Aus der Kinderklinik und Kinderpoliklinik
im Dr. von Haunerschen Kinderspital
der Ludwig-Maximilians-Universität München

Direktor: Prof. Dr. Dr. Christoph Klein

Verlaufsbeschreibung der regionalen zerebralen Gewebssättigung bei reifen und gesunden Neugeborenen unmittelbar nach Geburt

Dissertation zum Erwerb des Doktorgrades der Medizin an der Medizinischen Fakultät der Ludwig-Maximilians-Universität zu München

vorgelegt von:
Dr. med. univ. Elisabeth Beckenbach (geb. Kratky)
aus (Geburtsort): Graz, Österreich
Jahr: 2013

Mit Genehmigung der Medizinischen Fakultät der Universität München

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Ich erkläre hiermit an Eides statt, dass ich die vorliegende Dissertation mit dem Thema „Verlaufsbeschreibung der regionalen zerebralen Gewebssättigung bei reifen und gesunden Neugeborenen unmittelbar nach Geburt“ selbständig verfasst, mich außer der angegebenen keiner weiteren Hilfsmittel bedient und
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Inhaltsverzeichnis

Abkürzungen

FTOE	Fractional tissue oxygen extraction
HR	Herzfrequenz (heart rate)
LM	Lebensminute
NG	Neugeborene(s)
NIRS	Nahinfrarotspektroskopie
rSO_2brain	regionale zerebrale Sättigung
SaO_2	arterielle Sättigung (nicht-invasiv gemessen)

Liste der Publikationen

1.1 Publikation I:

Titel: ***Regional cerebral oxygen saturation in newborn infants in the first 15 min of life after vaginal delivery***

Autoren: Kratky E, Pichler G, Rehak T, Avian A, Pocivalnik M, Müller W, Urlesberger B.

Forschungsgruppe: Division of Neonatology, Department of Pediatrics, Medical University of Graz, Austria.

Erschienen: ***Physiological Measurement***, 2012 Jan;33(1):95-102. doi: 10.1088/0967-3334/33/1/95.

1.2 Publikation II

Titel: ***Regional Oxygen Saturation of the Brain during Birth Transition of Term Infants: Comparison between Elective Cesarean and Vaginal Deliveries***

Autoren: Urlesberger B, Kratky E, Rehak T, Pocivalnik M, Avian A, Czihak J, Müller W, Pichler G.

Forschungsgruppe: Research Unit for Cerebral Development and Oximetry, Division of Neonatology, Department of Pediatrics, Medical University of Graz, Austria.

Erschienen: ***The Journal of Pediatrics***, September 2011, 159(3):404-8. doi: 10.1016 /j.jpeds.2011.02.030., Epub 2011 Apr 9.

Deklaration Koautoren

1.3 Deklaration Koautoren Publikation I

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"Regional cerebral oxygen saturation in newborn infants in the first 15 min of life after vaginel delivery"

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3. Avian Alexander	Statistik, Grafikerstellung	
4. Pocivalnik Nirajam	Messdatenerhebung Geräteeinweisung	
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4. Avian Alexander	Statistik, technische Verarbeitung	
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1.5 Zusammenfassung Publikation I

Ziel dieser Studie war es die zerebrale Gewebssättigung (rSO_2brain) beim reifen Neugeborenen (NG) unmittelbar nach der Geburt zu messen und diese mit nicht-invasiv präduktal gemessenen arteriellen Sättigungswerten zu vergleichen. In dieser prospektiven Studie wurden reife Neugeborenen in den ersten 15 Lebensminuten nach vaginaler Spontangeburt und unauffälliger Anpassung inkludiert. Dabei wurde die rSO_2brain mittels Nahinfrarotspektroskopie (NIRS) an der rechten Schläfe des Kindes gemessen. Zeitgleich wurde die Herzfrequenz (HR) und die arterielle Sättigung (SaO_2) am rechten Handgelenk (präduktal) mittels Pulsoxymetrie ermittelt. Diese drei Parameter (rSO_2brain, HR, SaO_2) wurden von der 1. bis zur 15. Lebensminute kontinuierlich gemessen. Weiters wurde die regionale zerebrale Sauerstoffextraktion (Fractional tissue oxygen extraction, FTOE) mittels der Formel (SaO_2-rSO_2brain)/SaO_2 berechnet.

63 von 145 NG erfüllten die Einschlusskriterien.

Das Geschlechterverhältnis war 31 Mädchen (49,2%) und 32 Knaben (50,8%). rSO_2brain zeigte von Minute 2 (39%) bis Minute 5 (69%) einen hoch signifikanten Anstieg. SaO_2 zeigte von Minute 2 (72%) bis Minute 14 (96%) einen signifikanten Anstieg. Die FTOE zeigte von Min 2 (0,47) bis Min 4 (0,3) einen signifikanten Abfall und einen neuerlichen Anstieg von Minute 8 bis 13.

Der Anstieg der Sauerstoffsättigung des Gehirns erfolgt nach Spontangeburt sehr rasch. Obwohl SaO_2 in den ersten 14 Minuten anstieg, zeigte die rSO_2brain schon nach 5 Minuten keine weiteren Veränderung mehr. Die zerebrale FTOE fiel in den ersten 4 Minuten ab, danach erreichte sie Normalwerte.

1.6 Zusammenfassung Publikation II

In dieser prospektiven Beobachtungsstudie wurde die Oxygenierung bei 63 NG nach Spontangeburt und 51 NG nach Kaiserschnittentbindung in den ersten 10 Lebensminuten miteinander verglichen. Auch hier wurde die rSO_2brain an der Stirn mittels NIRS gemessen. HR und SaO_2 wurde an der rechten Hand mittels Pulsoxymetrie ermittelt. Die FTOE wurde für jede Minute berechnet. Die Ergebnisse zeigten, dass zwischen der 4. und 8. Lebensminute die SaO_2 Werte bei den NG nach Kaiserschnitt signifikant niedriger waren im Vergleich zu NG nach Spontangeburt. Die Herzfrequenz der NG nach Kaiserschnitt zeigte sich während des gesamten Messzeitraumes von 10 Minuten signifikant niedriger. Bezüglich der rSO_2brain konnten keine signifikanten Unterschiede in den 2 Gruppen festgestellt werden. Obwohl sich SpO_2 und HR-Werte in der Kaiserschnitt-Gruppe deutlich niedriger waren, konnte bezüglich der zerebralen Sättigung kein Unterschied zwischen den Geburtsmodi nachgewiesen werden.

Einleitung

Die vorliegenden Publikationen sind aus einer Studie im Rahmen meiner Diplomarbeit an der Medizinischen Universität Graz (Österreich) entstanden. Seit mehreren Jahren beschäftigt sich die Forschungsgruppe der Neonatologie (Leiter Prof. Dr. Urlesberger) mit Veränderungen der Oxygenierung bei Neu und Frühgeborenen. Die Umstellungsprozesse nach der Geburt bieten diesbezüglich sehr interessante Aspekte. Als Mitglied dieser Forschungsgruppe durfte ich über einen längeren Zeitpunkt bei verschiedenen Studien mitwirken. Dabei entstand eine Studie, bei dem ich die Veränderungen der Oxygenierung an Neugeborenen unmittelbar nach der Geburt untersuchte. Als Projektleiterin hatte ich unterschiedliche Aufgabenbereiche, auf die ich im Folgenden näher eingehen möchte. Die Vorbereitungsphase beinhaltete das Einholen des Einverständnisses der Ethikkomission, Projektvorstellung im Kreißsaal-Team und Planung der Durchführbarkeit. In der Zeit von Oktober 2009 bis März 2010 rekrutierte ich das Patientenkollektiv und führte alle Messungen selbst durch. Gemeinsam mit den anderen Forschungsgruppenmitgliedern wurden die Messdaten analysiert und publiziert. In meiner Diplomarbeit[1] befasste ich mich ausführlich mit den medizinischen Grundlagen der Anpassung des Kreislaufs unter der Geburt, sowie den technischen Grundlagen der verwendeten Messgeräte und Messtechnologien. Weiters beschrieb ich die durchgeführte Studie und verglich sie mit den bisher publizierten Daten auf diesem Gebiet. In den letzten 2 Jahren konnten die Ergebnisse in zwei internationalen Zeitschriften publiziert werden. Diese sind Bestand meiner hier vorliegenden kumulativen Dissertation. Wie eingangs erwähnt, beschäftigt sich die Forschungsgruppe mit Veränderungen der zerebralen Gewebssättigung unmittelbar nach der Geburt.

„Der Übergang eines ungeborenen Kindes zu einem lebensfähigen Neugeborenen (NG) bedarf vieler physiologischer und teils komplexer Anpassungsleistungen. Es ist seit vielen Jahren bekannt, dass sich die Sauerstoffverhältnisse in dieser Übergangsphase drastisch verändern. Diese Veränderungen können mittels Pulsoxymetrie gemessen werden. Mit dieser Methode misst man die arterielle Sättigung (SaO_2), die den Prozentsatz an sauerstoffbeladenem Blutfarbstoff Hämoglobin anzeigt. Die engmaschige Überwachung dieser SaO_2 hat heutzutage in der intensiv-medizinischen Überwachung einen großen Stellenwert. Aus wissenschaftlichem Interesse haben sich einige Forschungsgruppen mit der Veränderung der SaO_2 von NG unmittelbar nach der Geburt beschäftigt[2 3 4 5 6 7 8]. Diese erfährt bei gesunden NG innerhalb des Übergangs vom fetalen zum neonatalen Kreislauf einen rapiden Anstieg[4-6]. Bei nicht regelrechtem Ablauf dieser physiologischen Prozesse kann

es zu einer Mangelversorgung durch Sauerstoff (O_2) der Organe kommen. Das Gehirn ist das empfindlichste Organ des Menschen bezüglich O_2-Mangel. Verschiedenste Ursachen vor, während und nach der Geburt können zu einem O_2-Mangel führen und schwerwiegende Konsequenzen für die Entwicklung des Gehirns haben. Trotz aller Fortschritte der modernen Medizin im Bereich der intensivmedizinischen Betreuung von NG stellen hypoxisch-ischämische Gehirnveränderungen noch immer ein großes Problem dar.

Es ist noch weitgehend unerforscht, inwieweit sich die O_2-Verhältnisse im Gehirn unter gesunden Bedingungen unmittelbar nach der Geburt verändern. Mehr Wissen darüber könnte in Zukunft eine abnormale O_2-Versorgung des Gehirns erkennen lassen und für therapeutische Interventionen potentiell hilfreich sein.

Jöbsis[9] beschrieb vor mehr als 30 Jahren eine Methode der Nahinfrarotspektroskopie (NIRS), welche Auskunft über die zerebrale Zirkulation gibt. Mit dieser Methode wurde es möglich, in verschieden Geweben im Körper Informationen über die regionale Gewebssättigung zu erhalten. In den letzten Jahrzehnten wurden einzelne Organsysteme wie die Niere, Gehirn, Leber und auch Muskelgewebe auf ihre O_2-Sättigung näher untersucht. Es gibt auch Studien, die sich mit der zerebralen Gewebssättigung am ersten Lebenstag bei NG beschäftigten[10] [11] [12]. Die Messgenauigkeit und die Aussagekraft dieser Methode stellen weiterhin ein großes Problem dar. Deshalb ist der klinisch-routinemäßige Einsatz bislang noch nicht erfolgt.

Das Ziel meiner Arbeiten war es, im Rahmen einer prospektiven klinischen Studie Informationen über die zerebrale Gewebssättigung in den ersten 15 Lebensminuten bei gesunden NG zu erhalten und eine Korrelation zu den arteriell gemessenen Werten darzustellen. Diese Studie wurde mittels einer Kooperation zwischen der Abteilung für Neonatologie (Universitätsklinik für Kinder- und Jugendheilkunde Graz) und dem Kreißsaal der Universitätsklinik für Gynäkologie und Geburtshilfe Graz möglich.“ [1]

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Regional cerebral oxygen saturation in newborn infants in the first 15 min of life after vaginal delivery

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Abstract

The objective of this study was to evaluate regional oxygen saturation of the brain during immediate transition after birth, and to correlate it with pre-ductal arterial oxygen saturation in newborn infants. The prospective observational study including newborn infants in the first 15 min after spontaneous vaginal delivery and uncomplicated transitional period was undertaken. Regional cerebral oxygen saturation (rSO_2brain) was measured using near-infrared spectroscopy. Arterial oxygen saturation (SpO_2) and heart rate (HR) were measured on the right wrist by pulse oximetry. rSO_2brain, SpO_2 and HR measurements were started immediately after birth and were performed in the first 15 min of life. Cerebral fractional tissue oxygen extraction (FTOE) was calculated for each minute. Of 145 newborn infants, 16 were included and the gender allocation was 31 females (49.2%) and 32 males (50.8%). rSO_2brain increased rapidly from 39% (2 min) to 69% (5 min), SpO_2 increased from 72% (2 min) to 96% (14 min) and FTOE showed a significant decrease from minute 2 (0.47) until minute 4 (0.30) and an increase between 8 to 13 min. rSO_2brain increased rapidly after vaginal delivery. Although SpO_2 increased within the first 14 min after delivery, rSO_2brain showed no further significant changes after 5 min. FTOE decreased in the first 4 min and reached standard values subsequently.

Keywords: near-infrared spectroscopy, neonate, cerebral, oxygenation, transitional period

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Introduction

Arterial oxygen saturation (SpO_2) undergoes tremendous changes during transition from the foetus to newborn. Those changes can be seen clinically in the colour of the newborn's skin turning from cyanotic to pink but also can be measured objectively and non-invasively by pulse oximetry. In 1971, Oski and Delivoria-Papadopoulos (1971) already reported low oxygen saturation levels of about 60% in the newborn immediately after birth. Since then many reports have described the behaviour of oxygen saturation in this first phase of life. The oxygen saturation needs more than 5 min to attain levels >80% and almost 10 min to reach 90% (Kamlin *et al* 2006, Rabi *et al* 2006, Dawson *et al* 2007, House *et al* 1987). However, the SpO_2 measured on the right hand/wrist gives only indirect information on oxygen supply of the brain. As the brain is the most vulnerable organ system regarding oxygen deficiency, the adequate supply of oxygen to the brain is vital to provide accurate functioning.

After the introduction of near-infrared spectroscopy (NIRS) (Jöbsis 1977), the method allowed only the use of relative parameter changes in clinical use for years (Litscher and Schwarz 1997). A new variant of NIRS, called spatially resolved spectroscopy, introduced a new parameter, the regional tissue oxygen saturation (rSO2) (Suzuki *et al* 1999), which is an absolute parameter for calculating the ratio of oxygenated haemoglobin to total haemoglobin. With this technology, it is possible to measure rSO2 in different organ systems (brain, kidney, liver, muscle and others) or body regions (pre- and post-ductal peripheral tissue).

Knowing that SpO_2 changes significantly in the newborn infant after birth, interest has grown to monitor the changes of regional cerebral oxygen saturation (rSO_2brain). Some reports described the rSO_2brain in pre-term infants on the first day of life (Sorensen and Greisen 2009) and during the first weeks of life (Verhagen *et al* 2007, Naulaers *et al* 2002, 2003). Only a few studies measured cerebral oxygenation during the transitional period in healthy term infants (Isobe *et al* 2002, Fauchère *et al* 2010, Urlesberger *et al* 2010, 2011). The majority of studies investigated infants born after caesarean delivery. Therefore, recently we conducted a study, comparing infants after vaginal deliveries and elective caesarean sections (Urlesberger *et al* 2011). The publication focused on behaviour of SpO_2 and rSO_2brain between minutes 3 and 10 after birth. Until now there was no publication of the detailed behaviour of rSO_2brain after spontaneous vaginal delivery. Therefore, this study describes the behaviour of SpO_2 and rSO_2brain from minutes 2 to 15 in these healthy newborn infants after spontaneous vaginal delivery for the first time, and thus presenting physiological data of a perfectly normal transitional process in detail.

Methods

In this prospective observational study, we included newborn infants over 37 weeks of gestational age after uncomplicated pregnancy. Only infants after spontaneous vaginal delivery and uncomplicated transitional period were included. Infants after vacuum/ forceps assisted delivery or caesarean section were excluded. All infants with any suspected malformations, need of respiratory support or supplemental inspired oxygen during transition were excluded.

Instruments

The Invos Cerebral/Somatic Oximeter Monitor (Covidien, Mansfield, MA, USA) was used with the neonatal transducer. The transducer contains a light-emitting diode and two sensors at different distances. The Invos calculates the rSO_2, which is expressed as the percentage of oxygenated haemoglobin (oxygenated haemoglobin/total haemoglobin). The transducer was

positioned on the left fronto-parietal forehead of the infant. The sample rate of rSO_2 was 8 s (0.13 Hz).

SpO_2 and the heart rate (HR) were measured with the Intelli-Vue MMS X2 Monitor (Philips, Eindhoven, the Netherlands). The transcutaneous transducer was placed on the right wrist (pre-ductal) of the infant. Values of the SpO_2 and rSO_2 were stored every second.

Procedure

As soon as the whole body of the infant was delivered, a stopwatch was started to record the age in minutes. Immediately after birth, the skin on the left forehead was cleaned with a towel to reduce the amount of amnion fluid and vernix. Both could have a negative influence on the signal quality detection. Straight after the NIRS transducer was put on the left fronto-parietal region of the infant, the transducer was fixed with a red headband (Medijet nCPAP Bonnet, Size Medium). Subsequently, the transcutaneous pulse oximetry transducer was positioned on the right wrist of the newborn as quickly as possible. In the mean time, the cord was clamped and the infants were placed on the naked skin of the mother's chest to have close skin-to-skin contact. The infants were positioned in prone position and covered with a warm towel. All values were stored continuously in both devices. A neonatologist observed the transition of the newborn infants and recorded Apgar (Apgar 1953) scores at 1, 5 and 10 minutes. The Apgar score is a simple and repeatable method to quickly assess the clinical situation of newborn infants immediately after birth. Five items (skin colour, HR, reflex irritability, muscle tone and respiration) are scored with a range from 0 to 2, and summed up (resulting in ten points for a healthy normal newborn after transition). After 15 min, both transducers and the headband were taken off. Our procedure ensured an uninterrupted bonding phase (relationship) between child and mother, i.e. there was no need to take the child away from the mother as a result of our measurements. All measurements were done by the same investigator (EK).

Quality criteria

To detect and eliminate artefacts, the following quality criteria for rSO_2brain were used. For physiological reasons, the SpO_2 should not be equal or below the rSO_2brain. Such data were considered not to be physiological and, therefore, the arterial as well as the regional saturation values were excluded.

Ethics

The Regional Committee on Biomedical Research Ethics approved the project. Written informed consent was obtained from the mothers/parents before birth of their infant.

Statistics

Mean values of arterial oxygen saturations and rSO_2brain were calculated for each minute after birth. Data are presented as mean and 95% confidence interval (CI). In addition, the 'fractional tissue oxygen extraction' (FTOE) was calculated $(SpO_2–rSO_2\text{brain})/SpO_2$) (Naulaers *et al* 2007). A linear mixed model with a fixed effect for time and a first-order autoregressive covariance structure was used for the calculation of significant differences to endpoint of measurements (15 min value). A p-value of <0.05 (*) was considered statistically significant and a p-value <0.01 (**) as highly significant. Statistical analysis was performed using SPSS 17.0.3 (SPSS Inc., Chicago, IL, USA, 2010).

Table 1. Demographic data and patient's characteristics.

Gestational age (weeks)	40 (1.3)
Birthweight (g)	3370 (437)
Headcircumference (cm)	34.9 (1.4)
APGAR- 1 min	9 (0.5)
APGAR- 2 min	10 (0)
pH umbilical artery	7.28 (0.08)

Mean (SD).

Table 2. Mean (CI) of oxygen saturation parameter, HR and FTOE for minute 2 to minute 15.

Minute	rSO_2brain (%)	SpO_2 (%)	HR (1/min)	FTOE
2	39 (33–46)*	72 (69–76)*	146 (134–158)	0.47*
3	49 (43–56)*	78 (75–81)*	157 (145–169)*	0.38*
4	61 (55–67)*	85 (82–88)*	160 (148–172)*	0.30*
5	69 (63–75)*	89 (86–92)*	160 (148–172)*	0.24
6	73 (67–79)	92 (89–95)*	157 (146–169)*	0.21
7	75 (69–82)	94 (91–97)*	155 (144–167)*	0.19
8	77 (71–83)	95 (92–98)*	153 (142–165)	0.18*
9	78 (72–84)	95 (92–98)*	152 (141–163)	0.18*
10	77 (72–83)	95 (92–98)	152 (141–163)	0.19*
11	77 (72–82)	95 (92–98)*	151 (141–161)	0.19*
12	77 (74–82)	95 (93–98)*	149 (139–159)	0.19*
13	76 (72–81)	96 (93–98)*	148 (139–157)	0.20*
14	76 (72–80)	96 (94–98)*	148 (140–156)	0.21
15	75 (72–78)	97 (95–98)	149 (143–154)	0.22

*Significant differences ($p < 0.05$) to endpoint of measurements (15 min value).

Results

Between October 2009 and August 2010, 134 newborn infants fulfilled inclusion criteria primarily (before delivery). Sixty-one (46%) infants were excluded because the mode of delivery was finally not spontaneous vaginal but vacuum/forceps assisted ($n = 37$) or caesarean sections ($n = 24$). Moreover, four (3%) infants were excluded because they needed respiratory support after delivery and six (4%) were not assessed due to organizational reasons (i.e. two deliveries at the same time). The gender allocation of the remaining 63 (47%) was 32 males and 31 females (table 1).

By 2 min of age, saturation signals could be measured for at least 85% of infants. Therefore, the data presentation begins at 2 min. From minute 4 to minute 15, saturation signals were available for at least 96.8% of the infants. Six (0.7%) out of 812 rSO_2brain values failed quality criteria and subsequently were removed (the corresponding SpO_2 was removed too, six (0.7%) out of 804).

All three measured parameters (rSO_2brain, SpO_2 and HR) and the calculated FTOE are presented in table 2. Mean rSO_2brain increased rapidly from 39% at 2 min to 69% at 5 min; subsequently, no significant changes occurred. Mean SpO_2 increased from 72% at 2 min up to 96% at 14 min. Only at 10 min there was no significant difference, but it was very close to significance ($p = 0.056$). The time course of SpO_2 and rSO_2brain are presented in figure 1 and of FTOE in figure 2. FTOE values show a decline from 0.47 at 2 min to 0.3 at 4 min. Subsequently, a slight increase from 8 min to 13 min was observed.

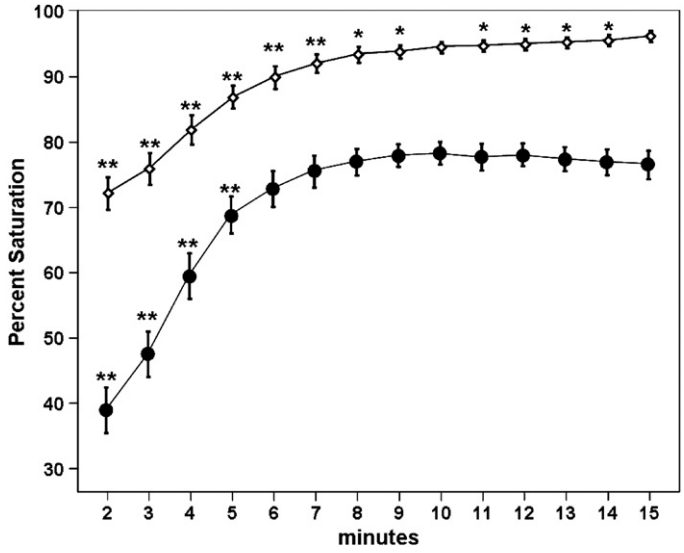

Figure 1. Arterial oxygen saturation (SpO_2) (open diamonds) and regional oxygen saturation of the brain (rSO_2brain) (closed circles) from minute 2—to minute 15 (mean, 95%CI). $^{*}p < 0.05$, $^{**}p < 0.001$: difference to value minute 15.

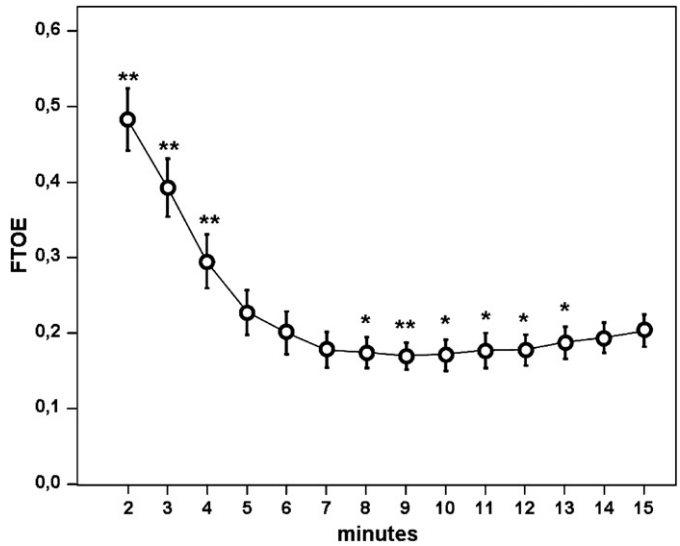

Figure 2. Time course of fractional oxygen tissue extraction FTOE (mean, 95%CI). $^{*}p < 0.05$, $^{**}p < 0.001$: difference to value minute 15.

Discussion

We analysed changes in regional oxygen saturation in the brain and simultaneous changes in pre-ductal SpO_2 during transitional period in healthy newborn infants after spontaneous vaginal delivery. Our group performed these measurements for the first time in a significant number of newborns. The lack of data till now is certainly due to the difficulty to measure

in a delicate situation immediately after vaginal delivery. Nevertheless, we tried to ensure an uninterrupted bonding for mother and child. Comparing spontaneous vaginal delivery and caesarean section we have already analysed data from minute 3 to minute 10[16]. In this study we present data from minute 2 to minute 15 in more detail.

rSO_2 depends on the local balance of oxygen delivery and oxygen consumption, and the regional arterial/venous volume ratio of veins (70–80%), capillaries (5%) and arteries (15–25%) (Watzman *et al* 2000). The main component of tissue oxygen saturation is venous blood, thus representing oxygen saturation after oxygen consumption by the tissue. Therefore, the values for rSO_2 tend to be close to venous oxygen saturation, but do not equate venous saturation (Watzman *et al* 2000).

In our study rSO_2brain showed a significant increase within the first 5 min after birth, thereafter there was no longer any significant change. In contrast to that, SpO_2 values showed a significant increase during the whole observation period (but minute 10). So far all publications on SpO_2 values described a period up to minute 10. Our results show a constant further increase beyond minute 10 until minute 14. These results clearly show a different behaviour of arterial versus rSO_2brain, the latter showing no further increase after 5 min. We speculate, that there may be a difference in oxygen delivery to the brain compared to the body. Recently, we described significantly lower values of SpO_2 and HR in caesarean-delivered infants, but there were no differences in rSO_2 brain values between infants after vaginal and caesarean delivery (Urlesberger *et al* 2011).

Fauchère *et al* (2010) published data on rSO_2brain measured in 17 healthy term infants after caesarean section using a different NIRS device (NIRO 300, Hamamatsu, Japan). They also observed a plateau of rSO_2 after a steep increase until 7 min. Their absolute values for rSO_2 were lower compared to this study using a different measurement device. Isobe *et al* (2002) also investigated healthy term infants after vaginal delivery ($n = 20$) and elective caesarean section ($n = 7$). They did not measure rSO_2brain directly but calculated a value for rSO_2 of the brain. They also observed a plateau of cerebral oxygen saturation 8.5 min after birth (Isobe *et al* 2002). The observational periods differed between those studies: two lasted for 10 min (Fauchère *et al* 2010, Urlesberger *et al* 2010), and one for 15 min (Isobe *et al* 2002).

By calculating the FTOE, information on oxygen consumption is gained (Naulaers *et al* 2003). An increase in fractional oxygen extraction indicates an increase of oxygen consumption because of increased cerebral metabolic rate, or a decreased oxygen delivery, or both (van den Berg *et al* 2010, Kissack *et al* 2005, 2004). In this study, FTOE values are very high in the first few minutes of life. This is probably due to the low oxygen supply in arterial blood at that time (SpO_2 60% at 1 min) so that the brain extracts almost half (FTOE of 0.47) of the available oxygen in the blood. After a few minutes, the percentage of oxygenated haemoglobin in the blood increases so that the brain can extract smaller amount of oxygen to be adequately provided and FTOE values reach standard values of 20–30%. This significant fall in FTOE lasted only until minute 4. Thereafter, an increase of FTOE was observed from 8 to 13 min. The increase was small, and this may not be relevant clinically. We can only speculate about the reasons for this behaviour. Cerebral oxygen delivery is a product of blood flow and oxygen content. On one hand, a decrease in HR with a consecutive decrease in cardiac output may have reduced cerebral oxygen delivery again. There was a trend of decreasing HR at the same time, but there were no significant changes. Nevertheless, it has been shown in a newborn dog model that even significant changes in cardiac output were compensated and did not result in changes in cerebral blood flow (CBF) (Camp *et al* 1982). As SpO_2 did show a significant increase during this period, oxygen content of arterial blood should not have been decreased. Another possible explanation could be first sensory orientation and/or starting motor movements in

this phase of transition. This may lead to higher oxygen demand and therefore to a higher oxygen extraction in the brain.

Our results show that oxygen supply of the brain is provided very quickly although the increase of SpO_2takes much longer. This might indicate some sort of preference of oxygen supply to the brain compared to other organ systems. We recently showed (Urlesberger *et al* 2010) that regional oxygen saturation increase in muscle tissue takes 7 min, whereas the brain showed no significant changes 5 min after birth.

The slight increase after 8 min was an unexpected observance. At that moment there were no corresponding changes in HR or SpO_2.

At the moment we do not know, whether or not rSO_2 of the brain may differ significantly between different regions of the brain. Recently, Lemmers and Van Bel (2009) have shown, that especially during situations with unstable arterial saturation, differences can exist between the left and right hemisphere. Therefore, we used the same fronto-parietal region in all infants.

As we have no detailed information on cardio-circulatory changes, behaviour of CBF and blood gas changes (PaO_2 and $PaCO_2$), we cannot define the impact of these parameters on changes in oxygen saturation parameters. Myocardial function is crucial during haemodynamic transition to extrauterine life. Beside left ventricular output and blood pressure, CBF is furthermore regulated by cerebral autoregulation. Cerebral autoregulation is influenced by changes in PaO_2 and $PaCO_2$. $PaCO_2$ seems to have even more influence on CBF than mean arterial blood pressure (Noori *et al* 2009). There is a negative correlation between $PaCO_2$ and CBF (Sorensen and Greisen 2006). We saw a steep increase of SpO_2, which certainly has influence on cerebral oxygen extraction (Kissack *et al* 2005), but whether there was a concomitant change in CBF is unknown. In the situation of normal transition, one would expect that the increase in SpO_2 (reassuring improving gas exchange via the lungs) would be accompanied by a decrease in pCO_2 (resulting in an increase of CBF).

One has to emphasize, that at the moment comparison of absolute values of rSO_2 has to be done with caution. The absolute value of rSO_2 lacks the precision (Sorensen and Greisen 2006) to be used as a quantitative variable, but it can be used as a trend monitor with helpful clinical information (van Bel *et al* 2008). Comparison of values of rSO_2 attained with different technical devices may be problematic (Thavasothy *et al* 2002, Gagnon *et al* 2002). However, there are some comparative studies done between the two most used devices: the INVOS system and the NIRO 300 (Hamamatsu, Japan) (Thavasothy *et al* 2002, Gagnon *et al* 2002). The standard deviation of the difference between the two monitors was 7.5%, but they showed a very good correlation of the trend values (Pryds *et al* 1988).

In conclusion, this paper is able to show a rapid increase of cerebral oxygen saturation in newborn infants during the first few minutes after vaginal delivery. Further studies are needed to gain more normative data from healthy term infants. These studies will show the potential value of rSO_2 measurements of the brain during neonatal transition (and define their value in evaluation of the use of supplemental oxygen at the resuscitation table in future).

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Regional Oxygen Saturation of the Brain during Birth Transition of Term Infants: Comparison between Elective Cesarean and Vaginal Deliveries

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Objective To evaluate differences in regional oxygen saturation of the brains of term infants of vaginal or cesarean deliveries.

Study design Vaginal delivery (n = 63) and elective cesarean delivery infants were prospectively evaluated for the first 10 minutes after delivery. Peripheral arterial oxygen saturation (SpO_2) and heart rate were measured on the right hand using pulsoximetry with near infrared spectroscopy. Regional oxygen saturation of the brain (rSO_2brain) was measured. Fractional tissue oxygen extraction was calculated for each minute.

Results From 4 to 8 minutes, SpO_2 values for cesarean delivery infants were significantly lower than for vaginally delivered infants. Heart rate of the cesarean delivery infants was significantly lower throughout the whole observation period. There was no difference between groups in rSO_2brain. Fractional tissue oxygen extraction only differed at minute 10.

Conclusions Although SpO_2 and heart rate were significantly lower in cesarean-delivered infants, there were no differences in rSO_2brain with respect to mode of delivery. *(J Pediatr 2011;159:404-8)*.

The transition from fetus to newborn is a complex physiological process. In recent years, interest has grown in the use of pulsoximetry to monitor arterial oxygen saturation during this transitional period.[1-3] All newborn infants have oxygen desaturation at birth. A newborn infant undergoing normal postnatal transition needs more than 5 minutes to attain an arterial oxygen saturation >80% and almost 10 minutes to reach 90%. Several studies have shown that there are significant differences in the time course of arterial oxygen saturation (SpO_2) according to the mode of delivery. Newborn infants after elective caesarean delivery have lower SpO_2 values during transition compared with infants after vaginal delivery.[1-3]

There is an ongoing discussion about the use of supplemental oxygen during neonatal resuscitation because it is not known which oxygen concentration is appropriate for preterm and term infants during resuscitation.[3,4] Because the brain is the most vulnerable organ system of the infant, a more direct way to assess its oxygenation in a simple noninvasive way would be useful. A new approach to cerebral oxygenation is to measure regional oxygen saturation using near infrared spectroscopy (NIRS).

Spatially resolved spectroscopy, a new NIRS method, was recently introduced for evaluation of regional oxygen saturation (rSO_2).[5] With this technology, it is possible to measure regional tissue oxygen saturation in different organ systems (brain, kidney, liver, muscle, and others) or body regions (preductal and postductal peripheral tissues). There are some reports of regional oxygen saturation of the brain (rSO_2brain) on the first day of life,[6-10] during the first weeks, and during birth transition.[11-13]

A question remains as to whether rSO_2 of the brain shows significant differences during transition according to mode of delivery in analogy to SpO_2 behavior. Therefore, we measured rSO_2 brain in newborn infants after vaginal delivery and elective cesarean delivery to evaluate whether there was a significant difference.

Methods

In this prospective, observational study, we included newborn infants >37 weeks gestational age delivered after an uncomplicated pregnancy. Two groups were formed according to the mode of delivery, either vaginal delivery or delivery by elective cesarean delivery. All infants with malformations were excluded. Only infants after uncomplicated vaginal delivery were included. Infants from vacuum-assisted or forceps deliveries were excluded. All infants in need of any respiratory support or supplemental inspired oxygen during transition were excluded. Only infants with uncomplicated transitional periods were included.

CBF	Cerebral blood flow
HR	Heart rate
NIRS	Near infrared spectroscopy
rSO_2	Regional oxygen saturation
rSO2 brain	Regional oxygen saturation of the brain
SpO_2	Peripheral arterial oxygen saturation

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For NIRS measurements, the Invos Cerebral/Somatic Oximeter Monitor (Covidien, Mansfield, Massachusetts) was used with the neonatal transducer. The transducer contains a light-emitting diode and two sensors at different distances. The Invos calculates the rSO_2, which is expressed as the percentage of oxygenated hemoglobin (oxygenated hemoglobin/total hemoglobin). The transducer was positioned on the left frontoparietal region of the forehead of each infant, regardless of mode of delivery. The sensor on the forehead was secured with a bandage. Arterial oxygen saturation and heart rate (HR) were measured with the IntelliVue MP30 Monitor (Philips, Eindhoven, The Netherlands) in the cesarean delivery group and the IntelliVue MMS X2 Monitor (Philips) in vaginal delivery group. The transducer was placed on the right hand/wrist. In the cesarean delivery group, blood pressures were measured once 5 minutes after birth with the IntelliVue MP30 Monitor (Philips). Rectal and peripheral temperatures were measured with the IntelliVue MP30 Monitor (Philips).

All variables were stored continuously in a multichannel system, "alpha-trace digital MM" (B.E.S.T. Medical Systems, Vienna, Austria), for subsequent analysis. Values of the arterial and regional oxygen saturation were stored every second, and the sample rate of rSO_2 was 8 seconds (0.13 Hz). The Regional Committee on Biomedical Research Ethics approved the project. Written informed consent was obtained before the birth of the infant.

Procedure

A stopwatch was started when the cord was clamped.

Vaginal Delivery Group

Immediately after birth, the NIRS transducer was applied to the left forehead (rSO_2brain), and, concurrently, transcutaneous pulsoximetry was started on a preductal level (right hand) (SpO_2). After that, the child was given to the mother, and for the rest of the 10-minute transition period, the infant was positioned in prone position on the mother's chest. A neonatologist observed the transition of the newborn infant and recorded APGAR scores at 1, 5, and 10 minutes. Measurement of blood pressure and rectal temperature were omitted because of the delicate measurement situation immediately after delivery and to ensure an uninterrupted bonding of mother and child.

Cesarean Delivery Group

All infants were dried and wrapped with warmed towels. Immediately after arrival at the resuscitation table, the NIRS transducer was applied to the left forehead (rSO_2-brain), and transcutaneous pulsoximetry was started on a preductal level (right hand) (SpO_2). The infant was positioned supine and was breathing room air. A neonatologist observed the transition of the newborn infant and recorded APGAR scores at 1, 5, and 10 minutes. A clinical assessment at 10 minutes was done before the newborn infant was given to the parents. Fractional tissue oxygen extraction was calculated for each minute $[(SpO_2\text{-}rSO_2)/SpO_2]$ [xiv].[14]

Quality Criteria

To detect and eliminate artifacts, the following quality criteria for rSO_2 measurements were used. For physiological reasons, the SpO_2 should not be equal or below the rSO_2. Such data were considered to be not physiological, and therefore the arterial as well as the regional saturation values were excluded. Furthermore, if $\geq$5 rSO_2 data in any category failed quality criteria ($\leq$50% data completeness), the patient was excluded from the study.

Statistics

Mean values of arterial oxygen saturations and regional oxygen saturations were calculated for each minute after birth. Data are presented as mean and 95% CI or mean $\pm$ SD. A linear mixed model with a fixed effect for time and a first-order autoregressive covariance structure was used for calculation of significant differences between both groups. To compare patient characteristics, *t* tests were used. A *P* value of <.05 was considered significant. Statistical analysis was performed using SPSS 17.0.3 (SPSS Inc, Chicago, Illinois, 2009).

Results

Between October 2009 and August 2010, 185 infants fulfilled inclusion criteria and thus were included in the study (all before delivery). In the cesarean delivery group, 51 newborn infants fulfilled inclusion criteria initially. Two infants (4%) were excluded because of the need of respiratory support after delivery. Five infants (10%) were excluded because SpO_2 values were not able to be measured within 10 minutes. The sex allocation of remaining 44 infants in the cesarean delivery group was 23 male and 21 female (Table).

In the vaginal delivery group, 134 infants fulfilled inclusion criteria initially (before delivery). Four (3%) infants were excluded because of the need of respiratory support after delivery, six infants (4%) were not assessed because of organizational reasons (two deliveries at the same time), and 61 (46%) infants were excluded because they failed vaginal delivery (24 infants, cesarean delivery; 35 infants, vacuum-assisted delivery; and two infants, forceps delivery). The sex allocation of remaining 63 infants in vaginal delivery group was 32 male and 31 female (Table).

Table. Demographic data and patients characteristics

	Cesarean delivery	Vaginal delivery
Gestational age, wk	38.5 (1.1)	40 (1.3)
Body weight, g	3197 (448)	3369 (437)
Head circumference, cm	34.6 (1.1)	34.9 (1.4)
APGAR: 1 min	9 (0.2)	9 (0.5)
APGAR: 5 min	10 (0.15)	10 (0)
pH Umbilical artery	7.29 (0.03)	7.28 (0.08)
Mean arterial blood pressure, mm Hg	49.3 (8.6)	
Temperature rectal, Celsius	36.7 (0.04)	

Values are mean (SD).

By 3 minutes, both saturation signals (rSO_2 and SpO_2) could be measured for at least 90% of infants. Therefore, the data presentation begins at 3 minutes. In the cesarean delivery group, 10 (1.8%) of 559 rSO_2 values failed quality criteria and subsequently were removed (the corresponding SpO_2 values also were removed, 10 (1.8%) of 556). In the vaginal delivery group, six (0.7%) of 812 rSO_2 values failed quality criteria and subsequently were removed (the corresponding SpO_2 value also was removed, six (0.7%) of 804).

From 4 to 8 minutes, SpO_2 values of the cesarean delivery group were significantly lower. HR of the cesarean delivery group was significantly lower throughout the whole observation period (Figure 1). There was not any difference between the groups in rSO_2brain. Fractional tissue oxygen extraction only differed at minute 10 (Figure 2).

Discussion

We analyzed changes of the regional tissue oxygen saturation of the brain and simultaneous changes of the preductal arterial oxygen saturation during transition in a large group of healthy infants after vaginal delivery in comparison with cesarean delivery infants. Regional tissue oxygen saturation depends on the local balance of oxygen delivery and oxygen consumption and the regional arterial/venous volume ratio,

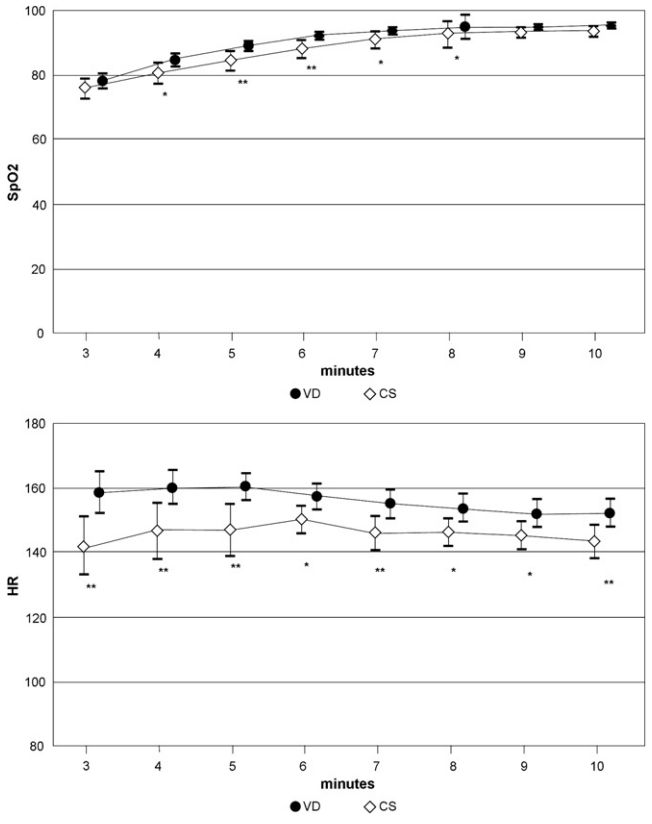

Figure 1. Course of arterial oxygen saturation and heart rate (mean, 95% CI; *$P < .05$, **$P < .001$, comparison between groups).

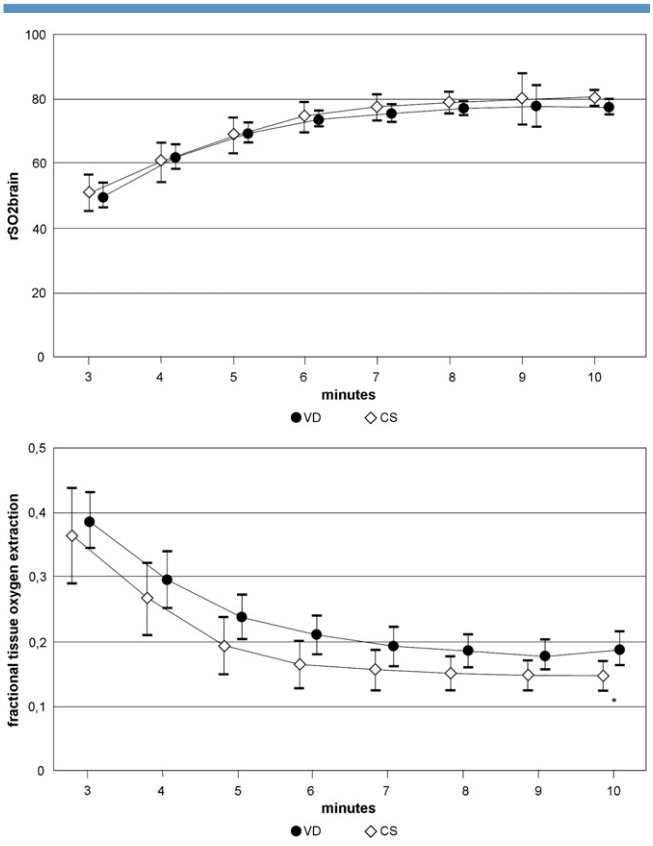

Figure 2. Course of regional cerebral oxygen saturation and fractional tissue oxygen extraction (mean, 95% CI; * $P < .05$, comparison between groups.

reflecting oxygen saturation in veins (70% to 80%), capillaries (5%) and arteries (15% to 25%).[15] The main component of tissue oxygen saturation is venous blood, thus representing oxygen saturation after oxygen consumption by the tissue. Therefore, the values for regional oxygen saturation tend to be close to venous oxygen saturation but do not equate venous saturation.[15]

Rabi et al[2] demonstrated that term infants born by cesarean delivery had modestly lower oxygen saturations and required longer to reach a stable oxygen saturation ≥85% in the immediate newborn period compared with infants born vaginally. The mean difference at 5 minutes was 3%. Very similar results were reported by Kamlin et al.[1] Recently, Dawson et al[16] showed in a large group of patients that there were significantly lower SpO_2 values in infants delivered by cesarean birth from 1 until 5 minutes after birth. Thereafter, the SpO_2 values did not differ. Furthermore, Dawson et al[17] did show that HR was significantly lower in newborn infants after cesarean delivery (from 2 to 10 minutes). Therefore, the course of the SpO_2 and HR values of the present study are in accordance with the literature.

Although there were significantly lower SpO_2 and HR values in the cesarean delivery group, there was not any significant difference in rSO_2brain between both groups. Years ago, before spatially resolved spectroscopy was introduced

to measure rSO_2, Isobe et al[11] calculated a value for regional cerebral oxygen saturation in a small number of infants (6 infants after cesarean delivery, 20 infants after vaginal delivery) during transition. They, too, did not find a significant difference in cerebral oxygen saturation within the first 10 minutes of life. It is difficult to differentiate whether oxygen delivery and/or oxygen consumption of the brain were different between the two groups. Cerebral oxygen delivery is a product of blood flow and oxygen content. Because cardiac output in neonates is mainly influenced by HR, one would expect a reduction in oxygen delivery with reduced HR (cesarean delivery group). Nevertheless, in a newborn dog model, even significant changes in cardiac output were compensated and did not result in changes in cerebral blood flow (CBF).[18] Because oxygen content of the arterial blood also influences oxygen delivery, significantly lower SpO_2 in the cesarean delivery group would be expected to result in reduced cerebral oxygen delivery. Nevertheless, in a newborn lamb model, changes of arterial oxygen content were accompanied by reciprocal changes in CBF to maintain constant cerebral oxygen delivery.[19] The authors of both studies explained their results by cerebral autoregulatory response mechanisms.

The fractional tissue oxygen extraction may give information on differences in oxygen extraction and/or consumption.[1,20,21] Cerebral oxygen extraction is inversely correlated to oxygen delivery in preterm infants.[20,21] In these studies, there was no correlation of changes in mean arterial blood pressure and cerebral fractional oxygen extraction. In our study, there was a trend to lower values in cesarean delivery group, but only at 10 minutes was there a significant difference. As extraction is increased with decreased oxygen content, one would have expected that lower oxygen delivery in the cesarean delivery group (due to significantly lower HR and SpO_2) would result in increased instead decreased extraction values to explain missing differences in rSO_2brain. Because it is the other way around, behavior of rSO_2brain cannot be explained with differences in oxygen extraction. Therefore, observations of our study may be due cerebral autoregulatory response.

Vaginally delivered infants had significantly higher catecholamine levels at birth compared with infants born by cesarean delivery.[22] In hemodynamically stable near-term sheep, dopamine infusion was associated with cerebral vasoconstriction.[23] Therefore, besides autoregulation, one further explanation for our observation may be that rSO_2brain after vaginal delivery was reduced as the result of catecholamine-induced vasoconstriction.

The present study has some shortcomings. At the moment, we do not know whether or not rSO_2 of the brain may differ significantly between different regions of the brain. Recently, Lemmers et al[24] showed that especially during situations with unstable arterial saturation, differences can exist between the left and right hemispheres. Therefore, we used the same frontoparietal region (left side) in all infants. We calculated the power of the present study. Estimating a mean difference of 10% of rSO_2brain as significant, the probability of type II error is 0.02.

Because we have no detailed information on cardiocirculatory changes, behavior of CBF, and blood gas changes (PaO_2 and $PaCO_2$), we cannot define the impact of these variables on changes in oxygen saturation. Myocardial function is crucial during hemodynamic transition to extrauterine life. Besides left ventricular output and blood pressure, CBF is furthermore regulated by cerebral autoregulation. Cerebral autoregulation is influenced by changes in blood gas (PaO_2 and $PaCO_2$). $PaCO_2$ appears to have even more influence on CBF than mean arterial blood pressure.[25] There is a positive correlation between cerebral rSO_2 and $PaCO_2$ and a negative correlation between fractional tissue oxygen extraction and $PaCO_2$.[26] We saw a steep increase of SpO_2, which certainly has influence on cerebral oxygen extraction,[20] but, whether there was a concomitant change in CBF is unknown. In the situation of normal transition, one would expect that the increase in SpO_2 (reassuring improving gas exchange via the lungs) would be accompanied by a decrease in $PaCO_2$ (resulting in a decrease of rSO_2).

We emphasize that comparisons of absolute values of rSO_2 must be done with caution. The absolute value of regional tissue oxygen saturation lacks the precision[27] to be used as a quantitative variable, but it can be used as a trend monitor with helpful clinical information.[28] Comparison of values of rSO_2 attained with different technical devices may be problematic.[29,30] However, there are some comparative studies between the two most used devices, the INVOS system and the NIRO 300 (Hamamatsu, Japan).[29,30] The standard deviation of the difference between the two monitors was 7.5%, but they showed a very good correlation of the trend values.[30] Furthermore, because the calculation of cerebral fractional tissue oxygen extraction values uses cerebral rSO_2 but preductal SpO_2 values, there must be some caution with interpretation.

In conclusion, we show that rSO_2brain remained unchanged in situations with significant changes in HR and SpO_2. Therefore, oxygen delivery to the brain cannot be estimated reliably with SpO_2. Further studies are needed in term and preterm infants to gain normative data from a range of infants. These studies show the potential value of rSO_2 measurements of the brain during neonatal transition and demonstrate their value in the evaluation of supplemental oxygen for resuscitation. ■

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Diskussion

Beide vorgelegten Publikationen beinhalten eine ausführliche Diskussion, sodass dieser Teil lediglich eine kleine Zusammenfassung beinhaltelt und kürzlich erschienene Publikationen auf diesem Gebiet erwähnt.

In der Literatur findet man nur wenige direkt vergleichbare Studien. Beide vorgelegten Arbeiten beschäftigen sich mit den physiologischen Veränderungen der zerebralen Oxygenierung unmittelbar nach der Geburt. In Publikation I handelt es sich um gesunde Neugeborene (n=63) nach Spontangeburt. „Der Grund für die wenig vorhandenen Studien bei spontan geborenen Kindern ist am ehesten aus ethischen und organisatorischen Gründen gegeben. Um diese Messungen zu erhalten, muss die Intimsphäre einer Geburt zu einem gewissen Grad gestört werden. Es bedarf vieler organisatorischer, persönlicher und technischer Faktoren, um eine solche Studie durchzuführen zu können.“[1]

In Publikation II bestand das Patientenkollektiv zusätzlich auch aus gesunden NG nach Kaiserschnitt. Diese werden ohnehin primär zur Erstversorgung vom Kinderarzt betreut, und damit räumlich von der Mutter getrennt. Somit entstanden keine zusätzlichen Unterbrechungen bzw. Störfaktoren der Mutter-Kind-Interaktion während der ersten 15 Lebensminuten. Die Väter durften nach einigen Minuten ihr NG sehen und nach der Messphase zu sich nehmen.

Zusammengefasst konnte Publikation I einen signifikanten und raschen Anstieg der rSO_2brain in Lebensminute (LM) 1-5 zeigen. Die SaO_2 hingegen zeigte einen langsameren signifikanten Anstieg von LM 2-15.

In Publikation II wurden SaO_2, rSO_2brain, HF und FTOE Werte in den ersten 15 LM bei NG bezüglich ihres Geburtsmodus (Kaiserschnitt versus Spontanpartus) miteinander verglichen. Dabei konnte gezeigt werden, dass NG nach Kaiserschnitt (n=43) zwischen LM 4-8 signifikant niedriegere SaO_2 Werte sowie eine niedrigere HF während des gesamten Messzeitraumes hatten. Bezüglich der rSO_2brain konnte jedoch kein Unterschied zwischen den Gruppen beobachtet werden.

Eine erst kürzlich veröffentlichte Arbeit von Almaazmi et al.[13] verglich ebenfalls die zerebrale Oxygenierung bei NG in den ersten 10 LM nach Kaiserschnitt (n=22), Spontanpartus (n=20) und Vakuumextraktion (n=2). In dieser Publikation konnte ebenfalls kein Unterschied bezüglich der zerebralen Oxygenierung zwischen den 3 Gruppen festgestellt

werden. Die mediane zerebrale Gewebssättigung betrug in LM 2 36-42% und stieg auf 62-77% in LM 8 an.

Fuchs et al. [14] beschrieb erstmals die zerebrale Oxygenierung bei 51 extrem Frühgeborenen (medianes Gestationsalter 27,8 Schwangerschaftswoche). In diesem Kollektiv konnte ein Anstieg von rSO_2brain-Werte von 37% am Ende der LM 1 auf 61-84% in LM 7 beobachtet werden. Damit konnten die Autoren erstmals zeigen, dass auch bei extrem Frühgeborenen die Messung der zerebrale Oxygenierung in den ersten Lebensminuten möglich ist.

„Faucheré et al [12] untersuchten mit Hilfe einer anderen NIRS-Technik 20 NG nach Kaiserschnitt und konnten auch ein rSO_2brain Plateau nach 7 Minuten zeigen. Isobe et al.[11] beschrieben in ihrer Studie die Messung von 7 NG nach Spontangeburt. In dieser Studie wurde aber wiederum eine andere Messart verwendet, sodass diese nur indirekt miteinander vergleichbar sind. Sie beschreiben ebenfalls einen Anstieg der zerebralen Gewebssättigung mit nachfolgendem Plateau 8,5 Minuten nach der Geburt.“[1]

„Die Interpretation und die Vergleichbarkeit verschiedener Geräte bei der Messung der regionalen Sättigung muss mit Vorsicht geschehen[15]. Die bisher entwickelten Technologien weisen eine schlechte Präzision auf[16]. Van Bel et al[17] verfassten eine Arbeit über den Wert und die Mängel des Monitorings von der regionalen zerebralen Gewebsoxygenierung bei NG. Aufgrund der großen intra- und interpersonellen Variabilität kann diese Technik nicht als robuste quantitative Messung der zerebralen Oxygenierung herangezogen werden. Verwendet man diese Technik jedoch bloß als Trendmonitoring des individuellen Patienten, könnte dies hilfreiche klinische Informationen bringen[17]. Auch der Vergleich verschiedener Studien, die rSO_2brain Werte erheben, ist aufgrund der verschiedenen verwendeten Technologien sehr schwierig[18].“[1] Die unterschiedlichen Technologien basieren auf verschiedenen Berechnungen bezüglich arteriellen und venösen Sättigungsanteilen[19,20] sowie unterschiedlich großen Sensoren[21].

Eine neue Technologie mit Laserlicht (FORE-SIGHT) verspricht eine bessere Übereinstimmung der zerebral gemessenen Werte mit invasiv gemessenen.[22,20]

Zusammengefasst kann man sagen, dass mittels NIRS eine niedrige zerebrale oder andere Gewebssättigung nicht-invasiv detektiert werden kann. Dies kann hilfreiche klinische Hinweise auf eine niedrige kardiale Auswurfleistung geben bzw. eine niedrige Perfusion des Gewebes anzeigen[23].

Gerade in der Erstversorgung kranker Neu- und Frühgeborener gibt es weltweit noch keine einheitlichen Richtlinien, welche genauen Sauerstoffsättigungen erreicht werden sollen und

die damit verbundene Menge an supplementärem Sauerstoff. Die Kurz- und Langzeitfolgen von Hyperoxygenierung in der Erstversorgung sind noch nicht ausreichend erforscht.
Inwieweit die zerebrale Gewebsoxygenierung ihren Stellenwert in der diagnostischen Routine finden wird, ist bisher unklar. Dafür sind noch viele Studien in den nächsten Jahren notwendig. Viele Arbeitsgruppen beschäftigen sich aktuell mit der Erstellung der Normwerte für die verschiedenen Altersgruppen und Krankheitsbilder in der Neonatologie.

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