cognitive, technical, and behavioural skills, and SBME has been recognized as a proven methodology to acquire, maintain and improve these skills. (196) While in situ simulation offers added benefits in comparison to "traditional" SBME, studies about in situ simulation training are still scarce. (187) Therefore, it is not surprising that this is one of the very first studies in the field of neonatology which has investigated the effect of a dedicated in situ simulation training program not only on behaviour in the simulation laboratory and on neonatal short-term outcome such as cardiorespiratory stability after birth, but also on the length of hospitalization and in-hospital mortality. Thus, in the concept of translational research this study reflects T2 and T3 research, investigating translation to patients and clinical practice, previously recognized as "from bench to bedside". (172,197)

Eckels et al. (198) described the successful implementation of in situ simulation training in their level III neonatal intensive care unit, but reported limited opportunities for staff to participate due to patient care duties, "*medical leave or per diem schedules*" as the main challenge. Other studies also reported clinical obligations as a major challenge for any in situ simulation training program. (199) We were able to deliver 2.6 trainings per week over our intervention period, which is slightly below the targeted number of three to five simulation sessions per week. Still, our number of delivered trainings compares well to the "*roughly one simulation per month*" achieved by Eckels et al. (198)

The in situ simulation trainings were planned and delivered as suggested by current guidelines for simulation-based team training in paediatrics and adolescent medicine, which define best practices for providing a safe learning environment, adequate human resources, appropriate scenarios, and delivering effective debriefing. (200) Specific focus was placed on adequate and effective debriefing after the training sessions, as debriefing has been recognized to provide "*a forum for learners to reflect on action, identify performance gaps, discuss areas for improvement, and consolidate knowledge and skills*". (201) Through moderated reflection, debriefing not only allows for participants' 'mental models' to be recognized and analysed, but also to develop new mental frames and, thus, modified (clinical) behaviour. (202) Therefore, debriefings were structured as recommended, including a reactions, description, analysis, and application and/or summary phase, based on the Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework. (188) In addition, debriefing sessions utilized a learner-centred approach to further improve their effectiveness, allowing participants to take on an active role while the trainers facilitated discussion involving all training participants and encouraged self-reflexion and -assessment. (203) Due to the ad-hoc character of the in situ training sessions we did not video-record trainings for debriefing purposes, although video-assisted debriefing may yield an additional educational benefit. (204-207)

While the two video reviewers did not find any differences in the four ANTS categories Task Management, Team Working, Situation Awareness, and Decision Making, the already high level of non-technical skills and team interaction before the implementation of in situ simulation training has to be acknowledged. Both video assessors scored three of the four major categories with a 4, corresponding to a "good" performance, before the delivery of in situ simulation training, leaving few opportunities for further improvement due to the educational intervention. Accordingly, there were no significant differences in the individual ANTS elements between the pre- and post-training period.

Nonetheless, the increase in the numbers of all five teamwork events, (193) which even reached statistical significance for "evaluation of plans", clearly illustrates the impact of the in situ simulation training sessions. This finding is even more remarkable, as the targeted number of 30 neonates requiring postnatal stabilization and/or resuscitation, as based on our sample size calculation, was not reached. Correspondingly, there was a non-significant increase in the total number of teamwork events after the delivery of in situ simulation training.

These findings correspond well with previous research. Thomas et al. (193) found a higher incidence of teamwork events when adding teamwork training to high-fidelity simulation. Furthermore, simulated neonatal resuscitations were faster (time reduction of 24%) in the intervention group in comparison to those participants receiving standard low-fidelity Neonatal Resuscitation Program® training. (193) Similarly, Hunziker et al. (208) reported longer hands-on time and a shorter time until initiation of cardiopulmonary resuscitation following leadership training in their simulation-based, randomized controlled superiority trial. Further studies from different medical disciplines showed an association between teamwork training and improved actual team performance and patient outcomes, such as reduced times from arrival to computer tomography, to endotracheal intubation and to operating room in trauma patients, (209) improved adherence to protocols and shorter activation times of extracorporeal cardiopulmonary resuscitation teams, (210) reduced door-to-needle time for stroke thrombolysis, (211) or reduction of maternal blood transfusions and postpartum haemorrhage. (212) Brogaard et al. (213) also described a positive correlation between non-technical skills scores and clinical performance when treating neonates after birth, which further emphasizes the potential impact of dedicated team training. Accordingly, a systematic literature review found training in team behaviour to result in improved clinical performance. (214)

The transfer of skills acquired through SBME to actual clinical practice is being intensively studied, as several factors may support or hinder this essential process. (215-217) Mema et al. (216) identified concern for patients' wellbeing, corrective actions in the real situation, the complexity of the intensive care unit, and the procedure itself as barriers for effective transfer of skills, while specific instructions, mastery training, direct observation with feedback, supervision, and actual real-life experiences were perceived as beneficial. Our finding of improved post-training non-technical skills levels during actual patient care adds to the growing body of evidence, which shows effective skills transfer from the simulated environment to clinical team performance. Studies have demonstrated improved management and neonatal outcome after shoulder dystocia, (218) less complications and higher success rates for central venous catheter insertion in a medical intensive care unit, (219) and a reduced incidence of blood stream infections following introduction of a central line care bundle including procedure standardization and simulation-based training. (220)

There were no differences between the pre- and post-training period either for time to HR assessment or for time to first ventilation breath. HR auscultation was initiated within ten seconds after arrival at the resuscitation table both before and after the delivery of in situ simulation training, which is well within the recommended time frame. (74,75) This finding compares very well to the study by Schilleman et al. (221), in which video recording of delivery room management of preterm neonates revealed a mean time from birth to HR assessment by auscultation of 65 seconds. Skåre et al. (222) also reported relevant delays in

HR assessment in compromised neonates requiring PPV after birth, with only 66% of neonates having their HR checked by stethoscope within 60 seconds.

In those neonates presenting apnoeic or with ineffective spontaneous breathing, PPV was initiated within 30 seconds after arrival at the resuscitation table, both during the pre- and post-training period. Current neonatal resuscitation guidelines recommend commencing PPV "*without delay*" (74) and "*ideally within 60 s of birth*", (75) underlining the effective postnatal care that was being provided both before and after the educational intervention. Again, our numbers compare well to other findings, as Schilleman et al. (221) reported a mean time from birth to initiating non-invasive respiratory support of 70 seconds. Accordingly, McCarthy et al. (223) found a median time of 56 seconds from arrival at the resuscitation table until delivery of respiratory support in preterm neonates with a median gestational age of 29 weeks, with only 38% receiving respiratory support within 60 seconds after birth.

We did not find any significant differences, neither qualitatively nor quantitatively, in the delivered respiratory support interventions between the pre- and post-training period. This is not surprising, as we primarily included preterm neonates, who have an increased need for postnatal stabilization or resuscitation (75) and who require manoeuvres to improve respiratory support more often in comparison to term neonates. (120) Our observed measures of respiratory support in terms of oropharyngeal suctioning, mPPV, and postnatal endotracheal intubation are comparable to previous reports by observational delivery room studies. (224,225)

Significant face mask leak is common when providing non-invasive PPV to preterm neonates after birth. (117,118,226,227) As face mask leak is negatively correlated with expiratory tidal volume, (226,227) it is a major determinant of postnatal stabilization and resuscitation. Therefore, we had planned to measure and analyse face mask leak during PPV in our patients using a respiratory function monitor. Unfortunately, however, this analysis could not be performed due to technical problems.

Other studies investigated the effect of simulation-based neonatal ventilation training on provider proficiency. van Vonderen et al. (228) reported a significant reduction in face mask leak and excessive peak inspiratory pressures both in experienced and inexperienced providers following a two-minute training, consisting of verbal instruction and demonstration of mask PPV. This finding is consistent with our presented one (see 1.3.1), showing that a one-day simulation-based training resulted in a significantly lower substantial face mask leak in rather inexperienced paramedics. (180) Further underlining these findings, Sawyer et al. (229) found coaching involving real-time feedback on ventilation quality to result in more appropriate peak inspiratory pressures and tidal volumes as well as reduced face mask leak in their simulation-based randomized cross-over study.

Both SpO_2 and HR, assessed at five minutes after arrival of the neonate at the resuscitation table, also did not differ when comparing neonates of the pre- and post-training period. However, it has to be acknowledged that the median SpO_2 did not reach the recommended value of 85% at five minutes after birth (75) in neither of the observational phases. Not reaching an SpO_2 of 80% or higher at five minutes after birth is associated with significantly decreased $crSO_2$ (230) and higher odds of intraventricular haemorrhage in preterm neonates requiring postnatal respiratory support, (231) emphasizing the importance of delivery room practices during the first five minutes after birth. (232)

Median heart rates during the pre- and post-training period were well within recommended ranges for preterm neonates after birth. (75) Nerdrum Aagaard et al. (233) reported median heart rates between 150 and 169 beats per minute at five minutes after birth in "*mainly non-ventilated term and preterm infants*". Interestingly, Yam et al. (234) found that 67% of preterm neonates below 30 weeks of gestation, who were initially bradycardic and required PPV after birth, did not remain stable before reaching a HR of around 150 beats per minute; this suggests that targeted HR in preterm neonates requiring postnatal stabilization should possibly be higher than the currently recommended minimum of 100 beats per minute. It is important to note that of the two preterm neonates in our study with heart rates below 100 beats per minute at five minutes after arrival at the resuscitation table, both in the post-training group, one extremely preterm neonate died on the ninth day after birth from severe bilateral intra- and periventricular haemorrhage. This underlines the detrimental effect of prolonged bradycardia after birth. (77,231,235)

The majority of neonates in the pre- and post-training group had a normal body temperature during/immediately after postnatal stabilization and resuscitation (93.3% and 61.5%, respectively), which is being defined as 36.5-37.5°C. (75) Maintaining or achieving

normothermia after birth is especially important in preterm neonates, as hypothermia significantly increases the risk of adverse outcome and early death. (51,56,236) Conversely, interventions dedicated to postnatal thermal support, such as the use of plastic bags, wraps and/or caps, and heated humidified gases for respiratory support, have been shown to decrease the risk of brain injury and mortality. (237)
In this study, we observed a statistically non-significant, yet higher incidence of mild to moderate hypothermia in the post-training group. While this could be interpreted as a result of less effective thermal care, one must bear in mind that neonates included after the delivery of in situ simulation training had a significantly lower birth weight, and that low birth weight and immaturity are negatively correlated with the frequency of postnatal hypothermia. (54,238) In addition, maternal body temperature at delivery is a significant predictor of neonatal hypothermia, (236) but these data were not recorded and we can, thus, only speculate about the potential effect of maternal hypothermia on our findings.

Neonates who were included after the delivery of in situ simulation training had a significantly lower 5-minute Apgar score. At first sight, this finding could suggest a potential detrimental effect of the trainings, but it must be interpreted with caution. First, Apgar scores at one and ten minutes after birth did not differ between the pre- and post-training group, suggesting no significant differences in postnatal stability and adaptation. Second, there is a positive correlation between birth weight and 5-minute Apgar score in low- and very-low-birth-weight infants, (239) and neonates in our post-training group had a significantly lower birth weight. Third, it is well known that the Apgar score has poor interobserver reliability, (72) especially in preterm neonates. (240) Fourth, when removing the three deceased neonates from the analysis, Apgar scores at five minutes after birth did not differ any more. Finally, in a cohort study involving more than 636000 high-risk births, the implementation of structured neonatal resuscitation training was associated with higher Apgar scores, and, thus, potentially improved neonatal outcome. (241)

Despite the immaturity of our included patients, we observed a low number of pneumothoraces and a rather low mortality rate, without any differences between the pre- and post-training period. Although we did not find an effect of our in situ training on patient outcome and survival, studies, such as the one by Andreatta et al. (242), have shown that in situ simulation training may in fact improve patient survival. They described a significant increase in survival after paediatric cardiopulmonary arrest following the introduction of unannounced ‘mock codes’ over a period of 48 months, and found a significant correlation between increasing numbers of mock codes and improved survival rates. (242) Awadhare et al. (243) also reported improved in-hospital paediatric cardiopulmonary resuscitation after the introduction of a quality improvement bundle consisting of simulation training and debriefing of actual cardiac arrest events. Accordingly, Reed et al. (244) regularly delivered in situ simulation training at a level IV neonatal intensive care unit over four years and found a marked reduction in so-called code-blue events involving cardiopulmonary resuscitation from three to eight per month to zero to two every month. While none of the aforementioned studies proves a causative relationship between SBME and improved patient outcome and survival, they certainly provide evidence that must not be neglected.

There was no difference in the duration of hospitalization in our study, even when adjusting the statistical analysis for the three extremely preterm neonates who had died within the first nine days after birth. In contrast, Theilen et al. (178) reported an association between in situ simulation training and fewer admissions to and shorter stays at a paediatric intensive care unit. Sonesh et al. (245) also showed a reduction in neonates’ length of hospital stay after the delivery of dedicated obstetrical team training.

As another secondary outcome parameter, we assessed training participants’ knowledge of neonatal resuscitation guidelines and found a significant improvement after the delivery of in situ simulation training. This finding was to be expected, as many studies have consistently reported improved theoretical knowledge after SBME. (168-170,173,174,180,246) However, in comparison to non-simulation-based educational interventions, SBME does not offer added benefit regarding acquisition of theoretical knowledge. (168,174) This underlines the focus of SBME on technical and non-technical, team-oriented skills acquisition and practice, as well as the need to adapt the format and modality of simulation-based training to pre-defined educational goals and specific target groups. (247)

4.1 Limitations

Several limitations of this study have to be acknowledged:

First, based on the sample size calculation we targeted 30 events of postnatal stabilization and resuscitation, but this number could not be reached, which limits the power and generalizability of the results. On the other hand, the fact that the targeted number of patients was not met further underlines the significant improvement in the teamwork event “evaluation of plans” following the delivery of in situ simulation training.

Second, being video-recorded may have caused concern or even emotional distress on behalf of some healthcare providers. (248,249) This – consciously or unconsciously – could have affected actual clinical behaviour. However, we can only speculate about this potential effect, as we did not assess participants’ experience of delivery room video-recordings in this study.

Third, based on feedback from the video reviewers, the ANTS element “Planning and preparing“ could not be sufficiently assessed in every video, because due to the acuity of some delivery room stabilizations not all team briefings, which are important determinants of clinical performance, (250) had been recorded.

Fourth, video assessors found the scoring of the ANTS category “Decision Making” challenging in situations where no critical decisions were actually required during postnatal stabilization.

Finally, we have used the ANTS score to measure the quality of non-technical skills. However, this score has not been developed or validated for postnatal stabilization and resuscitation, and since our study conceptualization and delivery several teamwork assessment tools have been developed and studied for delivery rooms, (251) among them the Global Assessment Of Team Performance checklist. (213) While our video reviewers found the ANTS score to be suitable for our specific setting and study question, we do not know whether having used an alternative teamwork assessment tool would have generated different results.

5. Conclusion

For this study, we were able to successfully implement an in situ simulation training program with almost three trainings per week over a period of four months at our neonatal intensive care unit. Non-technical skills and team interaction during actual postnatal stabilization and resuscitation were already at a high level in the pre-training period, and there was no further improvement after the educational intervention when employing the ANTS score. Nonetheless, there was a significant increase in the teamwork event “evaluation of plans” following the delivery of in situ simulation training. Training participants’ knowledge of neonatal resuscitation guidelines was also significantly improved after in situ simulation training, while we found no further improvements in several important clinical outcome parameters, including time to first ventilation breath, SpO_2 and HR at five minutes, body temperature during/immediately after postnatal stabilization and resuscitation, Apgar scores, length of hospitalization, and mortality.

While this study has failed to prove a relevant effect on clinical outcome parameters, the observed improvement in non-technical skills should not be underestimated, as these may significantly impact the quality and effectiveness of patient care. Therefore, we are glad that we have used this study to successfully introduce and establish regular interdisciplinary and interprofessional in situ simulation training as part of our local educational practices. Ultimately, establishing such simulation-based training curricula will aid the development of healthcare into a high-reliability organization. (252)

Bibliography

1. Morton SU, Brodsky D. Fetal Physiology and the Transition to Extrauterine Life. *Clin Perinatol*. 2016;43(3): 395-407. doi: 10.1016/j.clp.2016.04.001.
2. Schittny JC. Development of the lung. *Cell Tissue Res*. 2017;367(3): 427-444. doi: 10.1007/s00441-016-2545-0.
3. Burri PH. Fetal and postnatal development of the lung. *Annu Rev Physiol*. 1984;46: 617-628. doi: 10.1146/annurev.ph.46.030184.003153.
4. Berger TM. Guidelines for the management of extremely preterm deliveries in the grey zone of viability between 23 and 24 weeks' gestation vary widely in developed countries. *Evid Based Med*. 2015;20(6): 227. doi: 10.1136/ebmed-2015-110288.
5. Kornhauser Cerar L, Lucovnik M. Ethical Dilemmas in Neonatal Care at the Limit of Viability. *Children (Basel)*. 2023;10(5): 784. doi: 10.3390/children10050784.
6. Guillén Ú, Weiss EM, Munson D, Maton P, Jefferies A, Norman M, et al. Guidelines for the Management of Extremely Premature Deliveries: A Systematic Review. *Pediatrics*. 2015;136(2): 343-350. doi: 10.1542/peds.2015-0542.
7. Moessinger AC, Harding R, Adamson TM, Singh M, Kiu GT. Role of lung fluid volume in growth and maturation of the fetal sheep lung. *J Clin Invest*. 1990;86(4): 1270-1277. doi: 10.1172/JCI114834.
8. Swanson JR, Sinkin RA. Transition from fetus to newborn. *Pediatr Clin North Am*. 2015;62(2): 329-343. doi: 10.1016/j.pcl.2014.11.002.
9. Hooper SB, Harding R. Fetal lung liquid: a major determinant of the growth and functional development of the fetal lung. *Clin Exp Pharmacol Physiol*. 1995;22(4): 235-247. doi: 10.1111/j.1440-1681.1995.tb01988.x.
10. McCray PB Jr, Bettencourt JD, Bastacky J. Developing bronchopulmonary epithelium of the human fetus secretes fluid. *Am J Physiol*. 1992;262(3 Pt 1): L270-L279. doi: 10.1152/ajplung.1992.262.3.L270.
11. Burri PH. Structural aspects of postnatal lung development - alveolar formation and growth. *Biol Neonate*. 2006;89(4): 313-322. doi: 10.1159/000092868.
12. Narayanan M, Owers-Bradley J, Beardsmore CS, Mada M, Ball I, Garipov R, et al. Alveolarization continues during childhood and adolescence: new evidence from helium-3

magnetic resonance. *Am J Respir Crit Care Med*. 2012;185(2): 186-191. doi: 10.1164/rccm.201107-1348OC.

13. Narayanan M, Beardsmore CS, Owers-Bradley J, Dogaru CM, Mada M, Ball I, et al. Catch-up alveolarization in ex-preterm children: evidence from (3)He magnetic resonance. *Am J Respir Crit Care Med*. 2013;187(10): 1104-1109. doi: 10.1164/rccm.201210-1850OC.
14. Harding R. Fetal pulmonary development: the role of respiratory movements. *Equine Vet J*. 1997;(24): 32-39. doi: 10.1111/j.2042-3306.1997.tb05076.x.
15. Inanlou MR, Baguma-Nibasheka M, Kablar B. The role of fetal breathing-like movements in lung organogenesis. *Histol Histopathol*. 2005;20(4): 1261-1266. doi: 10.14670/HH-20.1261.
16. Natale R, Nasello-Paterson C, Connors G. Patterns of fetal breathing activity in the human fetus at 24 to 28 weeks of gestation. *Am J Obstet Gynecol*. 1988;158(2): 317-321. doi: 10.1016/0002-9378(88)90146-9.
17. Salihagic Kadic A, Predojevic M, Kurjak A. Advances in Fetal Neurophysiology. *Donald School Journal of Ultrasound in Obstetrics and Gynecology*. 2008;2(3): 19-34.
18. Koos BJ, Rajaee A. Fetal breathing movements and changes at birth. *Adv Exp Med Biol*. 2014;814: 89-101. doi: 10.1007/978-1-4939-1031-1_8.
19. van Vonderen JJ, Roest AA, Siew ML, Walther FJ, Hooper SB, te Pas AB. Measuring physiological changes during the transition to life after birth. *Neonatology*. 2014;105(3): 230-242. doi: 10.1159/000356704.
20. Graves BW, Haley MM. Newborn transition. *J Midwifery Womens Health*. 2013;58(6): 662-670. doi: 10.1111/jmwh.12097.
21. Barker PM, Olver RE. Invited review: Clearance of lung liquid during the perinatal period. *J Appl Physiol (1985)*. 2002;93(4): 1542-1548. doi: 10.1152/japplphysiol.00092.2002.
22. Siew ML, Wallace MJ, Kitchen MJ, Lewis RA, Fouras A, Te Pas AB, et al. Inspiration regulates the rate and temporal pattern of lung liquid clearance and lung aeration at birth. *J Appl Physiol (1985)*. 2009;106(6): 1888-1895. doi: 10.1152/japplphysiol.91526.2008.
23. Milner AD, Sauders RA. Pressure and volume changes during the first breath of human neonates. *Arch Dis Child*. 1977;52(12): 918-924. doi: 10.1136/adc.52.12.918.

24. te Pas AB, Wong C, Kamlin CO, Dawson JA, Morley CJ, Davis PG. Breathing patterns in preterm and term infants immediately after birth. *Pediatr Res*. 2009;65(3): 352-356. doi: 10.1203/PDR.0b013e318193f117.

25. Blank DA, Gaertner VD, Kamlin COF, et al. Respiratory changes in term infants immediately after birth. *Resuscitation*. 2018;130: 105-110. doi: 10.1016/j.resuscitation.2018.07.008.

26. Mouradian Jr GC, Lakshminrusimha S, Konduri GG. Perinatal Hypoxemia and Oxygen Sensing. *Compr Physiol*. 2021;11(2): 1653-1677. doi: 10.1002/cphy.c190046.

27. Longo LD. Sir Joseph Barcroft: one victorian physiologist's contributions to a half century of discovery. *J Physiol*. 2016;594(5): 1113-1125. doi: 10.1113/JP270078.

28. Goffinet F, Langer B, Carbonne B, Berkane N, Tardif D, Le Goueff F, et al. Multicenter study on the clinical value of fetal pulse oximetry. I. Methodologic evaluation. The French Study Group on Fetal Pulse Oximetry. *Am J Obstet Gynecol*. 1997;177(5): 1238-1246. doi: 10.1016/s0002-9378(97)70045-0.

29. Dawson JA, Kamlin CO, Vento M, Wong C, Cole TJ, Donath SM, et al. Defining the reference range for oxygen saturation for infants after birth. *Pediatrics*. 2010;125(6): e1340-e1347. doi: 10.1542/peds.2009-1510.

30. Rabi Y, Yee W, Chen SY, Singhal N. Oxygen saturation trends immediately after birth. *J Pediatr*. 2006;148(5): 590-594. doi: 10.1016/j.jpeds.2005.12.047.

31. Nuntnarumit P, Rojnueangnit K, Tangnoo A. Oxygen saturation trends in preterm infants during the first 15 min after birth. *J Perinatol*. 2010;30(6): 399-402. doi: 10.1038/jp.2009.178.

32. Snarr BS, McQuinn TC, Wessels A. Chapter 50: Cardiovascular Development. In: Polin RA, Abman SH, Rowitch DH, Benitz WE, Fox WW, editors. Fetal and neonatal physiology. 5th edition. Philadelphia, United States of America: Elsevier; 2017. p. 515-522.

33. Finnemore A, Groves A. Physiology of the fetal and transitional circulation. *Semin Fetal Neonatal Med*. 2015;20(4): 210-216. doi: 10.1016/j.siny.2015.04.003.

34. Di Tommaso M, Seravalli V, Martini I, La Torre P, Dani C. Blood gas values in clamped and unclamped umbilical cord at birth. *Early Hum Dev*. 2014;90(9): 523-525. doi: 10.1016/j.earlhumdev.2014.03.010.

35. Prsa M, Sun L, van Amerom J, Yoo SJ, Grosse-Wortmann L, Jaeggi E, et al. Reference ranges of blood flow in the major vessels of the normal human fetal circulation at term by

phase-contrast magnetic resonance imaging. *Circ Cardiovasc Imaging*. 2014;7(4): 663-670. doi: 10.1161/CIRCIMAGING.113.001859.

36. van Vonderen JJ, te Pas AB, Kolster-Bijdevaate C, van Lith JM, Blom NA, Hooper SB, et al. Non-invasive measurements of ductus arteriosus flow directly after birth. *Arch Dis Child Fetal Neonatal Ed*. 2014;99(5): F408-F412. doi: 10.1136/archdischild-2014-306033.
37. Singh Y, Tissot C. Echocardiographic Evaluation of Transitional Circulation for the Neonatologists. *Front Pediatr*. 2018;6: 140. doi: 10.3389/fped.2018.00140.
38. Bhatt S, Alison BJ, Wallace EM, Crossley KJ, Gill AW, Kluckow M, et al. Delaying cord clamping until ventilation onset improves cardiovascular function at birth in preterm lambs. *J Physiol*. 2013;591(8): 2113-2126. doi: 10.1113/jphysiol.2012.250084.
39. Ersdal HL, Linde J, Mduma E, Auestad B, Perlman J. Neonatal outcome following cord clamping after onset of spontaneous respiration. *Pediatrics*. 2014;134(2): 265-272. doi: 10.1542/peds.2014-0467.
40. Hooper SB, Te Pas AB, Lang J, van Vonderen JJ, Roehr CC, Kluckow M, et al. Cardiovascular transition at birth: a physiological sequence. *Pediatr Res*. 2015;77(5): 608-614. doi: 10.1038/pr.2015.21.
41. Asakura H. Fetal and neonatal thermoregulation. *J Nippon Med Sch*. 2004;71(6): 360-370. doi: 10.1272/jnms.71.360.
42. Laptook AR, Watkinson M. Temperature management in the delivery room. *Semin Fetal Neonatal Med*. 2008;13(6): 383-391. doi: 10.1016/j.siny.2008.04.003.
43. Gilbert RD, Schröder H, Kawamura T, Dale PS, Power GG. Heat transfer pathways between fetal lamb and ewe. *J Appl Physiol (1985)*. 1985;59(2): 634-638. doi: 10.1152/jappl.1985.59.2.634.
44. Laburn HP, Mitchell D, Goelst K. Fetal and maternal body temperatures measured by radiotelemetry in near-term sheep during thermal stress. *J Appl Physiol (1985)*. 1992;72(3): 894-900. doi: 10.1152/jappl.1992.72.3.894.
45. Bienboire-Frosini C, Wang D, Marcet-Rius M, Villanueva-García D, Gazzano A, Domínguez-Oliva A, et al. The Role of Brown Adipose Tissue and Energy Metabolism in Mammalian Thermoregulation during the Perinatal Period. *Animals (Basel)*. 2023;13(13): 2173. doi: 10.3390/ani13132173.
46. Carter BW, Schucany WG. Brown adipose tissue in a newborn. *Proc (Bayl Univ Med Cent)*. 2008;21(3): 328-330. doi: 10.1080/08998280.2008.11928419.

47. Lidell ME. Brown Adipose Tissue in Human Infants. *Handb Exp Pharmacol*. 2019;251: 107-123. doi: 10.1007/164_2018_118.

48. World Health Organization, Maternal and Newborn Health/Safe Motherhood Unit. Thermal Protection Of The Newborn: A Practical Guide. Geneva, Switzerland: World Health Organization; 1997.

49. Dahm LS, James LS. Newborn temperature and calculated heat loss in the delivery room. *Pediatrics*. 1972;49(4): 504-513.

50. Laptook AR, Salhab W, Bhaskar B, Neonatal Research Network. Admission temperature of low birth weight infants: predictors and associated morbidities. *Pediatrics*. 2007;119(3): e643-e649. doi: 10.1542/peds.2006-0943.

51. Mohamed SOO, Ahmed SMI, Khidir RJY, Shaheen MTHA, Adam MHM, Ibrahim BAY, et al. Outcomes of neonatal hypothermia among very low birth weight infants: a Meta-analysis. *Matern Health Neonatol Perinatol*. 2021;7(1): 14. doi: 10.1186/s40748-021-00134-6.

52. Lunze K, Bloom DE, Jamison DT, Hamer DH. The global burden of neonatal hypothermia: systematic review of a major challenge for newborn survival. *BMC Med*. 2013;11: 24. doi: 10.1186/1741-7015-11-24.

53. Wilson E, Maier RF, Norman M, Misselwitz B, Howell EA, Zeitlin J, et al. Admission Hypothermia in Very Preterm Infants and Neonatal Mortality and Morbidity. *J Pediatr*. 2016;175: 61-67.e4. doi: 10.1016/j.jpeds.2016.04.016.

54. McCall EM, Alderdice F, Halliday HL, Vohra S, Johnston L. Interventions to prevent hypothermia at birth in preterm and/or low birth weight infants. *Cochrane Database Syst Rev*. 2018;2(2): CD004210. doi: 10.1002/14651858.CD004210.pub5.

55. Newton T, Watkinson M. Preventing hypothermia at birth in preterm babies: at a cost of overheating some? *Arch Dis Child Fetal Neonatal Ed*. 2003;88(3): F256. doi: 10.1136/fn.88.3.f256-a.

56. Lyu Y, Shah PS, Ye XY, Warre R, Piedboeuf B, Deshpandey A, et al. Association between admission temperature and mortality and major morbidity in preterm infants born at fewer than 33 weeks' gestation. *JAMA Pediatr*. 2015;169(4): e150277. doi: 10.1001/jamapediatrics.2015.0277.

57. Niles DE, Cines C, Insley E, Foglia EE, Elci OU, Skåre C, et al. Incidence and characteristics of positive pressure ventilation delivered to newborns in a US tertiary

academic hospital. *Resuscitation*. 2017;115: 102-109. doi: 10.1016/j.resuscitation.2017.03.035.

58. Bjorland PA, Øymar K, Ersdal HL, Rettedal SI. Incidence of newborn resuscitative interventions at birth and short-term outcomes: a regional population-based study. *BMJ Paediatr Open*. 2019;3(1): e000592. doi: 10.1136/bmjpo-2019-000592.
59. Berazategui JP, Aguilar A, Escobedo M, Dannaway D, Guinsburg R, de Almeida MF, et al. Risk factors for advanced resuscitation in term and near-term infants: a case-control study. *Arch Dis Child Fetal Neonatal Ed*. 2017;102(1): F44-F50. doi: 10.1136/archdischild-2015-309525.
60. Hug L, Alexander M, You D, Alkema L, UN Inter-agency Group for Child Mortality Estimation. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. *Lancet Glob Health*. 2019;7(6): e710-e720. doi: 10.1016/S2214-109X(19)30163-9.
61. Guinsburg R, Sanudo A, Kiffer CRV, Marinonio ASS, Costa-Nobre DT, Areco KN, et al. Annual trend of neonatal mortality and its underlying causes: population-based study - São Paulo State, Brazil, 2004-2013. *BMC Pediatr*. 2021;21(1): 54. doi: 10.1186/s12887-021-02511-8.
62. Ersdal HL, Mduma E, Svensen E, Perlman J. Birth asphyxia: a major cause of early neonatal mortality in a Tanzanian rural hospital. *Pediatrics*. 2012;129(5): e1238-e1243. doi: 10.1542/peds.2011-3134.
63. Apgar V. A proposal for a new method of evaluation of the newborn infant. *Curr Res Anesth Analg*. 1953;32(4): 260-267.
64. Apgar V. The newborn (Apgar) scoring system. Reflections and advice. *Pediatr Clin North Am*. 1966;13(3): 645-650. doi: 10.1016/s0031-3955(16)31874-0.
65. Apgar V, Holaday DA, James LS, Weisbrot IM, Berrien C. Evaluation of the newborn infant; second report. *J Am Med Assoc*. 1958;168(15): 1985-1988. doi: 10.1001/jama.1958.03000150027007.
66. Crawford JS, Davies P, Pearson JF. Significance of the individual components of the Apgar score. *Br J Anaesth*. 1973;45(2): 148-158. doi: 10.1093/bja/45.2.148.
67. Papile LA. The Apgar score in the 21st century. *N Engl J Med*. 2001;344(7): 519-520. doi: 10.1056/NEJM200102153440709.

68. Li F, Wu T, Lei X, Zhang H, Mao M, Zhang J. The apgar score and infant mortality. *PLoS One*. 2013;8(7): e69072. doi: 10.1371/journal.pone.0069072.

69. American Academy of Pediatrics Committee on Fetus and Newborn; American College of Obstetricians and Gynecologists Committee on Obstetric Practice. The Apgar Score. *Pediatrics*. 2015;136(4): 819-822. doi: 10.1542/peds.2015-2651.

70. Hegyi T, Carbone T, Anwar M, Ostfeld B, Hiatt M, Koons A, et al. The apgar score and its components in the preterm infant. *Pediatrics*. 1998;101(1 Pt 1): 77-81. doi: 10.1542/peds.101.1.77.

71. Rüdiger M, Küster H, Herting E, Berger A, Müller C, Urlesberger B, et al. Variations of Apgar score of very low birth weight infants in different neonatal intensive care units. *Acta Paediatr*. 2009;98(9): 1433-1436. doi: 10.1111/j.1651-2227.2009.01347.x.

72. O'Donnell CP, Kamlin CO, Davis PG, Carlin JB, Morley CJ. Interobserver variability of the 5-minute Apgar score. *J Pediatr*. 2006;149(4): 486-489. doi: 10.1016/j.jpeds.2006.05.040.

73. Rüdiger M, Braun N, Aranda J, Aguar M, Bergert R, Bystricka A, et al. Neonatal assessment in the delivery room--Trial to Evaluate a Specified Type of Apgar (TEST-Apgar). *BMC Pediatr*. 2015;15: 18. doi: 10.1186/s12887-015-0334-7.

74. Aziz K, Lee HC, Escobedo MB, Hoover AV, Kamath-Rayne BD, Kapadia VS, et al. Part 5: Neonatal Resuscitation: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2020;142(16_suppl_2): S524-S550. doi: 10.1161/CIR.0000000000000902.

75. Madar J, Roehr CC, Ainsworth S, Ersdal H, Morley C, Rüdiger M, et al. European Resuscitation Council Guidelines 2021: Newborn resuscitation and support of transition of infants at birth. *Resuscitation*. 2021;161: 291-326. doi: 10.1016/j.resuscitation.2021.02.014.

76. Linde JE, Perlman JM, Øymar K, Schulz J, Eilevstjønn J, Thallinger M, et al. Predictors of 24-h outcome in newborns in need of positive pressure ventilation at birth. *Resuscitation*. 2018;129: 1-5. doi: 10.1016/j.resuscitation.2018.05.026.

77. Kapadia V, Oei JL, Finer N, Rich W, Rabi Y, Wright IM, et al. Outcomes of delivery room resuscitation of bradycardic preterm infants: A retrospective cohort study of randomised trials of high vs low initial oxygen concentration and an individual patient data analysis. *Resuscitation*. 2021;167: 209-217. doi: 10.1016/j.resuscitation.2021.08.023.

78. Saugstad OD, International Liason Committee on Resuscitation. New guidelines for newborn resuscitation--a critical evaluation. *Acta Paediatr*. 2011;100(8): 1058-1062. doi: 10.1111/j.1651-2227.2011.02301.x.

79. Dawson JA, Kamlin COF, Wong C, te Pas AB, Vento M, Cole TJ, et al. Changes in heart rate in the first minutes after birth. *Arch Dis Child Fetal Neonatal Ed*. 2010;95(3): F177-F181. doi: 10.1136/adc.2009.169102.

80. Bjorland PA, Ersdal HL, Eilevstjønn J, Øymar K, Davis PG, Rettedal SI. Changes in heart rate from 5 s to 5 min after birth in vaginally delivered term newborns with delayed cord clamping. *Arch Dis Child Fetal Neonatal Ed*. 2021;106(3): 311-315. doi: 10.1136/archdischild-2020-320179.

81. Owen CJ, Wyllie JP. Determination of heart rate in the baby at birth. *Resuscitation*. 2004;60(2): 213-217. doi: 10.1016/j.resuscitation.2003.10.002.

82. Kamlin COF, O'Donnell CPF, Everest NJ, Davis PG, Morley CJ. Accuracy of clinical assessment of infant heart rate in the delivery room. *Resuscitation*. 2006;71(3): 319-321. doi: 10.1016/j.resuscitation.2006.04.015.

83. Murphy MC, De Angelis L, McCarthy LK, O'Donnell CPF. Comparison of infant heart rate assessment by auscultation, ECG and oximetry in the delivery room. *Arch Dis Child Fetal Neonatal Ed*. 2018;103(5): F490-F492. doi: 10.1136/archdischild-2017-314367.

84. Kamlin COF, Dawson JA, O'Donnell CPF, Morley CJ, Donath SM, Sekhon J, et al. Accuracy of pulse oximetry measurement of heart rate of newborn infants in the delivery room. *J Pediatr*. 2008;152(6): 756-760. doi: 10.1016/j.jpeds.2008.01.002.

85. Narayen IC, Smit M, van Zwet EW, Dawson JA, Blom NA, te Pas AB. Low signal quality pulse oximetry measurements in newborn infants are reliable for oxygen saturation but underestimate heart rate. *Acta Paediatr*. 2015;104(4): e158-e163. doi: 10.1111/apa.12932.

86. Johnson PA, Cheung PY, Lee TF, O'Reilly M, Schmölzer GM. Novel technologies for heart rate assessment during neonatal resuscitation at birth - A systematic review. *Resuscitation*. 2019;143: 196-207. doi: 10.1016/j.resuscitation.2019.07.018.

87. Luong D, Cheung PY, Barrington KJ, Davis PG, Unrau J, Dakshinamurti S, et al. Cardiac arrest with pulseless electrical activity rhythm in newborn infants: a case series. *Arch Dis Child Fetal Neonatal Ed*. 2019;104(6): F572-F574. doi: 10.1136/archdischild-2018-316087.

88. Patel S, Cheung PY, Solevåg AL, Barrington KJ, Kamlin COF, Davis PG, et al. Pulseless electrical activity: a misdiagnosed entity during asphyxia in newborn infants? *Arch Dis Child Fetal Neonatal Ed*. 2019;104(2): F215-F217. doi: 10.1136/archdischild-2018-314907.

89. Chua C, Schmölzer GM, Davis PG. Airway manoeuvres to achieve upper airway patency during mask ventilation in newborn infants - An historical perspective. *Resuscitation*. 2012;83(4): 411-416. doi: 10.1016/j.resuscitation.2011.11.007.

90. Haase B, Badinska AM, Poets CF, Koos B, Springer L. An approach to define newborns´ sniffing position using an angle based on reproducible facial landmarks. *Paediatr Anaesth*. 2021;31(4): 404-409. doi: 10.1111/pan.14154.

91. von Ungern-Sternberg BS, Erb TO, Frei FJ. [Management of the upper airway in spontaneously breathing children. A challenge for the anaesthetist]. *Anaesthesist*. 2006;55(2): 164-170. doi: 10.1007/s00101-005-0946-7.

92. Disma N, Virag K, Riva T, Kaufmann J, Engelhardt T, Habre W, et al. Difficult tracheal intubation in neonates and infants. NEonate and Children audiT of Anaesthesia pRactice IN Europe (NECTARINE): a prospective European multicentre observational study. *Br J Anaesth*. 2021;126(6): 1173-1181. doi: 10.1016/j.bja.2021.02.021.

93. Sawyer T, Yamada N, Umoren R. The difficult neonatal airway. *Semin Fetal Neonatal Med*. 2023;28(5): 101484. doi: 10.1016/j.siny.2023.101484.

94. Berisha G, Boldingh AM, Blakstad EW, Rønnestad AE, Solevåg AL. Management of the Unexpected Difficult Airway in Neonatal Resuscitation. *Front Pediatr*. 2021;9: 699159. doi: 10.3389/fped.2021.699159.

95. Foglia EE, Te Pas AB. Effective ventilation: The most critical intervention for successful delivery room resuscitation. *Semin Fetal Neonatal Med*. 2018;23(5): 340-346. doi: 10.1016/j.siny.2018.04.001.

96. Te Pas AB, Kitchen MJ, Lee K, Wallace MJ, Fouras A, Lewis RA, et al. Optimizing lung aeration at birth using a sustained inflation and positive pressure ventilation in preterm rabbits. *Pediatr Res*. 2016;80(1): 85-91. doi: 10.1038/pr.2016.59.

97. Ersdal HL, Mduma E, Svensen E, Perlman JM. Early initiation of basic resuscitation interventions including face mask ventilation may reduce birth asphyxia related mortality in low-income countries: a prospective descriptive observational study. *Resuscitation*. 2012;83(7): 869-873. doi: 10.1016/j.resuscitation.2011.12.011.

98. Eilevstjønn J, Linde JE, Blacy L, Kidanto H, Ersdal HL. Distribution of heart rate and responses to resuscitation among 1237 apnoeic newborns at birth. *Resuscitation*. 2020;152: 69-76. doi: 10.1016/j.resuscitation.2020.04.037.

99. Poulton DA, Schmölzer GM, Morley CJ, Davis PG. Assessment of chest rise during mask ventilation of preterm infants in the delivery room. *Resuscitation*. 2011;82(2): 175-179. doi: 10.1016/j.resuscitation.2010.10.012.

100. Schmölzer GM, Kamlin OC, O'Donnell CP, Dawson JA, Morley CJ, Davis PG. Assessment of tidal volume and gas leak during mask ventilation of preterm infants in the delivery room. *Arch Dis Child Fetal Neonatal Ed*. 2010;95(6): F393-F397. doi: 10.1136/adc.2009.174003.

101. Kang LJ, Cheung PY, Pichler G, O'Reilly M, Aziz K, Schmölzer GM. Monitoring lung aeration during respiratory support in preterm infants at birth. *PLoS One*. 2014;9(7): e102729. doi: 10.1371/journal.pone.0102729.

102. Kong JY, Rich W, Finer NN, Leone TA. Quantitative end-tidal carbon dioxide monitoring in the delivery room: a randomized controlled trial. *J Pediatr*. 2013;163(1): 104-108.e1. doi: 10.1016/j.jpeds.2012.12.016.

103. Schmölzer GM, Roehr CC. Use of respiratory function monitors during simulated neonatal resuscitation. *Klin Padiatr*. 2011;223(5): 261-266. doi: 10.1055/s-0031-1275696.

104. Schmölzer GM, Morley CJ, Wong C, Dawson JA, Kamlin COF, Donath SM, et al. Respiratory function monitor guidance of mask ventilation in the delivery room: a feasibility study. *J Pediatr*. 2012;160(3): 377-381.e2. doi: 10.1016/j.jpeds.2011.09.017.

105. van Zanten HA, Kuypers KLAM, van Zwet EW, van Vonderen JJ, Kamlin COF, Springer L, et al. A multi-centre randomised controlled trial of respiratory function monitoring during stabilisation of very preterm infants at birth. *Resuscitation*. 2021:167: 317-325. doi: 10.1016/j.resuscitation.2021.07.012.

106. Foglia EE, Weinberg DD, Te Pas AB, Dekker J, Hsu JY. Reliability of respiratory function monitor interpretation for neonatal resuscitation. *Arch Dis Child Fetal Neonatal Ed*. 2023;108(3): 321-322. doi: 10.1136/archdischild-2022-324369.

107. Foglia EE, Shah BA, Szyld E. Positive pressure ventilation at birth. *Semin Perinatol*. 2022;46(6): 151623. doi: 10.1016/j.semperi.2022.151623.

108. Szyld E, Aguilar A, Musante GA, Vain N, Prudent L, Fabres J, et al. Comparison of devices for newborn ventilation in the delivery room. *J Pediatr*. 2014;165(2): 234-239.e3. doi: 10.1016/j.jpeds.2014.02.035.

109. Siew ML, Te Pas AB, Wallace MJ, Kitchen MJ, Lewis RA, Fouras A, et al. Positive end-expiratory pressure enhances development of a functional residual capacity in preterm rabbits ventilated from birth. *J Appl Physiol (1985)*. 2009;106(5): 1487-1493. doi: 10.1152/japplphysiol.91591.2008.

110. Dawson JA, Gerber A, Kamlin COF, Davis PG, Morley CJ. Providing PEEP during neonatal resuscitation: which device is best? *J Paediatr Child Health*. 2011;47(10): 698-703. doi: 10.1111/j.1440-1754.2011.02036.x.

111. Trevisanuto D, Roehr CC, Davis PG, Schmölzer GM, Wyckoff MH, Liley HG, et al. Devices for Administering Ventilation at Birth: A Systematic Review. *Pediatrics*. 2021;148(1): e2021050174. doi: 10.1542/peds.2021-050174.

112. Deindl P, O'Reilly M, Zoller K, Berger A, Pollak A, Schwindt J, et al. Influence of mask type and mask position on the effectiveness of bag-mask ventilation in a neonatal manikin. *Eur J Pediatr*. 2014;173(1): 75-79. doi: 10.1007/s00431-013-2122-4.

113. Wilson EV, O'Shea JE, Thio M, Dawson JA, Boland R, Davis PG. A comparison of different mask holds for positive pressure ventilation in a neonatal manikin. *Arch Dis Child Fetal Neonatal Ed*. 2014;99(2): F169-F171. doi: 10.1136/archdischild-2013-304582.

114. Trevisanuto D, Cavallin F, Nguyen LN, Nguyen TV, Tran LD, Tran CD, et al. Supreme Laryngeal Mask Airway versus Face Mask during Neonatal Resuscitation: A Randomized Controlled Trial. *J Pediatr*. 2015;167(2): 286-291.e1. doi: 10.1016/j.jpeds.2015.04.051.

115. Pejovic NJ, Myrnerts Höök S, Byamugisha J, Alfvén T, Lubulwa C, Cavallin F, et al. A Randomized Trial of Laryngeal Mask Airway in Neonatal Resuscitation. *N Engl J Med*. 2020;383(22): 2138-2147. doi: 10.1056/NEJMoa2005333.

116. Wyckoff MH, Greif R, Morley PT, Ng KC, Olasveengen TM, Singletary EM, et al. 2022 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. *Circulation*. 2022;146(25): e483-e557. doi: 10.1161/CIR.0000000000001095.

117. Schmölzer GM, Dawson JA, Kamlin COF, O'Donnell CPF, Morley CJ, Davis PG. Airway obstruction and gas leak during mask ventilation of preterm infants in the delivery room. *Arch Dis Child Fetal Neonatal Ed*. 2011;96(4): F254-F257. doi: 10.1136/adc.2010.191171.

118. Kaufman J, Schmölzer GM, Kamlin COF, Davis PG. Mask ventilation of preterm infants in the delivery room. *Arch Dis Child Fetal Neonatal Ed*. 2013;98(5): F405-F410. doi: 10.1136/archdischild-2012-303313.

119. Mileder LP, Schwaberger B, Urlesberger B. "MR SOPA" - A German Adaption of the Acronym to Optimize Non-Invasive Ventilation in Preterm and Term Neonates. *Klin Padiatr*. 2022;234(4): 248-249. doi: 10.1055/a-1583-9916.

120. Mileder LP, Derler T, Baik-Schneditz N, Schwaberger B, Urlesberger B, Pichler G. Optimizing noninvasive respiratory support during postnatal stabilization: video-based analysis of airway maneuvers and their effects. *J Matern Fetal Neonatal Med*. 2022;35(20): 3991-3997. doi: 10.1080/14767058.2020.1846176.

121. Welsford M, Nishiyama C, Shortt C, Isayama T, Dawson JA, Weiner G, et al. Room Air for Initiating Term Newborn Resuscitation: A Systematic Review With Meta-analysis. *Pediatrics*. 2019;143(1): e20181825. doi: 10.1542/peds.2018-1825.

122. Oei JL, Kapadia V. Oxygen for respiratory support of moderate and late preterm and term infants at birth: Is air best? *Semin Fetal Neonatal Med*. 2020;25(2): 101074. doi: 10.1016/j.siny.2019.101074.

123. Rawat M, Chandrasekharan PK, Swartz DD, Mathew B, Nair J, Gugino SF, et al. Neonatal resuscitation adhering to oxygen saturation guidelines in asphyxiated lambs with meconium aspiration. *Pediatr Res*. 2016;79(4): 583-588. doi: 10.1038/pr.2015.259.

124. Schmölzer GM, Pichler G, Solevåg AL, Law BHY, Mitra S, Wagner M, et al. Sustained inflation and chest compression versus 3:1 chest compression to ventilation ratio during cardiopulmonary resuscitation of asphyxiated newborns (SURV1VE): A cluster randomised controlled trial. *Arch Dis Child Fetal Neonatal Ed*. 2024 Jan 11: fetalneonatal-2023-326383. doi: 10.1136/archdischild-2023-326383. Online ahead of print.

125. Jiang J, Zou Y, Shi W, Zhu Y, Tao R, Jiang Y, et al. Two-thumb-encircling hands technique is more advisable than 2-finger technique when lone rescuer performs cardiopulmonary resuscitation on infant manikin. *Am J Emerg Med*. 2015;33(4): 531-534. doi: 10.1016/j.ajem.2015.01.025.

126. Bruckner M, Neset M, O'Reilly M, Lee TF, Cheung PY, Schmölzer GM. Four Different Finger Positions and Their Effects on Hemodynamic Changes during Chest Compression in Asphyxiated Neonatal Piglets. *Children (Basel)*. 2023;10(2): 283. doi: 10.3390/children10020283.

127. Wyllie J, Bruinenberg J, Roehr CC, Rüdiger M, Trevisanuto D, Urlesberger B. European Resuscitation Council Guidelines for Resuscitation 2015: Section 7. Resuscitation and support of transition of babies at birth. *Resuscitation*. 2015:95: 249-263. doi: 10.1016/j.resuscitation.2015.07.029.

128. Meyer A, Nadkarni V, Pollock A, Babbs C, Nishisaki A, Braga M, et al. Evaluation of the Neonatal Resuscitation Program's recommended chest compression depth using computerized tomography imaging. *Resuscitation*. 2010;81(5): 544-548. doi: 10.1016/j.resuscitation.2010.01.032.

129. McPherson C. Know the Code: Medications for Resuscitation in Neonates. *Neonatal Netw*. 2022;41(2): 107-113. doi: 10.1891/NN-2021-0009.

130. Ramsie M, Cheung PY, O'Reilly M, Roberts CT, Polglase GR, Schmölzer GM. Cardiac Agents during Neonatal Cardiopulmonary Resuscitation. *Neonatology*. 2024 Jan 16: 1-10. doi: 10.1159/000535502. Online ahead of print.

131. Wagner M, Olischar M, O'Reilly M, Goeral K, Berger A, Cheung PY, et al. Review of Routes to Administer Medication During Prolonged Neonatal Resuscitation. *Pediatr Crit Care Med*. 2018;19(4): 332-338. doi: 10.1097/PCC.0000000000001493.

132. Vali P, Chandrasekharan P, Rawat M, Gugino S, Koenigsknecht C, Helman J, et al. Evaluation of Timing and Route of Epinephrine in a Neonatal Model of Asphyxial Arrest. *J Am Heart Assoc*. 2017;6(2): e004402. doi: 10.1161/JAHA.116.004402.

133. Sankaran D, Chandrasekharan PK, Gugino SF, Koenigsknecht C, Helman J, Nair J, et al. Randomised trial of epinephrine dose and flush volume in term newborn lambs. *Arch Dis Child Fetal Neonatal Ed*. 2021;106(6): 578-583. doi: 10.1136/archdischild-2020-321034.

134. Benitz WE, Frankel LR, Stevenson DK. The pharmacology of neonatal resuscitation and cardiopulmonary intensive care. Part I--Immediate resuscitation. *West J Med*. 1986;144(6): 704-709.

135. Beveridge CJE, Wilkinson AR. Sodium bicarbonate infusion during resuscitation of infants at birth. *Cochrane Database Syst Rev*. 2006;2006(1): CD004864. doi: 10.1002/14651858.CD004864.pub2.

136. Schwaberger B, Schlatzer C, Freidorfer D, Bruckner M, Wolfsberger CH, Mileder LP, et al. The Use of a Disposable Umbilical Clamp to Secure an Umbilical Venous Catheter in Neonatal Emergencies-An Experimental Feasibility Study. *Children (Basel)*. 2021;8(12): 1093. doi: 10.3390/children8121093.

137. Brickmann C, Zang FC, Klotz D, Kunze M, Lenz S, Hentschel R. Emergency button cannula vs. umbilical catheter as neonatal emergency umbilical vein access - a randomized cross-over pilot study. *J Perinat Med*. 2022;51(1): 27-33. doi: 10.1515/jpm-2022-0071.

138. Suominen PK, Nurmi E, Lauerma K. Intraosseous access in neonates and infants: risk of severe complications - a case report. *Acta Anaesthesiol Scand*. 2015;59(10): 1389-1393. doi: 10.1111/aas.12602.

139. Schwindt E, Pfeiffer D, Gomes D, Brenner S, Schwindt JC, Hoffmann F, et al. Intraosseous access in neonates is feasible and safe - An analysis of a prospective nationwide surveillance study in Germany. *Front Pediatr*. 2022;10: 952632. doi: 10.3389/fped.2022.952632.

140. Scrivens A, Reynolds PR, Emery FE, Roberts CT, Polglase GR, Hooper SB, et al. Use of Intraosseous Needles in Neonates: A Systematic Review. *Neonatology*. 2019;116(4): 305-314. doi: 10.1159/000502212.

141. Mileder LP, Urlesberger B, Schwaberger B. Use of Intraosseous Vascular Access During Neonatal Resuscitation at a Tertiary Center. *Front Pediatr*. 2020;8: 571285. doi: 10.3389/fped.2020.571285.

142. Issenberg SB, Gordon MS, Gordon DL, Safford RE, Hart IR. Simulation and new learning technologies. *Med Teach*. 2001;23(1): 16-23. doi: 10.1080/01421590020007324.

143. Issenberg SB, McGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach*. 2005;27(1): 10-28. doi: 10.1080/01421590500046924.

144. Shapiro MJ, Simmons W. High fidelity medical simulation: a new paradigm in medical education. *Med Health R I*. 2002;85(10): 316-317.

145. Gaba DM. The future vision of simulation in health care. *Qual Saf Health Care*. 2004;13 Suppl 1: i2-i10. doi: 10.1136/qhc.13.suppl_1.i2.

146. Abrahamson S, Denson JS, Wolf RM. Effectiveness of a simulator in training anesthesiology residents. *J Med Educ*. 1969;44(6): 515-519. doi: 10.1097/00001888-196906000-00006.

147. Grenvik A, Schaefer JJ 3rd. Medical simulation training coming of age. *Crit Care Med*. 2004;32(12): 2549-2550. doi: 10.1097/01.ccm.0000148247.25532.50.

148. Gosling CG, Schreiner R, Sternecker C. Conception and construction of a teaching simulator (umbilical vessel catheterization). *J Biocommun*. 1978;5(2): 18-21.

149. Simons RS. ABC of resuscitation. Training manikins. *Br Med J (Clin Res Ed)*. 1986;292(6534): 1509-1513. doi: 10.1136/bmj.292.6534.1509.

150. Halamek LP, Kaegi DM, Gaba DM, Sowb YA, Smith BC, Smith BE, et al. Time for a new paradigm in pediatric medical education: teaching neonatal resuscitation in a simulated delivery room environment. *Pediatrics*. 2000;106(4): E45. doi: 10.1542/peds.106.4.e45.

151. Halamek LP. The simulated delivery-room environment as the future modality for acquiring and maintaining skills in fetal and neonatal resuscitation. *Semin Fetal Neonatal Med*. 2008;13(6): 448-453. doi: 10.1016/j.siny.2008.04.015.

152. Bradley P. The history of simulation in medical education and possible future directions. *Med Educ*. 2006;40(3): 254-262. doi: 10.1111/j.1365-2929.2006.02394.x.

153. Perkins GD. Simulation in resuscitation training. *Resuscitation*. 2007;73(2): 202-211. doi: 10.1016/j.resuscitation.2007.01.005.

154. Institute of Medicine (US) Committee on Quality of Health Care in America; Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington, United States of America: National Academies Press; 2000. [Cited May 23, 2022] Available from: http://www.ncbi.nlm.nih.gov/books/NBK225182

155. Landrigan CP, Parry GJ, Bones CB, Hackbarth AD, Goldmann DA, Sharek PJ. Temporal trends in rates of patient harm resulting from medical care. *N Engl J Med*. 2010;363(22): 2124-2134. doi: 10.1056/NEJMsa1004404.

156. Makary MA, Daniel M. Medical error-the third leading cause of death in the US. *BMJ*. 2016;353: i2139. doi: 10.1136/bmj.i2139.

157. Joint Commission on Accreditation of Healthcare Organizations. Sentinel Event Alert – Issue 30: Preventing infant death and injury during delivery. Oakbrook Terrace, United States of America; 2004. [Cited July 9, 2022] Available from: https://www.jointcommission.org/resources/patient-safety-topics/sentinel-event/sentinel-event-alert-newsletters/sentinel-event-alert-issue-30-preventing-infant-death-and-injury-during-delivery/

158. Naik VN, Brien SE. Review article: simulation: a means to address and improve patient safety. *Can J Anaesth*. 2013;60(2): 192-200. doi: 10.1007/s12630-012-9860-z.

159. Schmidt E, Goldhaber-Fiebert SN, Ho LA, McDonald KM. Simulation exercises as a patient safety strategy: a systematic review. *Ann Intern Med*. 2013;158(5 Pt 2): 426-432. doi: 10.7326/0003-4819-158-5-201303051-00010.

160. Friedlander MJ, Andrews L, Armstrong EG, Aschenbrenner C, Kass JS, Ogden P, et al. What can medical education learn from the neurobiology of learning? *Acad Med*. 2011;86(4): 415-420. doi: 10.1097/ACM.0b013e31820dc197.

161. Knowland VCP, Thomas MSC. Educating the adult brain: How the neuroscience of learning can inform educational policy. *Int Rev Educ*. 2014;60(1): 99-122. doi: https://doi.org/10.1007/s11159-014-9412-6.

162. Zigmont JJ, Kappus LJ, Sudikoff SN. Theoretical foundations of learning through simulation. *Semin Perinatol*. 2011;35(2): 47-51. doi: 10.1053/j.semperi.2011.01.002.

163. Griswold S, Ponnuru S, Nishisaki A, Szyld D, Davenport M, Deutsch ES, et al. The emerging role of simulation education to achieve patient safety: translating deliberate practice and debriefing to save lives. *Pediatr Clin North Am*. 2012;59(6): 1329-1340. doi: 10.1016/j.pcl.2012.09.004.

164. Wagner M, Bibl K, Hrdliczka E, Steinbauer P, Stiller M, Gröpel P, et al. Effects of Feedback on Chest Compression Quality: A Randomized Simulation Study. *Pediatrics*. 2019;143(2): e20182441. doi: 10.1542/peds.2018-2441.

165. Dvorsky R, Rings F, Bibl K, Roessler L, Kumer L, Steinbauer P, et al. Real-Time Intubation and Ventilation Feedback: A Randomized Controlled Simulation Study. *Pediatrics*. 2023;151(5): e2022059839. doi: 10.1542/peds.2022-059839.

166. Garvey AA, Dempsey EM. Simulation in Neonatal Resuscitation. *Front Pediatr*. 2020;8: 59. doi: 10.3389/fped.2020.00059.

167. French HM, Hales RL. Neonatology faculty development using simulation. *Semin Perinatol*. 2016;40(7): 455-465. doi: 10.1053/j.semperi.2016.08.006.

168. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA*. 2011;306(9): 978-988. doi: 10.1001/jama.2011.1234.

169. Ilgen JS, Sherbino J, Cook DA. Technology-enhanced simulation in emergency medicine: a systematic review and meta-analysis. *Acad Emerg Med*. 2013;20(2): 117-127. doi: 10.1111/acem.12076.

170. Cheng A, Lang TR, Starr SR, Pusic M, Cook DA. Technology-enhanced simulation and pediatric education: a meta-analysis. *Pediatrics*. 2014;133(5): e1313-e1323. doi: 10.1542/peds.2013-2139.

171. Mileder LP, Urlesberger B, Szyld EG, Roehr CC, Schmölzer GM. Simulation-based neonatal and infant resuscitation teaching: a systematic review of randomized controlled trials. *Klin Padiatr*. 2014;226(5): 259-267. doi: 10.1055/s-0034-1372621.

172. McGaghie WC, Draycott TJ, Dunn WF, Lopez CM, Stefanidis D. Evaluating the impact of simulation on translational patient outcomes. *Simul Healthc*. 2011;6 Suppl: S42-S47. doi: 10.1097/SIH.0b013e318222fde9.

173. Mundell WC, Kennedy CC, Szostek JH, Cook DA. Simulation technology for resuscitation training: a systematic review and meta-analysis. *Resuscitation*. 2013;84(9): 1174-1183. doi: 10.1016/j.resuscitation.2013.04.016.

174. Kennedy CC, Cannon EK, Warner DO, Cook DA. Advanced airway management simulation training in medical education: a systematic review and meta-analysis. *Crit Care Med*. 2014;42(1): 169-178. doi: 10.1097/CCM.0b013e31829a721f.

175. Pammi M, Dempsey EM, Ryan CA, Barrington KJ. Newborn Resuscitation Training Programmes Reduce Early Neonatal Mortality. *Neonatology*. 2016;110(3): 210-224. doi: 10.1159/000443875.

176. Schwindt EM, Stockenhuber R, Kainz T, Stumptner N, Henkel M, Hefler L, et al. Neonatal simulation training decreases the incidence of chest compressions in term newborns. *Resuscitation*. 2022;178: 109-115. doi: 10.1016/j.resuscitation.2022.06.006.

177. Cohen ER, Feinglass J, Barsuk JH, Barnard C, O'Donnell A, McGaghie WC, et al. Cost savings from reduced catheter-related bloodstream infection after simulation-based education for residents in a medical intensive care unit. *Simul Healthc*. 2010;5(2): 98-102. doi: 10.1097/SIH.0b013e3181bc8304.

178. Theilen U, Fraser L, Jones P, Leonard P, Simpson D. Regular in-situ simulation training of paediatric Medical Emergency Team leads to sustained improvements in hospital response to deteriorating patients, improved outcomes in intensive care and financial savings. *Resuscitation*. 2017;115: 61-67. doi: 10.1016/j.resuscitation.2017.03.031.

179. Schaffer AC, Babayan A, Einbinder JS, Sato L, Gardner R. Association of Simulation Training With Rates of Medical Malpractice Claims Among Obstetrician-Gynecologists. *Obstet Gynecol*. 2021;138(2): 246-252. doi: 10.1097/AOG.0000000000004464.

180. Mileder LP, Gressl J, Urlesberger B, Raith W. Paramedics' Newborn Life Support Knowledge and Skills Before and After a Targeted Simulation-Based Educational Intervention. *Front Pediatr*. 2019;7: 132. doi: 10.3389/fped.2019.00132.

181. Patterson MD, Blike GT, Nadkarni VM. In Situ Simulation: Challenges and Results. In: Henriksen K, Battles JB, Keyes MA, Grady ML, editors. Advances in Patient Safety: New Directions and Alternative Approaches (Vol. 3: Performance and Tools). Rockville, United States of America: Agency for Healthcare Research and Quality; 2008. [Cited June 1, 2022] Available from: http://www.ncbi.nlm.nih.gov/books/NBK43682

182. Bender J, Shields R, Kennally K. Transportable enhanced simulation technologies for pre-implementation limited operations testing: neonatal intensive care unit. *Simul Healthc*. 2011;6(4): 204-212. doi: 10.1097/SIH.0b013e3182183c0b.

183. Theilen U, Leonard P, Jones P, Ardill R, Weitz J, Agrawal D, et al. Regular in situ simulation training of paediatric medical emergency team improves hospital response to deteriorating patients. *Resuscitation*. 2013;84(2): 218-222. doi: 10.1016/j.resuscitation.2012.06.027.

184. Patterson MD, Geis GL, Falcone RA, LeMaster T, Wears RL. In situ simulation: detection of safety threats and teamwork training in a high risk emergency department. *BMJ Qual Saf*. 2013;22(6): 468-477. doi: 10.1136/bmjqs-2012-000942.

185. O'Leary F, McGarvey K, Christoff A, Major J, Lockie F, Chayen G, et al. Identifying incidents of suboptimal care during paediatric emergencies-an observational study utilising in situ and simulation centre scenarios. *Resuscitation*. 2014;85(3): 431-436. doi: 10.1016/j.resuscitation.2013.12.001.

186. Dadiz R, Riccio J, Brown K, Emrich P, Robin B, Bender J. Qualitative analysis of latent safety threats uncovered by in situ simulation-based operations testing before moving into a single-family-room neonatal intensive care unit. *J Perinatol*. 2020;40(Suppl 1): 29-35. doi: 10.1038/s41372-020-0749-3.

187. Rosen MA, Hunt EA, Pronovost PJ, Federowicz MA, Weaver SJ. In situ simulation in continuing education for the health care professions: a systematic review. *J Contin Educ Health Prof*. 2012;32(4): 243-254. doi: 10.1002/chp.21152.

188. Eppich W, Cheng A. Promoting Excellence and Reflective Learning in Simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc*. 2015;10(2): 106-115. doi: 10.1097/SIH.0000000000000072.

189. Rall M, Lackner CK. Crisis Resource Management (CRM). Der Faktor Mensch in der Akutmedizin. *Notfall Rettungsmed*. 2010;13: 349-356. doi: https://doi.org/10.1007/s10049-009-1271-5.

190. Kolbe M, Eppich W, Rudolph J, Meguerdichian M, Catena H, Cripps A, et al. Managing psychological safety in debriefings: a dynamic balancing act. *BMJ Simul Technol Enhanc Learn*. 2020;6(3): 164-171. doi: 10.1136/bmjstel-2019-000470.

191. Richmond S, Wyllie J. European Resuscitation Council Guidelines for Resuscitation 2010 Section 7. Resuscitation of babies at birth. *Resuscitation*. 2010;81(10): 1389-1399. doi: 10.1016/j.resuscitation.2010.08.018.

192. Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *Br J Anaesth*. 2003;90(5): 580-588. doi: 10.1093/bja/aeg112.

193. Thomas EJ, Williams AL, Reichman EF, Lasky RE, Crandell S, Taggart WR. Team training in the neonatal resuscitation program for interns: teamwork and quality of resuscitations. *Pediatrics*. 2010;125(3): 539-546. doi: 10.1542/peds.2009-1635.

194. Riem N, Boet S, Bould MD, Tavares W, Naik VN. Do technical skills correlate with non-technical skills in crisis resource management: a simulation study. *Br J Anaesth*. 2012;109(5): 723-728. doi: 10.1093/bja/aes256.

195. Krage R, Zwaan L, Tjon Soei Len L, Kolenbrander MW, van Groeningen D, Loeret SA, et al. Relationship between non-technical skills and technical performance during cardiopulmonary resuscitation: does stress have an influence? *Emerg Med J*. 2017;34(11): 728-733. doi: 10.1136/emermed-2016-205754.

196. Halamek LP, Weiner GM. State-of-the art training in neonatal resuscitation. *Semin Perinatol*. 2022;46(6): 151628. doi: 10.1016/j.semperi.2022.151628.

197. Fernandez-Moure JS. Lost in Translation: The Gap in Scientific Advancements and Clinical Application. *Front Bioeng Biotechnol*. 2016;4: 43. doi: 10.3389/fbioe.2016.00043.

198. Eckels M, Zeilinger T, Lee HC, Bergin J, Halamek LP, Yamada N, et al. A Neonatal Intensive Care Unit's Experience with Implementing an In-Situ Simulation and Debriefing

Patient Safety Program in the Setting of a Quality Improvement Collaborative. *Children (Basel)*. 2020;7(11): 202. doi: 10.3390/children7110202.

199. Rivera EK, Siple LM, Wicks EJ, Johnson HS, Skov CM. In Situ Neonatal Mock Codes: Assessing the Impact. *Neonatal Netw*. 2020;39(1): 29-34. doi: 10.1891/0730-0832.39.1.29.
200. Löllgen RM, Mileder LP, Bibl K, Christian Dörfler, Annika Paulun, Jasmin Rupp, et al. Empfehlungen des Netzwerks Kindersimulation e.V. für die Durchführung simulationsbasierter pädiatrischer Teamtrainings. 1st edition. Tübingen, Germany: Netzwerk Kindersimulation e.V.; 2020. [Cited June 11, 2022] Available from: https://www.netzwerk-kindersimulation.org/media/pages/pdf-qualitaetskriterien/3233047602-1616346316/kindersimu-dt-isbn.pdf
201. Cheng A, Eppich W, Grant V, Sherbino J, Zendejas B, Cook DA. Debriefing for technology-enhanced simulation: a systematic review and meta-analysis. *Med Educ*. 2014;48(7): 657-666. doi: 10.1111/medu.12432.
202. Rudolph JW, Simon R, Rivard P, Dufresne RL, Raemer DB. Debriefing with good judgment: combining rigorous feedback with genuine inquiry. *Anesthesiol Clin*. 2007;25(2): 361-376. doi: 10.1016/j.anclin.2007.03.007.
203. Cheng A, Morse KJ, Rudolph J, Arab AA, Runnacles J, Eppich W. Learner-Centered Debriefing for Health Care Simulation Education: Lessons for Faculty Development. *Simul Healthc*. 2016;11(1): 32-40. doi: 10.1097/SIH.0000000000000136.
204. Sawyer T, Sierocka-Castaneda A, Chan D, Berg B, Lustik M, Thompson M. The effectiveness of video-assisted debriefing versus oral debriefing alone at improving neonatal resuscitation performance: a randomized trial. *Simul Healthc*. 2012;7(4): 213-221. doi: 10.1097/SIH.0b013e3182578eae.
205. Farooq O, Thorley-Dickinson VA, Dieckmann P, Kasfiki EV, Omer RMIA, Purva M. Comparison of oral and video debriefing and its effect on knowledge acquisition following simulation-based learning. *BMJ Simul Technol Enhanc Learn*. 2017;3(2): 48-53. doi: 10.1136/bmjstel-2015-000070.
206. Zhang H, Mörelius E, Goh SHL, Wang W. Effectiveness of Video-Assisted Debriefing in Simulation-Based Health Professions Education: A Systematic Review of Quantitative Evidence. *Nurse Educ*. 2019;44(3): E1-E6. doi: 10.1097/NNE.0000000000000562.
207. Rueda-Medina B, Reina-Cabello JC, Buendía-Castro M, Aguilar-Ferrándiz ME, Gil-Gutiérrez R, Tapia-Haro RM, et al. Effectiveness of video-assisted debriefing versus oral

debriefing in simulation-based interdisciplinary health professions education: A randomized trial. *Nurse Educ Pract*. 2024:75: 103901. doi: 10.1016/j.nepr.2024.103901.

208. Hunziker S, Bühlmann C, Tschan F, Balestra G, Legeret C, Schumacher C, et al. Brief leadership instructions improve cardiopulmonary resuscitation in a high-fidelity simulation: a randomized controlled trial. *Crit Care Med*. 2010;38(4): 1086-1091. doi: 10.1097/CCM.0b013e3181cf7383.

209. Capella J, Smith S, Philp A, Putnam T, Gilbert C, Fry W, et al. Teamwork training improves the clinical care of trauma patients. *J Surg Educ*. 2010;67(6): 439-443. doi: 10.1016/j.jsurg.2010.06.006.

210. Sawyer T, Burke C, McMullan DM, Chan T, Valdivia H, Yalon L, et al. Impacts of a Pediatric Extracorporeal Cardiopulmonary Resuscitation (ECPR) Simulation Training Program. *Acad Pediatr*. 2019;19(5): 566-571. doi: 10.1016/j.acap.2019.01.005.

211. Ajmi SC, Advani R, Fjetland L, Dehli Kurz K, Lindner T, Qvindesland SA, et al. Reducing door-to-needle times in stroke thrombolysis to 13 min through protocol revision and simulation training: a quality improvement project in a Norwegian stroke centre. *BMJ Qual Saf*. 2019;28(11): 939-948. doi: 10.1136/bmjqs-2018-009117.

212. Bogne Kamdem V, Daelemans C, Englert Y, Morin F, Sansregret A. Using simulation team training with human's factors components in obstetrics to improve patient outcome: A review of the literature. *Eur J Obstet Gynecol Reprod Biol*. 2021;260: 159-165. doi: 10.1016/j.ejogrb.2021.03.015.

213. Brogaard L, Hvidman L, Esberg G, Finer N, Hjorth-Hansen KR, Manser T, et al. Teamwork and Adherence to Guideline on Newborn Resuscitation-Video Review of Neonatal Interdisciplinary Teams. *Front Pediatr*. 2022;10: 828297. doi: 10.3389/fped.2022.828297.

214. Schmutz J, Manser T. Do team processes really have an effect on clinical performance? A systematic literature review. *Br J Anaesth*. 2013;110(4): 529-544. doi: 10.1093/bja/aes513.

215. Finan E, Bismilla Z, Campbell C, Leblanc V, Jefferies A, Whyte HE. Improved procedural performance following a simulation training session may not be transferable to the clinical environment. *J Perinatol*. 2012;32(7): 539-544. doi: 10.1038/jp.2011.141.

216. Mema B, Harris I. The Barriers and Facilitators to Transfer of Ultrasound-Guided Central Venous Line Skills From Simulation to Practice: Exploring Perceptions of Learners

and Supervisors. *Teach Learn Med*. 2016;28(2): 115-124. doi: 10.1080/10401334.2016.1146604.

217. Rød I, Kynø NM, Solevåg AL. From simulation room to clinical practice: Postgraduate neonatal nursing students' transfer of learning from in-situ resuscitation simulation with interprofessional team to clinical practice. *Nurse Educ Pract*. 2021:52: 102994. doi: 10.1016/j.nepr.2021.102994.

218. Draycott TJ, Crofts JF, Ash JP, Wilson LV, Yard E, Sibanda T, et al. Improving neonatal outcome through practical shoulder dystocia training. *Obstet Gynecol*. 2008;112(1): 14-20. doi: 10.1097/AOG.0b013e31817bbc61.

219. Barsuk JH, McGaghie WC, Cohen ER, O'Leary KJ, Wayne DB. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. *Crit Care Med*. 2009;37(10): 2697-2701.

220. Steiner M, Langgartner M, Cardona F, Waldhör T, Schwindt J, Haiden N, et al. Significant Reduction of Catheter-associated Blood Stream Infections in Preterm Neonates After Implementation of a Care Bundle Focusing on Simulation Training of Central Line Insertion. *Pediatr Infect Dis J*. 2015;34(11): 1193-1196. doi: 10.1097/INF.0000000000000841.

221. Schilleman K, Siew ML, Lopriore E, Morley CJ, Walther FJ, Te Pas AB. Auditing resuscitation of preterm infants at birth by recording video and physiological parameters. *Resuscitation*. 2012;83(9): 1135-1139. doi: 10.1016/j.resuscitation.2012.01.036.

222. Skåre C, Calisch TE, Saeter E, Rajka T, Boldingh AM, Nakstad B, et al. Implementation and effectiveness of a video-based debriefing programme for neonatal resuscitation. *Acta Anaesthesiol Scand*. 2018;62(3): 394-403. doi: 10.1111/aas.13050.

223. McCarthy LK, Morley CJ, Davis PG, Kamlin COF, O'Donnell CPF. Timing of interventions in the delivery room: does reality compare with neonatal resuscitation guidelines? *J Pediatr*. 2013;163(6): 1553-1557.e1. doi: 10.1016/j.jpeds.2013.06.007.

224. DeMauro SB, Douglas E, Karp K, Schmidt B, Patel J, Kronberger A, et al. Improving delivery room management for very preterm infants. *Pediatrics*. 2013;132(4): e1018-e1025. doi: 10.1542/peds.2013-0686.

225. Konstantelos D, Dinger J, Ifflaender S, Rüdiger M. Analyzing video recorded support of postnatal transition in preterm infants following a c-section. *BMC Pregnancy Childbirth*. 2016;16(1): 246. doi: 10.1186/s12884-016-1045-2.

226. Murthy V, Dattani N, Peacock JL, Fox GF, Campbell ME, Milner AD, et al. The first five inflations during resuscitation of prematurely born infants. *Arch Dis Child Fetal Neonatal Ed*. 2012;97(4): F249-F253. doi: 10.1136/archdischild-2011-300117.

227. Schilleman K, van der Pot CJ, Hooper SB, Lopriore E, Walther FJ, te Pas AB. Evaluating manual inflations and breathing during mask ventilation in preterm infants at birth. *J Pediatr*. 2013;162(3): 457-463. doi: 10.1016/j.jpeds.2012.09.036

228. van Vonderen JJ, Witlox RS, Kraaij S, te Pas AB. Two-minute training for improving neonatal bag and mask ventilation. *PLoS One*. 2014;9(10): e109049. doi: 10.1371/journal.pone.0109049.

229. Sawyer T, Motz P, Schooley N, Umoren R. Positive pressure ventilation coaching during neonatal bag-mask ventilation: A simulation-based pilot study. *J Neonatal Perinatal Med*. 2019;12(3): 243-248. doi: 10.3233/NPM-1618119.

230. Binder-Heschl C, Pichler G, Avian A, Schwaberger B, Baik-Schneditz N, Mileder L, et al. Oxygen Saturation Targeting During Delivery Room Stabilization: What Does This Mean for Regional Cerebral Oxygenation? *Front Pediatr*. 2019;7: 274. doi: 10.3389/fped.2019.00274.

231. Oei JL, Finer NN, Saugstad OD, Wright IM, Rabi Y, Tarnow-Mordi W, et al. Outcomes of oxygen saturation targeting during delivery room stabilisation of preterm infants. *Arch Dis Child Fetal Neonatal Ed*. 2018;103(5): F446-F454. doi: 10.1136/archdischild-2016-312366.

232. Lara-Cantón I, Solaz A, Parra-Llorca A, García-Robles A, Millán I, Torres-Cuevas I, et al. Oxygen Supplementation During Preterm Stabilization and the Relevance of the First 5 min After Birth. *Front Pediatr*. 2020;8: 12. doi: 10.3389/fped.2020.00012.

233. Nerdrum Aagaard E, Solevåg AL, Saugstad OD. Significance of Neonatal Heart Rate in the Delivery Room-A Review. *Children (Basel)*. 2023;10(9): 1551. doi: 10.3390/children10091551.

234. Yam CH, Dawson JA, Schmölzer GM, Morley CJ, Davis PG. Heart rate changes during resuscitation of newly born infants <30 weeks gestation: an observational study. *Arch Dis Child Fetal Neonatal Ed*. 2011;96(2): F102-F107. doi: 10.1136/adc.2009.180950.

235. Bresesti I, Avian A, Bruckner M, Binder-Heschl C, Schwaberger B, Baik-Schneditz N, et al. Impact of bradycardia and hypoxemia on oxygenation in preterm infants requiring

respiratory support at birth. *Resuscitation*. 2021:164: 62-69. doi: 10.1016/j.resuscitation.2021.05.004.

236. de Almeida MF, Guinsburg R, Sancho GA, Rosa IR, Lamy ZC, Martinez FE, et al. Hypothermia and early neonatal mortality in preterm infants. *J Pediatr*. 2014;164(2): 271-275.e1. doi: 10.1016/j.jpeds.2013.09.049.
237. Abiramalatha T, Ramaswamy VV, Bandyopadhyay T, Pullattayil AK, Thanigainathan S, Trevisanuto D, et al. Delivery Room Interventions for Hypothermia in Preterm Neonates: A Systematic Review and Network Meta-analysis. *JAMA Pediatr*. 2021;175(9): e210775. doi: 10.1001/jamapediatrics.2021.0775.
238. Bruckner M, Mileder LP, Richter A, Baik-Schneditz N, Schwaberger B, Binder-Heschl C, et al. Association between Regional Tissue Oxygenation and Body Temperature in Term and Preterm Infants Born by Caesarean Section. *Children (Basel)*. 2020;7(11): 205. doi: 10.3390/children7110205.
239. Stark CF, Gibbs RS, Freedman WL. Comparison of umbilical artery pH and 5-minute Apgar score in the low-birth-weight and very-low-birth-weight infant. *Am J Obstet Gynecol*. 1990;163(3): 818-823. doi: 10.1016/0002-9378(90)91075-n.
240. Niemuth M, Küster H, Simma B, Rozycki H, Rüdiger M; European Society for Paediatric Research (ESPR) Neonatal Resuscitation Section Writing Group; Solevåg AL. A critical appraisal of tools for delivery room assessment of the newborn infant. *Pediatr Res*. 2021 Dec 30. doi: 10.1038/s41390-021-01896-7. Online ahead of print.
241. Patel D, Piotrowski ZH, Nelson MR, Sabich R. Effect of a statewide neonatal resuscitation training program on Apgar scores among high-risk neonates in Illinois. *Pediatrics*. 2001;107(4): 648-655. doi: 10.1542/peds.107.4.648.
242. Andreatta P, Saxton E, Thompson M, Annich G. Simulation-based mock codes significantly correlate with improved pediatric patient cardiopulmonary arrest survival rates. *Pediatr Crit Care Med*. 2011;12(1): 33-38. doi: 10.1097/PCC.0b013e3181e89270.
243. Awadhare P, Barot K, Frydson I, Balakumar N, Doerr D, Bhalala U. Impact of Quality Improvement Bundle on Compliance with Resuscitation Guidelines during In-Hospital Cardiac Arrest in Children. *Crit Care Res Pract*. 2023:2023: 6875754. doi: 10.1155/2023/6875754.

244. Reed DJW, Hermelin RL, Kennedy CS, Sharma J. Interdisciplinary onsite team-based simulation training in the neonatal intensive care unit: a pilot report. *J Perinatol*. 2017;37(4): 461-464. doi: 10.1038/jp.2016.238.

245. Sonesh SC, Gregory ME, Hughes AM, Feitosa J, Benishek LE, Verhoeven D, et al. Team training in obstetrics: A multi-level evaluation. *Fam Syst Health*. 2015;33(3): 250-261. doi: 10.1037/fsh0000148.

246. Mileder LP, Bereiter M, Wegscheider T. Telesimulation as a modality for neonatal resuscitation training. *Med Educ Online*. 2021;26(1): 1892017. doi: 10.1080/10872981.2021.1892017.

247. INACSL Standards Committee. INACSL standards of best practice: Simulation^{SM} Simulation design. *Clinical Simul Nurs*. 2016;12(S): S5-S12. http://dx.doi.org/10.1016/j.ecns.2016.09.005.

248. Nilsen S, Baerheim A. Feedback on video recorded consultations in medical teaching: why students loathe and love it - a focus-group based qualitative study. *BMC Med Educ*. 2005;5: 28. doi: 10.1186/1472-6920-5-28.

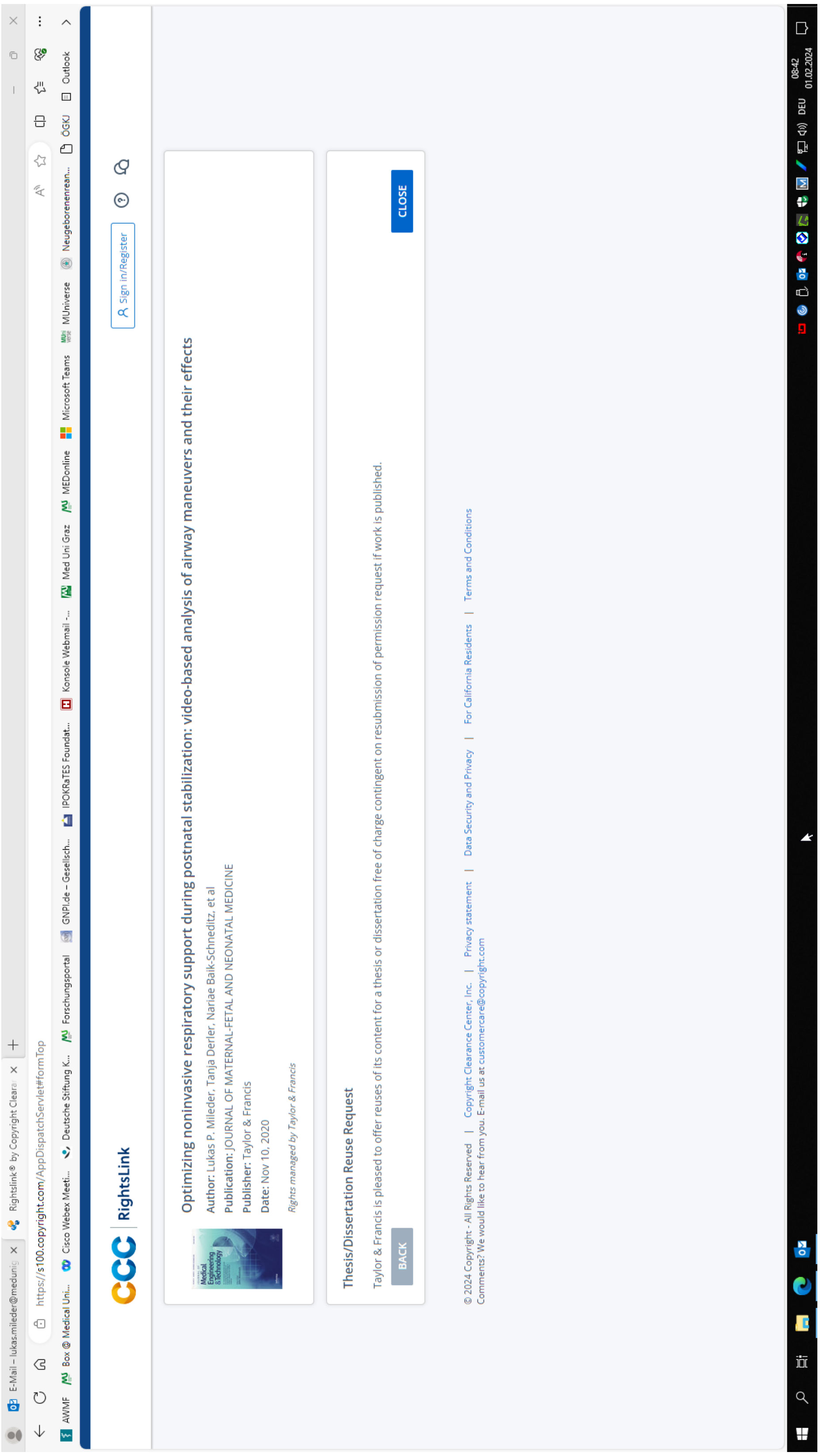
249. Gordon L, Reed C, Sorensen JL, Schulthess P, Strandbygaard J, Mcloone M, et al. Perceptions of safety culture and recording in the operating room: understanding barriers to video data capture. *Surg Endosc*. 2022;36(6): 3789-3797. doi: 10.1007/s00464-021-08695-5.

250. Halamek LP, Cady RAH, Sterling MR. Using briefing, simulation and debriefing to improve human and system performance. *Semin Perinatol*. 2019;43(8): 151178. doi: 10.1053/j.semperi.2019.08.007.

251. Onwochei DN, Halpern S, Balki M. Teamwork Assessment Tools in Obstetric Emergencies: A Systematic Review. *Simul Healthc*. 2017;12(3): 165-176. doi: 10.1097/SIH.0000000000000210.

252. Gaw M, Rosinia F, Diller T. Quality and the Health System: Becoming a High Reliability Organization. *Anesthesiol Clin*. 2018;36(2): 217-226. doi: 10.1016/j.anclin.2018.01.010.

Appendix



Optimizing noninvasive respiratory support during postnatal stabilization: video-based analysis of airway maneuvers and their effects

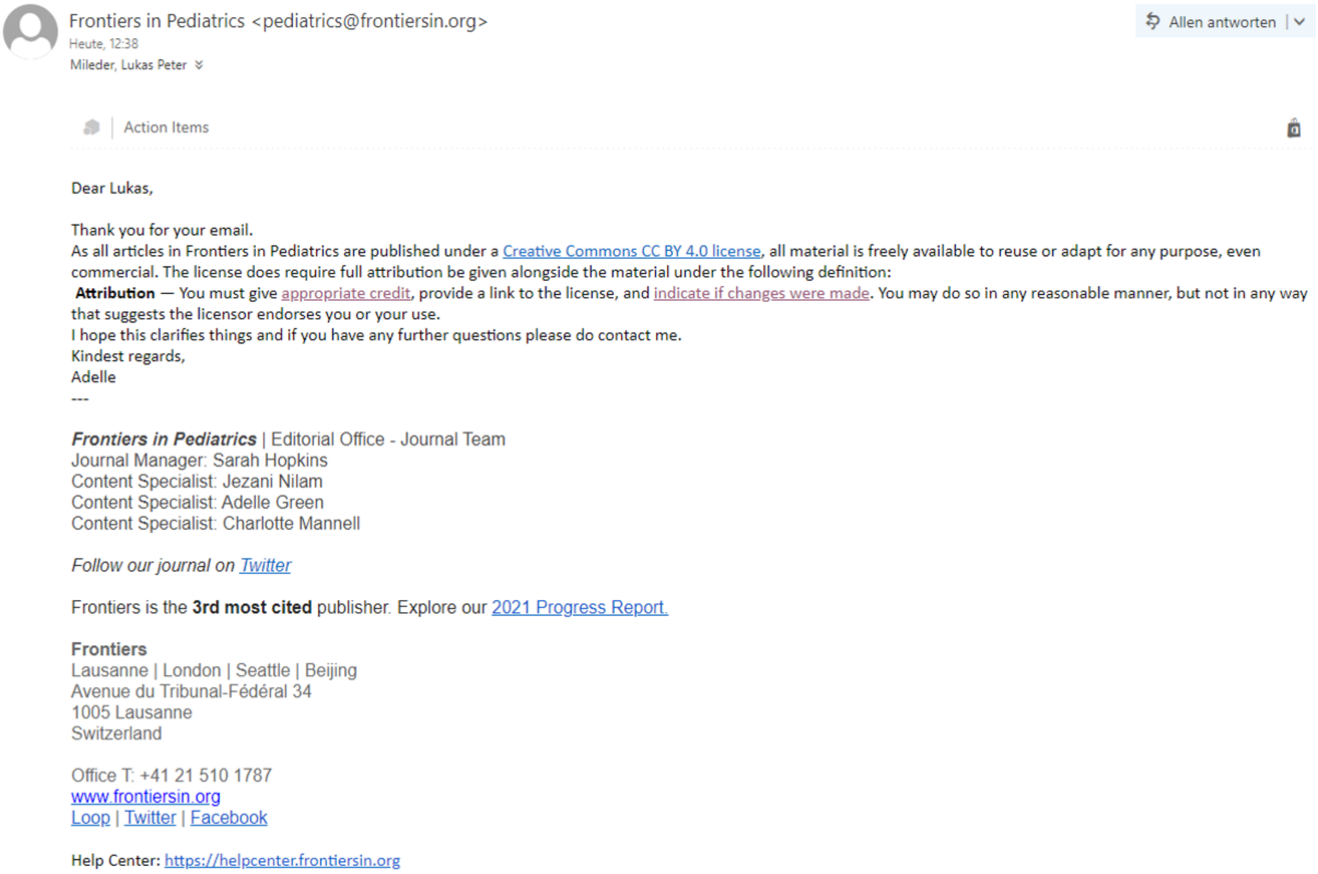
Author: Lukas P. Mileder, Tanja Derler, Nariae Baik-Schneditz, et al
Publication: JOURNAL OF MATERNAL-FETAL AND NEONATAL MEDICINE
Publisher: Taylor & Francis
Date: Nov 10, 2020

Rights managed by Taylor & Francis

Thesis/Dissertation Reuse Request

Taylor & Francis is pleased to offer reuses of its content for a thesis or dissertation free of charge contingent on resubmission of permission request if work is published.

© 2024 Copyright - All Rights Reserved | Copyright Clearance Center, Inc. | Privacy statement | Data Security and Privacy | For California Residents | Terms and Conditions
Comments? We would like to hear from you. E-mail us at customercare@copyright.com



Frontiers in Pediatrics <pediatrics@frontiersin.org>
Heute, 12:38
Mileder, Lukas Peter

Dear Lukas,

Thank you for your email.
As all articles in Frontiers in Pediatrics are published under a Creative Commons CC BY 4.0 license, all material is freely available to reuse or adapt for any purpose, even commercial. The license does require full attribution be given alongside the material under the following definition:
Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.
I hope this clarifies things and if you have any further questions please do contact me.
Kindest regards,
Adelle

Frontiers in Pediatrics | Editorial Office - Journal Team
Journal Manager: Sarah Hopkins
Content Specialist: Jezani Nilam
Content Specialist: Adelle Green
Content Specialist: Charlotte Mannell

Follow our journal on Twitter

Frontiers is the **3rd most cited** publisher. Explore our 2021 Progress Report.

Frontiers
Lausanne | London | Seattle | Beijing
Avenue du Tribunal-Fédéral 34
1005 Lausanne
Switzerland

Office T: +41 21 510 1787
www.frontiersin.org
Loop | Twitter | Facebook

Help Center: https://helpcenter.frontiersin.org