Original articles

J. Perinat. Med.
4 (1976) 72

Oxygen consumption, heart rate, respiratory rate and rectal temperature in healthy newborns during the first two hours after birth

Ch. Schubring, C. F. Michel, W. Höbel

With the assistance of R. Goetz

From the Division of Perinatology, Center for Obstetrics and Gynecology, Hospitals of the Justus Liebig University, Gießen (Acting Chairman: Professor Dr. R. KEPP); Department of Obstetrics and Gynecology of the Regional Hospital, Wetzlar, Institute for Medical Statistics and Documentation, Justus Liebig University, Gießen (Acting Chairman: Professor Dr. J. DUDECK), Germany

The measurement of the oxygen consumption in the neonatal period has been described by several authors [1, 2, 3, 9, 10, 13]. In earlier reports we have described the methodology of the continuous measurement of oxygen consumption and our first results in newborns [7, 11, 12]. The novel feature of our investigations is its application. While NEUHOF [8] was able to demonstrate the clinical usefulness of measuring oxygen consumption for early diagnosis and management of adult patients in shock, we wished to assess the usefulness of measuring oxygen consumption as a parameter to be monitored in the newborn. The continuous registration of oxygen uptake offers a good assessment of the total oxydative metabolism and thus gives an overall assessment of the vital functions of the organism.

1.1 Methods

We adopted for the use in newborn and premature infants the apparatus developed by NEUHOF [8] for continuous measurement of oxygen consumption in adult patients in shock. The methodology and their apparatus have been described elsewhere [7]. The infants were cared for after birth in the usual fashion and are positioned with the head under a plastic hood through which by means of a pump a constant air flow of 5–6 l/min is being suctioned. The

Curriculum vitae

Dr. CHRISTIAN SCHUBRING was born in 1941 after attending the Universities of Gießen, Würzburg, and Kiel and was graduated in 1969 from the University of Marburg Medical School. In 1971 he joined the staff of the Department for Obstetrics and Gynecology of the Justus Liebig University in Gießen (Acting Chairman: Professor Dr. R. KEPP). He qualified as a specialist in Obstetrics and Gynecology in 1975. His principal areas of interest are: perinatal medicine; continuous measurement of oxygen consumption in the newborn; and monitoring of newborns and prematures.

flow is regulated so that the ambient temperature in the hood is in the range of 30.5°–30.9° C. In our initial experiment we determined the influence of various rates of flow on the oxygen consumption. It was seen that characteristics of the flow under the hood had no recognizable negative influence on the oxygen consumption with the flow rates utilized. The relative humidity in the air varied between 50% and 100%. We corrected partially the volumes which were suctioned out to an air humidity of 75%. The oxygen difference between the air entering the hood and that being suctioned out was measured continuously with the Oxytest apparatus and was recorded

graphically. The results were corrected to STPD (standard, temperature, pressure, dry) conditions. The principle of the measurement is based on the high magnetic susceptibility of oxygen which is much larger than that of most other gases. The gas to be measured from the hood and the control gas from the ambient air surrounding the hood are suctioned as two partial streams into two chambers in the Oxytest apparatus. There they are exposed to an inhomogeneous magnetic field. Because of the magnetic characteristics of oxygen a pressure difference in the two chambers is generated if there is a differential oxygen concentration. This is indicated by a differential pressure gauge. Simultaneously, the respiratory and heart rates were continuously measured. A thermistor probe which was inserted at least 8 cm into the infant's rectum [6] registered the rectal temperature. The studies were done in a warming bed, the temperature of which was regulated at 37°C. Immediately after the birth an umbilical venous catheter was placed in order to obtain samples for blood gas analysis. The results of this study will be reported elsewhere.

1.2 Material

We examined 32 newborns who had been born spontaneously after a normal pregnancy. The mean birth weight was 3343 ± 399 grams. Blood gas analyses yielded normal values.

2 Results

Fig. 1 contains the individual values and means of the oxygen consumption as a function of time.

Fig. 1. Individual values and means for oxygen consumption as a function of time.

Both variables do not follow a normal distribution. Fig. 2 depicts the medians and ranges of the simultaneously obtained measurements of oxygen consumption, rectal temperature, respiratory rate and heart rate during the first two hours after birth. The oxygen consumption falls from the beginning of the observation until the 120th minute. Respiratory and heart rates show a similar course. The rectal temperature rises during the observation. The dependence of oxygen consumption from time can be approximated as a linear function. Regression analyses for this linear model showed a significant regression for 26 of the 32 infants, i.e. the regression co-efficient was significantly different from zero. A comparison of the individual regression lines for parallelity, resulted in significant F-values, thus indicating that the regression lines are not parallel. The oxygen consumption does not decline evenly in all infants. Fig. 3 demonstrates that oxygen consumption, respiratory rate and heart rate of an individual infant dropped throughout the observation while the rectal temperature in this

Fig. 2. Medians and ranges for oxygen consumption, rectal temperature, respiratory rate and heart rate.

Fig. 3. The monitoring record of a newborn.

case remains constant at 36.6° C. After the 60th postpartum minute a correlation between oxygen consumption and heart rate can be recognized in the infants examined. The correlation co-efficients from this point on are significantly different from zero (Tab. I).

Tab. I. KENDALL rank correlation. The Table contains the correlation co-efficient τ , the transformed value z and the probability factor p the correlation is between oxygen consumption and heart rate.

min	τ	z	p
15	-.0077	-.0589	.4765
30	-.0379	-.2885	.3826
45	.1673	1.2741	.1013
60	.2904	2.2117	.0135
75	.2677	2.0386	.0207
90	.3579	2.7260	.0032
105	.4244	3.2321	.0006
120	.4061	3.0924	.0010

At all times during the observation period there is a positive correlation between heart rate and oxy-

gen consumption because the tests for parallelity of the regression curve yields a non-significant F-value (Fig. 4). The common regression equation is

Fig. 4. Heart rate as a function of oxygen consumption, regression equation: $y = 98.09 + 5.68 \text{ oxygen}$.

$y = 98.09 + 5.68 \text{ ml O}_2$. There is no correlation between respiratory rate and oxygen consumption in the first two hours after birth; similarly there is no correlation between rectal temperature and oxygen consumption.

3 Discussion

The thermal regulation of the newborn has a significant influence on the oxygen consumption as has been shown by BRÜCK as well as PRIBYLOVA et al. in several studies [2, 3, 4, 9, 10] with varying ambient temperatures. In our studies we have maintained an ambient temperature of 30.5° to 30.9° C with a stable delivery room environment. A comparison of our results with those in the literature [3, 5, 10, 13] is difficult because the results were obtained during various ages of the newborn and by different methods (Tab. II).

Our studies aim to achieve a good reproducibility of the results in order to demonstrate the simplicity and clinical usefulness of the continuous measurement of oxygen consumption. The calibration of the apparatus is simple and offers great accuracy because of the strict linearity of the registration

[7]. In the first two hours after birth 26 of 32 infants examined demonstrated a nearly linear correlation between their oxygen consumption and time. Mostly probably multiple factors cause this arithmetical interrelation. This may explain that the approximate linear function is not apparent in some infants. The initial high oxygen consumption has its origin in the adaptive processes of the newborn for the new environment. The respiratory rate does not relate to the oxygen consumption. This may be explained by the irregular respiration of the newborn in the first two hours after birth. The rectal temperature is 36.5° C after 45 minutes and rises to 37.2° C towards the end of the observation. This temperature gradient is within the range of thermal neutrality for mature infants. At all times sampled, we registered a positive dependence of the heart rate from the oxygen consumption. After the 60th minute there is a correlation between heart rate and oxygen consumption. This interrelation between oxygen consumption and one of the most important variables in the circulatory feedback system in the first two hours after birth, i.e. the heart rate, is of great importance for the monitoring of newborns.

Tab. II. Oxygen consumption in various time periods after birth (MOC = minimal oxygen consumption)

	Age from birth	Environmental temperature $^\circ$ C	Weight grams	n	Oxygen consumption ml/kg min
K. BRÜCK et al.	days				
	25	32,4–32,7	2530	1	9,67 (moc)
	8	32,8–34,0	2040	1	7,00 (moc)
	33	32,0–32,5	2010	1	6,70 (moc)
	9	32,5–33,5	2160	1	7,07 (moc)
K. W. CROSS et al.	days				
	$4,89 \pm 2,93$		$\bar{x} = 3140 \pm 280$	11	$6,83 \pm 0,68$
H. PRIBYLOVA et al.	min				
	5–65	29°	$\bar{x} = 3400 \pm 176$	31	$4,29 \pm 0,91$
	5–65	34°	$\bar{x} = 3400 \pm 176$	31	$5,19 \pm 1,09$
J. W. SCOPES et al.	hours				
	0–6		$\bar{x} = 3322$	11	$4,63 \pm 0,30$
Own results	min				
	15–	30,5–30,9	$\bar{x} = 3343 \pm 399$	32	$6,85 \pm 0,70$
	180	30,5–30,9	$\bar{x} = 3343 \pm 399$	32	$4,67 \pm 1,17$

Summary

A report is made on the continuous registration of oxygen consumption, heart rate, respiratory rate and rectal temperature in 32 neonates during the first two hours of life. A short account of the registration technique is given. A comparative study shows, that oxygen consumption, heart rate and respiratory rate fall during the period of observation, whereas the rectal temperature rises. 26 out of the 32 neonates demonstrated a approximately linear fall of each of the oxygen consumption values during the period of observation. There is a similar relationship, which is statistically verified, between the oxygen uptake and heart rate. Oxygen consumption and heart rate can be correlated with each other after the first 60 minutes of

life. This close and direct relationship between the oxygen consumption and the heart rate, an important parameter of the heart and circulatory system, stresses clearly the importance of the continuous registration of oxygen consumption for monitoring the general condition of the neonate. A change from this situation means a risk for the neonate which must be clarified by blood-gas analysis. A continuous registration of oxygen uptake for the surveillance of the neonate includes numerous vital functions and appears to be a more suitable parameter than single parameters which include only partial functions. The application of the method is simple and safe for the infant.

Keywords: heart rate, neonate, oxygen consumption, rectal temperature, respiratory rate, surveillance of the neonate.

Zusammenfassung

Sauerstoffverbrauch, Herzfrequenz, Atemfrequenz und Rektaltemperatur bei gesunden Neugeborenen in den ersten 2 Stunden nach der Geburt

Es wird über kontinuierliche Messungen des Sauerstoffverbrauches, der Herzfrequenz, der Atemfrequenz und der Rektaltemperatur bei 32 Kindern in den ersten 2 Stunden nach der Geburt berichtet. Ein kurzer Überblick über die Methodik der Messung wird gegeben. Eine vergleichende Betrachtung zeigt, daß Sauerstoffverbrauch, Herzfrequenz und Atemfrequenz im Beobachtungszeitraum abnehmen. Die Rektaltemperatur steigt an. Bei 26 von 32 Kindern kommt es im Beobachtungszeitraum zu einem annähernd linearen Abfall der Einzelwerte des Sauerstoffverbrauches. Es besteht eine gleichsinnige Beziehung zwischen Sauerstoffaufnahme und Herzfrequenz,

die statistisch gesichert ist. Ab der 60. Minute post partum läßt sich eine Korrelation zwischen Sauerstoffverbrauch und Herzfrequenz errechnen. Diese enge direkte Beziehung des Sauerstoffverbrauches zur Herzfrequenz, einer der wichtigen Stellgrößen des Herz-Kreislauf-Systems, verdeutlicht noch mehr die Aussagekraft der kontinuierlichen Messung des Sauerstoffverbrauches für den Gesamtzustand des Kindes. Eine Abweichung von dieser Beziehung deutet auf eine Gefahrensituation für das Kind hin, die durch Blutgasanalyse abgeklärt werden sollte. Die kontinuierliche Registrierung der Sauerstoffaufnahme erfaßt zahlreiche vitale Funktionen global und erscheint als Parameter zur Überwachung von Neugeborenen besser als Einzelparameter geeignet zu sein, die nur Teilfunktionen erfassen. Die Anwendung der Meßmethode ist sehr einfach und für das Kind vollkommen ungefährlich.

Schlüsselwörter: Atemfrequenz, Herzfrequenz, Neugeborenes, Rektaltemperatur, Sauerstoffverbrauch, Überwachung.

Résumé

Consommation d'oxygène, fréquence cardiaque et respiratoire et température rectale chez les nouveaux-nés sains dans les deux premières heures de la vie

Une étude a été effectuée sur l'enregistrement continu de la consommation d'oxygène, de la fréquence cardiaque et respiratoire ainsi que de la température rectale chez 32 nouveaux-nés durant les deux premières heures de la vie. Un rapide exposé de la technique d'enregistrement a été aussi donné. Une étude comparative montre que la consommation d'oxygène ainsi que la fréquence cardiaque et respiratoire baissent durant la période d'observation tandis que la température rectale monte. 26 des 32 nouveaux-nés ont manifesté une baisse à peu près linéaire de chacune des valeurs de la consommation d'oxygène au cours de la période d'observation. Il existe une relation similaire,

confirmée par les statistiques, entre l'absorption d'oxygène et la fréquence cardiaque peuvent être mises en corrélation mutuelle après les 60 premières minutes de vie. Ces rapports étroits et directs entre la consommation d'oxygène et la fréquence cardiaque, un paramètre important du coeur et du système circulatoire, souligne clairement l'importance de l'enregistrement continu de la consommation d'oxygène pour l'examen de l'état général du nouveau-né. Un changement de cette situation signifie pour le nouveau-né un risque qu'il importe d'éclaircir par une analyse des gaz sanguins. Un enregistrement continu de l'absorption d'oxygène pour la surveillance du nouveau-né inclut de nombreuses fonctions vitales et semble constituer un paramètre plus significatif que les paramètres isolés qui se bornent à des fonctions partielles. La méthode est d'une application simple et sans danger pour l'enfant.

Mots-clés: Consommation d'oxygène, fréquence cardiaque, fréquence respiratoire, nouveau-né, surveillance du nouveau-né, température rectale.

Bibliography

- [1] BARTELS, H., K. RIEGEL, J. WENNER, H. WULF: Perinatale Atmung. Springer, Berlin-Heidelberg-New York 1972
- [2] BRÜCK, K.: Temperature regulation in the newborn infant. *Biol. Neonat.* 3 (1961) 65
- [3] BRÜCK, K., A. H. PARMELEE JR., M. BRÜCK: Neutral temperature range and range of "thermal" comfort in premature infants. *Biol. Neonat.* 4 (1962) 32
- [4] BRÜCK, K.: Neue Befunde und Vorstellungen zur Thermoregulation. *Hippokrates* 41 (1970) 46
- [5] CROSS, K. W., J. P. M. TIZARD, D. A. H. TRYTHALL: The gaseous metabolism of the newborn infant breathing 15% oxygen. *Acta paediat.* 47 (1958) 217
- [6] KARLBERG, P.: The significance of depth of insertion of the thermometer for recording rectal temperatures. *Acta paediat. (Uppsala)* 38 (1949) 359
- [7] MICHEL, C. F., CH. SCHUBRING: Gerät zur kontinuierlichen Messung des Sauerstoffverbrauches bei Neugeborenen. *Z. Geburtsh. Perinat.* 177 (1973) 449
- [8] NEUHOF, H., H. WOLF, R. ROTHERMUNDT, E. GLASER, H. G. LASCH: Die Sauerstoffaufnahme des Organismus im hämorrhagischen Schock. *Zschr. f. Kardiologie* 7 (1973) 663
- [9] PRIBYLOVÁ, H.: Einfluß der Umwelttemperatur auf den Sauerstoffverbrauch, auf die Körper- und Hauttemperatur und die Atmung des reifen Neugeborenen. *Ann. paediat.* 201 (1963) 399
- [10] PRIBYLOVÁ, H., K. ZNAMENÁČEK: Some aspects of thermoregulatory reactions in newborn infants during the first hours of life. *Biol. Neonat.* 6 (1964) 324
- [11] SCHUBRING, CH., C. F. MICHEL: Kontinuierliche Messung des Sauerstoffverbrauches bei gefährdeten Neu- und Frühgeborenen. In: DUDENHAUSEN, J. W., E. SALING, *Perinatale Medizin*, Bd. IV Thieme, Stuttgart 1973
- [12] SCHUBRING, CH., C. F. MICHEL: Kontinuierliche Messung des Sauerstoffverbrauches bei gesunden Neugeborenen in den ersten zwei Stunden nach der Geburt. *Geburtsh. u. Frauenheilk.* 34 (1974) 835
- [13] SCOPES, J. W., I. AHMED: Minimal rates of oxygen consumption in sick and premature newborn infants. *Arch. Dis. Childh.* 41 (1966) 407

Received October 23, 1975. Accepted March 11, 1976.

Dr. med. Ch. Schubring,
Zentrum für Frauenheilkunde
und Geburtshilfe am Klinikum
der Justus-Liebig-Universität
Gießen, 63 Gießen, Klinikstr. 32