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Clinical Paper

Prevalence of systemic air-embolism after prolonged cardiopulmonary resuscitation in newborns: A pilot study☆

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ABSTRACT

Background: Chest compressions (CC) during cardiopulmonary resuscitation (CPR) are the cornerstone of adult CPR protocols and are meant to restore circulation and improve outcome. Although adverse effects such as air-embolisms have been reported, these are rare and considered to be outweighed by beneficial effect. In newborns, however, the lung tissue is more fragile. Thus, the high intra-thoracic pressures resulting from CC may make the newborns more vulnerable for air-embolisms.
Objectives: We studied the postmortem prevalence of air-embolism in neonates that have received CPR.
Methods: Prospective cohort analysis of newborns receiving CC during CPR. CPR was performed by trained staff according to ILCOR guidelines, in a tertiary hospital. Air-embolisms were sought after using CT/MRI and autopsy.
Results: During a 61/2 year period (2007–2014), $n = 56$ newborns received CC. Newborns were resuscitated following severe perinatal hypoxia, or due to complications during NICU treatment. In $n = 14$ (25.0%) circulation could not be restored (mean CPR duration: 32.7 ± 15.2 min). Post-mortem CT/MRI was performed in $n = 9$, of whom $n = 8$ (88.9%) had air-embolisms. Autopsy was performed in $n = 9$. The air-embolisms could not be retraced on autopsy except for $n = 1$ patient.

In patients with CPR resulting in restored circulation ($n = 42$), no CT or MRI was performed for comparison due to radiation and/or hemodynamic instability. Cerebral ultrasound could not identify or exclude air-embolisms in this subgroup.
Conclusions: Post-mortem CT after prolonged resuscitation showed a high prevalence of intravascular air-embolism. Autopsy was not suited to detect air-embolism. The clinical importance of air-embolisms on the lethal outcome needs further research.

1. Introduction

Cardiopulmonary resuscitation (CPR) is one of the most direct and, if successful, rewarding interventions in medicine, with chest compressions (CC) being a cornerstone of modern CPR technique. Advantages of CPR are considered to outweigh the adverse effects caused by and CC, such as are rib fractures and lung contusion.[1–3] However, apart from these transient and treatable problems, more severe complications may occur. Systemic air-embolism, though less frequently reported, seem highly prevalent on post-mortem CT scans after CPR in non-trauma patients.[4,5]

In newborn CPR guidelines, CC have an important place as well. However most protocols are based on results from adult or experimental studies. Moreover, in newborns the cause for cardiopulmonary arrest is in general pulmonary disease or perinatal hypoxia requiring primarily ventilation and oxygenation. This is contrary to adults, where primary cardiac disease is the usual cause.[6] In newborn CPR, the main effect of CC is thought to initiate only a "bump start" of the hypoxic myocardium by transferring oxygen enriched blood necessary to regain its pumping function.[7]

However, the fragile newborn lung tissue might well be compromised by the combination of high pulmonary inflation pressures – necessary for pulmonary aeration to revert hypoxic bradycardia – and chest compressions which will further increase the intra-pulmonary pressure. Especially the pulmonary tissue in preterm infants has appeared to be prone to ventilation induced injury. So

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far, it has never been studied whether CC advantages outweigh adverse effects.

We therefore hypothesized that CC complications might be much more prevalent than usually assumed as being very rare complications, especially in premature newborns. We investigated the prevalence and extent of air-embolism in non-survivors with post-mortem CT/MRI imaging.

2. Methods

We performed a prospective cohort analysis. Newborns, resuscitated post-partum or during their admission at the neonatal intensive care unit (NICU), were analyzed during $6^1/_2$ years (30th July 2007 and 31 January 2014) in our level III Neonatal Intensive Care Unit (NICU) with a total number of NICU admissions of 350/year. Newborns were included if they had received chest compression in our center; those who were resuscitated in a referring hospital prior to being transferred to our NICU were excluded.

All resuscitations were performed by staff trained according to the most recent ERC/ILCOR recommendations [8]: lung insufflations were started with peak pressure of 20 cm H_2O and increased to a maximum of 25 cm H_2O using a T-piece device (Neopuff®), and CC were started when heart rate was below 60 beats/min, using either bimanual or finger pressure technique to a depth of a half to a third of anterior posterior thorax diameter. No airway pressure measurement was made, other than observing the pressure readings on the Neopuff; however transpulmonary/intrapulmonary pressures are likely to have exceeded those proximal readings. Epinephrine was given when prolonged (>1 min) chest compression was necessary; first choice of vascular access was an umbilical catheter, second peripheral cannulation. Special attention was given that no air was accidentally infused or aspirated, and umbilical catheters were immediately occluded when not used for infusion.

Demographic data (gestational age), Apgar scores, CPR duration, respiratory support, CC duration, vascular access, radiologic imaging and outcome were recorded. In non-survivors, parental consent for autopsy and post-mortem CT/MRI was asked and, if permitted, results were recorded. Special attention was given to the presence of intravascular air. As the imaging and autopsy data were routine procedures, and no randomization was applied, the hospital ethical committee concluded in accordance with national law, that no approval was needed from them.

Data are shown as mean and standard deviation (SD). Data were analyzed using chi-square for numeric data and Mann–Whitney-test for asymmetric, continuous data. Numeric data are presented as absolute numbers as well as percentage of cohort, asymmetric divided continuous data as median [range].

3. Results

A total of $n = 56$ newborns receiving CC were included (0.46% of all deliveries $n = 12{,}816$). Average gestational age (GA) was 31.2 ± 4.84 weeks ($n = 41$ GA < 37 weeks, $n = 34$ GA < 32 weeks). 28 were male and 28 female.

In $n = 43$ (77%) newborns CC were performed in the delivery room, in $n = 13$ during NICU admission (due to e.g. intubation procedure complicated by hypoxia and subsequent bradycardia).

3.1. Outcome

Circulation could not be restored in 14 (25%) newborns. In 7 patients, circulation was initially restored, but treatment was withdrawn after several hours as prognosis did not justify continuation of medical treatment, resulting in an overall mortality of $n = 21$ (37.5%).

3.2. Chest compression duration

The cohort was stratified in newborns receiving chest compression less than 5 min ($n = 37$; duration 2.5 ± 1.6 min) and those receiving prolonged chest compressions over 5 min ($n = 19$; duration 27.2 ± 16.2 min, p-value < 0.001). Patients with prolonged chest compressions had lower Apgar scores at 5 and 10 min than those needing CC < 5 min (median 0 resp. 1 versus 1 resp. 3), indicating a worse clinical condition. No statistically significant difference in mean GA was observed (30.1 ± 3.5 weeks vs. 33.7 ± 5.5 weeks, $p = 0.21$) between these cohort, although the proportion of preterm infants in the group with CC >5 min was larger (18/19 (94%) vs. 23/37 (62%) <37 weeks GA; 15/19 (79%) vs. 19/37 (51%) < 32 weeks. No statistical differences in gender were found.

Outcome and CPR complications in these subgroups are presented in Fig. 1.

3.2.1. Chest compressions <5 min

In the 37 patients with chest compressions <5 min, the cause of CPR was either asphyxia ($n = 29$) or hypoxic bradycardia ($n = 8$) resulting from complicated intubation on the ward.

Mortality (after restoring circulation) was observed in $n = 3$ (8.1%) patients. One of these newborns had severe hypoxic encephalopathy after to uterus rupture and treatment was withdrawn after 2 days NICU treatment. In the second patient chest compressions were started directly after birth due to respiratory failure, originating from congenital hypoventilation syndrome resulting in withdrawal of treatment 10 days after birth i.e. neurological damage due CPR complications was unlikely in this patient. In the third patient, in agreement with parents only short lasting CPR was performed as a very poor prognosis was expected in a 27 weeks neonate with very severe intrauterine bradycardia resulting from fetal hypoxia. Hence in only $n = 1$ (2.7%) of these 3 patients, an association between necessity of CPR, adverse outcome and withdrawal of treatment was observed.

In $n = 8$ (23.5%) survivors cerebral parenchyma abnormalities (transient periventricular echodensities and/or periventricular leukomalcy) were observed on routine cranial ultrasound; the prevalence was comparable with premature newborns not receiving CPR. No specific signs of presence or absence of air-embolism could be demonstrated on ultrasound. However, ultrasound is usually performed after stabilization which mostly several hours after CC and air might have been reabsorbed by then, or not visualized. For the same reason no CT/MRI was performed in this stage.

3.2.2. Chest compressions >5 min

Of 19 newborns with prolonged CC, $n = 14$ were resuscitated due to asphyxia, and 5 for complications during NICU treatment.

Of these infants, in $n = 14$ (73.7%) circulation could not be restored by CPR (mean CPR duration: 32.7 ± 15.2 min). In 5 patients circulation could be restored, however, in 4 of them IC-treatment was withdrawn several hours after resuscitation due to severe neurologic damage (CPR duration: 11.6 ± 4.7 min). Overall mortality thus was 18/19 (94.7%). The only surviving infant in this cohort with prolonged CC needed chest compressions during 10 min due to perinatal hypoxia, briefly interrupted for intubation.

3.3. CT/MRI and autopsy findings

3.3.1. CT/MRI

In 9 patients consent was given for postmortem CT/MRI. Imaging was done within 12 h after death. In all of these patients circulation was never restored following CPR; all had had prolonged CC (mean 35.6 ± 13.7 min). All patients were below 33 weeks GA (29.5 ± 2.2). No CT/MRI were performed in patients in who NICU treatment was withdrawn.