

# Reference Values of Capillary Blood Saturation in Neonates and its Difference from Pulse Oximetry

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## SUMMARY

**Introduction** Haemoglobin saturation is an obligatory oxygen parameter in the assessment of neonatal oxygenation. Although, pulse oximetry is currently one of the major methods in the determination of haemoglobin saturation, capillary blood saturation is still present in the diagnostic process. As well known, haemoglobin saturation value of capillary blood is insufficiently accurate, but not as much as the difference in relation to the values determined by pulse oximetry. Until now published studies have reported that capillary samples are obtained according to a protocol by the principle of free blood outflow, which is practically almost unachievable in the neonate.

**Objective** Determination of the reference values of oxygen saturation (ScO<sub>2</sub>) and partial pressure (pcO<sub>2</sub>) of capillary blood by squeezing of the foot. The determination of difference between ScO<sub>2</sub> and pulse oximetry (SpO<sub>2</sub>).

**Methods** In 134 term newborns, we determined SpO<sub>2</sub>. Subsequently, we measured the values of ScO<sub>2</sub> and pcO<sub>2</sub> from the same extremity. While withdrawing a capillary sample, we exerted multiple squeezing of the foot. The mean value of ScO<sub>2</sub>, pcO<sub>2</sub>, SpO<sub>2</sub> and the difference between ScO<sub>2</sub> and SpO<sub>2</sub> were determined.

**Results** Mean ScO<sub>2</sub> value was 80.5±8.5%, pcO<sub>2</sub> was 48.2±11.4 mm Hg and SpO<sub>2</sub> was 98±1.9%. The difference between ScO<sub>2</sub> and SpO<sub>2</sub> values was 17.5±8.6% (t=23.568; p=0.000).

**Conclusion** There is a statistically highly significant difference between the values of ScO<sub>2</sub> and SpO<sub>2</sub>. Having the knowledge of this difference can increase the accuracy of clinical evaluation and further diagnostics. Comparison in up-to-now conducted studies suggests that the squeezing of the foot for obtaining a capillary sample in relation to free blood outflow does not bear any significant influence on the resultant values of haemoglobin saturation.

**Keywords:** newborn; capillary blood; squeezing; haemoglobin saturation

## INTRODUCTION

Oxygen saturation of haemoglobin is a mandatory parameter in the assessment of oxygenation of neonates. Pulse oximetry and transcutaneous pO<sub>2</sub> and pCO<sub>2</sub> are considerably used. Nevertheless, recent analyses of blood gas monitoring performed in several European countries have shown that capillary samples are still often utilized [1]. During the time of most intensive use of capillary blood gas analysis many studies have pointed out a contradictory relation to arterial blood values. However, the conclusion of many studies have shown that pH and pCO<sub>2</sub> of capillary blood values in the neonate with good peripheral circulation are acceptable for clinical use in comparison with arterial blood measurements, while there is a substantial difference compared to pO<sub>2</sub>. The term „arterialized“ is still in use, although in 1988 it was shown that warming the puncture site at 40°C did not lead to a significant approximation of the arterial values of oxygen parameters [2]. Lately, it has been shown that arterialization is also often insufficient in adults [3]. Oxygen saturation of capillary blood was scarcely ever analyzed in the past along with the parameters of other gases, and it was rarely cited when reference values were determined [4].

A recent study has shown that oxygen saturation is the parameter of the highest importance for the survival of the fetus/neonate, contrary to pO<sub>2</sub> or oxygen content [5].

## OBJECTIVE

Determination of the reference values of ScO<sub>2</sub> and pcO<sub>2</sub> of capillary blood with the application of squeezing of the foot. The determination of difference between ScO<sub>2</sub> and SpO<sub>2</sub>.

## METHODS

The selected 134 term neonates, aged 1-30 days, were admitted to the Neonatology Department, in whom it was expected that gas analyses would be normal (for example: polydactyly, haemangioma, humeral fractures etc.). The patients were included in the study at the moment of discharge, when the hospitalization course was analyzed; any disorder of gas analyses was expected to be within normal limits.

Physical examination and arterial pressure measuring confirmed a normal haemodynamic state. Pulse oximetry of the left foot was done

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**Figure 1.** Appropriate manner of holding the foot during capillary blood sampling

by a Nonin Infant Flex 8001J oximeter, and subsequently capillary blood was withdrawn from the same foot for gas analyses. There was no need for prewarming, which otherwise we always perform if the extremity is extremely cold or cyanotic. At our Department the usual practice for capillary blood sample collection is to apply pressure, because capillary tube filling with free blood outflow in neonates is more difficult than in older children. Squeezing of the foot was done as gently as possible and was repeated until the tube was filled with blood, which required 1-6 repetitions (on average 4 times). The manner in which the foot was held and squeezed is shown on Figure 1. The benefit of such a manner of capillary blood collection lies in minimizing the number of punctures. The blood samples were analyzed using a Gem Premier 3000 analyzer (Instrumentation Laboratory), within 10 minutes of 15  $\mu$ L capillary tube filling.

To estimate statistical differences between the variables, we used the Student's test since our data were parametrically analyzed by the Kolmogorov-Smirnov test for normal distribution. The determined level of significance of 0.05 was considered significant and the level of significance of 0.01 was statistically highly significant.

The study was approved by the Ethical Committee of the University Children's Hospital.

## RESULTS

The mean value of  $ScO_2$  was  $80.5 \pm 8.5\%$ ,  $pcO_2$  was  $48.2 \pm 11.4$  mm Hg and of  $SpO_2$  it was  $98 \pm 1.9\%$  (Table 1). The difference between the values of  $ScO_2$  and  $SpO_2$  was  $17.5 \pm 8.6\%$ , which was statistically highly significant ( $t=23.568$ ,  $p=0.000$ ). There was no difference between the values of  $ScO_2$  and  $SpO_2$  in only 3 neonates.

## DISCUSSION

Despite attempts of many authors to analyze obtained capillary blood gas values by comparing them to the values of arterial blood, one undisputable conclusion has been reached in all studies: the values of capillary blood analyses are insufficiently precise. The most probable reason is a high variability in the neonatal peripheral perfusion. Therefore, despite

**Table 1.** Neonatal reference values of  $SpO_2$  and blood capillary  $ScO_2$  and  $pcO_2$  obtained from 134 neonates

Variables	Mean	SD	2.5%ile	97.5%ile
$SpO_2$ (%)	98.0	1.9	92.4	100
$ScO_2$ (%)	80.5	8.5	61.8	96.6
$pcO_2$ (mm Hg)	48.2	11.4	33	88.6

our efforts to accurately express the conditions of the examination of capillary blood gas analyses in the newborn, it was difficult to avoid the factor of variable and slower peripheral perfusion. Longer capillary refilling time in neonates compared to older children speaks in favour of the latter [6].

The problem of the imprecision of capillary blood gas analysis can be viewed as a relation between the fraction of venous blood and arterial blood in a capillary sample. All previous data from the literature, including our study, showed that the values of capillary blood gas analyses were significantly closer to the values of venous blood than the values of arterial blood. This is in accordance with the results of many publications on the correlation between the values of pH and  $pCO_2$ , but not of the values of  $pO_2$  between arterial and capillary blood [7, 8, 9]. There is a lower difference between the values of pH and  $pCO_2$  of venous blood and arterial blood compared to the values of  $pO_2$ . The greater the fraction of venous blood in a capillary sample, the greater the difference of the values of  $pO_2$  between arterial blood and capillary blood in comparison to the difference of pH and  $pCO_2$  values. Thus, oxygen parameters show that the capillary sample in newborns is more similar to venous than arterial blood.

The comparison of our results with accessible reference values from the literature is limited, because of possible different conditions under which each study was conducted and the different age of neonates (especially prematures). In our study it was only possible to compare the values of  $pcO_2$  to those reported by other authors, but not the values of  $ScO_2$ , because of their lack in the literature. The reference values of  $pO_2$  in a group reporting 78 premature infants were 55.0 mm Hg in venous blood and 83.1 mm Hg in arterial blood [10]. Brown and Eilerman [11] published a table with  $pcO_2$  values of 40-50 mm Hg. Dong et al. [12] reported a group of infants aged 1-25 days with the mean  $pcO_2$  value of 52 mm Hg. In a Cousineau's twenty-year later study [4] the mean value of  $pcO_2$  in newborns aged up to 3 days was 45.3 mm Hg, while in our study it was 48.2 mm Hg in the neonates aged up to 30 days. However, the difference between these values did not have significance that could effect clinical decision. Still, it should be kept in mind that we did not warm up the extremity, and while taking the sample, we exerted multiple squeezing on the foot.

In all previous studies of capillary blood gases free blood-flow was a part of the protocol for sample collection in order to secure accurate findings. However, most of the protocols involving the methods of biochemical analysis were first developed to be applied in adults and were only later utilized in patients of all ages. The neonate has a specific physiology that is different not just from the physiology of the adult, but also from the physiology of the older child. This case is about specific peripheral circulation. Our experience suggests that

the collection of capillary blood samples requires the application of some pressure on the foot of the neonate.

## CONCLUSION

To conclude,  $ScO_2$  is still in clinical use despite being insufficiently accurate. Under such circumstances, the data on the

difference between  $ScO_2$  and  $SpO_2$  can increase the accuracy of clinical assessment and further diagnostics. Comparison between mean  $pcO_2$  values, obtained in our study with the application of squeezing and the mean values of previous studies where the principle of free blood flow was applied suggests the need to evaluate the influence of squeezing on the values of  $pcO_2$  and  $ScO_2$  in correlation with age.

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## Референтне вредности засићености капиларне крви новорођенчади кисеоником и разлика у односу на пулсну оксиметрију

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### КРАТАК САДРЖАЈ

**Увод** Засићеност (сатурација) хемоглобина кисеоником је неизоставни параметар у процени оксигенације новорођенчета. Иако је пулсна оксиметрија једна од главних метода одређивања засићености хемоглобина, засићеност капиларне крви се и даље примењује током овог дијагностичког поступка. Зна се да су вредности засићености хемоглобина капиларне крви недовољно прецизне, али не и колика је разлика у односу на вредности измерене пулсном оксиметријом. Узорци капиларне крви су у досад објављеним студијама узимани према протоколу који подразумева слободно истицање крви, што је у свакодневној пракси код новорођенчади скоро неостварљиво. **Циљ рада** Циљ рада је био да се одреде референтне вредности засићености хемоглобина кисеоником ( $SkO_2$ ) и парцијалног притиска кисеоника ( $pkO_2$ ) капиларне крви стискањем стопала новорођенчади приликом узимања узорка крви, те разлике између  $SkO_2$  и пулсне оксиметрије ( $SpO_2$ ).

**Методе рада** Код 134 детета рођена у термину одређене су вредности  $SpO_2$ . Потом су измерене вредности  $SkO_2$  и  $pkO_2$  на истом екстремитету. Током узимања узорка капиларне крви примењено је вишеструко стискање стопала. Одређене су средње вредности  $SkO_2$ ,  $pkO_2$  и  $SpO_2$  и разлика између  $SkO_2$  и  $SpO_2$ .

**Резултати** Средња вредност  $SkO_2$  била је  $80,5 \pm 8,5$ ,  $pkO_2$   $48,2 \pm 11,4$  mm Hg, а  $SpO_2$   $98 \pm 1,9\%$ . Разлика између  $SkO_2$  и  $SpO_2$  била је  $17,5 \pm 8,6\%$  ( $t=23,568$ ;  $p=0,000$ ).

**Закључак** Утврђена је статистички високо значајна разлика између вредности  $SkO_2$  и  $SpO_2$ . Познавање вредности ове разлике може повећати прецизност клиничке процене и даље дијагностике. Поређење са досад изведеним студијама показује да стискање стопала новорођенчета током узимања узорка капиларне крви у односу на слободно истицање крви не утиче значајно на добијене вредности засићености хемоглобина кисеоником.

**Кључне речи:** новорођенче; капиларна крв; стискање; засићеност хемоглобина

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