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# Deleterious effects of smoking during pregnancy: studies on blood oxygen affinity

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16 mothers smoking 1—40 cigarettes daily during pregnancy and their infants were studied at delivery compared to 13 non-smoking controls. The infants of smoking mothers had significantly decreased weight and length at birth compared to the infants of non-smokers. In the smoker group the thiocyanate level in maternal venous and newborn cord blood sera was significantly higher than in the non-smokers. The standard blood oxygen affinity of cord blood was significantly increased in the smokers' group and was positively correlated to the thiocyanate level in cord blood. At the age of three and five days there were no differences in the newborns' capillary blood standard oxygen affinity between the two groups. The deleterious effect of maternal smoking on the fetus and newborn is discussed.

The harmful effects of smoking during pregnancy on the feto-placental unit is now generally accepted. Of the many possible deleterious effects we have studied the influence on blood oxygen affinity (st.$P_{50}$ value) in both the mother and the newborn, together with other clinical and laboratory measurements. Our motives for examining this parameter were based on our previous work [26] and other reports in the literature [2, 7, 20, 27].

## Material and Methods

29 pregnant women, 16 smokers and 13 non-smokers and their newborns were investigated at delivery, between April and November, 1982. After obtaining the history and informed consent, the following clinical and laboratory data were examined.

*Clinical data:* gestational time, daily cigarette consumption, body weight and length of newborn, length of umbilical cord, 1 minute Apgar score.

*Laboratory data:* from maternal venous blood obtained at the end of delivery the following parameters were examined: blood st. $P_{50}$ value, 2,3-diphosphoglycerate (2,3-

*Abbreviations*

st.$P_{50}$ value = $pO_2$ value of $O_2$ half saturated blood at 37 °C, pH 7.40, and $pCO_2$ of 5.33 kPa;
2,3-DPG = 2,3-diphosphoglycerate;
hb = haemoglobin;
htc = haematocrit

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DPG) and haemoglobin (hb) contents, haematocrit (htc) value and the concentration of serum thiocyanate. An arterial cord blood sample was obtained prior to the first breath of the newborn to evaluate the acid-base and blood gas status (pH, $HCO_3$, $pCO_2$, $pO_2$). Mixed cord blood was sampled for measuring blood st. $P_{50}$ value, 2,3-DPG and hb contents, the htc value and the serum thiocyanate concentration. After 3 and 5 days of life a capillary sample was obtained from the newborn and the blood pH and st. $P_{50}$ values were determined.

Blood gases, acid-base status, hb and htc were measured using standard laboratory methods. The st. $P_{50}$ value was determined by our own technique [1], serum thiocyanate concentration photometrically [21], and the whole blood 2,3-DPG concentration enzymatically (SIGMA 665).

Statistical calculations were performed with Student's unpaired *t*-test and by correlation analysis by means of a computer programme.

## Results

Clinical data are presented in Table I. The number of cigarettes consumed daily varied widely. All newborns from the smokers' group were born between the 37—41 weeks of gestation without active medical intervention. The infants of the smokers had a lower body weight and length at birth while the 1 minute Apgar score and the umbilical cord length did not show any statistical difference between the smoker and non-smoker groups.

The results of laboratory tests are shown in Table II and the Figures. Maternal serum thiocyanate concentration at the end of delivery was significantly higher in the smokers. Htc and hb in mixed cord blood did not show any difference between the two groups, the smoker group had a slightly lower value for 2,3-DPG than did the non-smokers. In the smoker group the st.$P_{50}$ value was significantly lower and thes erum thiocyanate level higher than in the non-smokers. A close correlation could be shown in the thiocyanate contents of the mothers' and of the mixed cord blood sera ($r = 0.918$, $t = 9.274$, $p <$

Table I

Clinical data of smoking and non-smoking mothers and their newborns

| | Smokers | | | Non-smokers | | |
|---|---|---|---|---|---|---|
| | n | range | mean ± SD | n | range | mean ± SD |
| Daily cigarette consumption | 16 | 2—40 | 9.06 ± 8.8 | 13 | — | — |
| Time of gestation, weeks | 16 | 37—41 | 39.1 ± 1.4 | 13 | 37—41 | 39.4 ± 1.1 |
| Birth weight, g | 16 | 1900—4150*** | 2825 ± 650 | 13 | 3150—4370 | 3555 ± 350 |
| Birth length, cm | 16 | 43—53*** | 47.6 ± 3.5 | 13 | 48—54 | 50.8 ± 1.7 |
| Length of umbilical cord, cm | 10 | 51—71 | 56.7 ± 6.1 | 8 | 40—65 | 52.1 ± 8.7 |
| 1 min Apgar score | 16 | 7—10 | 9.1 ± 1.2 | 13 | 7—10 | 9.8 ± 0.8 |

n = number of cases
*** Difference between smokers and non-smokers $p < 0.01$

TABLE II

Laboratory data of smoking and non-smoking mothers and their newborns

| | Smokers | | | Non-smokers | | |
|---|---|---|---|---|---|---|
| | n | range | mean ± SD | n | range | mean ± SD |
| *Maternal venous blood* | | | | | | |
| st.$P_{50}$ kPa | 10 | 2.83–5.1 | 3.8 ± 0.6 | 8 | 3.08–4.57 | 3.8 ± 0.5 |
| 2.3-DPG mmol/l | 10 | 1.3–2.8 | 2.0 ± 0.4 | 8 | 1.7–2.15 | 1.95 ± 0.2 |
| htc, percent | 10 | 35–45 | 40.8 ± 3.2 | 8 | 37–43 | 39.9 ± 2.0 |
| hb/fe, mmol/l | 10 | 6.3–8.2 | 7.6 ± 0.6 | 8 | 6.6–10.0 | 7.6 ± 1.05 |
| thiocyanate, μmol/l | 10 | 5–272* | 117 ± 97 | 8 | 8–54 | 34.5 ± 16.4 |
| *Mixed cord blood* | | | | | | |
| st.$P_{50}$ kPa | 16 | 2.0–3.7** | 2.65 ± 0.4 | 13 | 2.65–3.65 | 3.0 ± 0.3 |
| 2.3-DPG mmol/l | 10 | 1.2–2.65 | 2.1 ± 0.5 | 8 | 2.2–2.7 | 2.4 ± 0.2 |
| htc, percent | 10 | 38–58 | 49.5 ± 6.2 | 8 | 46–60 | 50.8 ± 4.3 |
| hb/fe, mmol/l | 10 | 7.8–10.8 | 9.1 ± 1.0 | 8 | 7.8–11.2 | 9.3 ± 1.2 |
| thiocyanate, μmol/l | 10 | 5–300** | 134 ± 94 | 8 | 8–71 | 39.5 ± 20.0 |
| *Newborn capillary blood* | | | | | | |
| 3rd day | | | | | | |
| st.$P_{50}$ kPa | 10 | 2.3–3.25 | 2.7 ± 0.3 | 8 | 2.4–3.0 | 2.8 ± 0.3 |
| pH | 10 | 7.28–7.48 | 7.34 ± 0.07 | 8 | 7.27–7.42 | 7.35 ± 0.06 |
| 5th day | | | | | | |
| st.$P_{50}$ kPa | 10 | 2.0–2.9 | 2.5 ± 0.3 | 8 | 2.2–3.0 | 2.7 ± 0.4 |
| pH | 10 | 7.28–7.41 | 7.33 ± 0.05 | 8 | 7.23–7.48 | 7.33 ± 0.1 |
| *Arterial cord blood* | | | | | | |
| $pO_2$ kPa | 10 | 2.0–4.4 | 3.3 ± 1.1 | 8 | 2.4–4.1 | 3.3 ± 0.6 |
| pH | 10 | 7.12–7.33 | 7.20 ± 0.07 | 8 | 7.11–7.32 | 7.20 ± 0.07 |
| $HCO_3^-$/mmol/l | 10 | 13.2–16.8 | 14.8 ± 1.2 | 8 | 12–17.2 | 14.0 ± 2.2 |
| $pCO_2$ kPa | 10 | 3.3–7.2 | 5.1 ± 1.3 | 8 | 4.0–4.8 | 4.6 ± 0.5 |

n = number of cases
Difference between smoker and non-smoker group
* $p < 0.05$
** $p < 0.02$

0.01). Similarly, a close correlation was shown between the daily cigarette consumption and the thiocyanate content of mixed cord blood sera (Fig. 1). There was a direct relationship between the thiocyanate concentration and the st.$P_{50}$ value in mixed cord blood (Fig. 2), while a similar connection could not be shown between the cord thiocyanate level and 2,3-DPG content ($r = 0.256, t = 1.06$, ns.). After 3 and 5 days, the st.$P_{50}$ value in capillary blood of newborns no longer indicated a significant difference between the two groups. Likewise, no difference was recorded in the blood gas and acid-base status of arterial cord blood obtained at birth and the newborns' capillary blood sampled after 3 and 5 days.

## DISCUSSION

The most harmful effect of maternal smoking on the fetus is a chronic

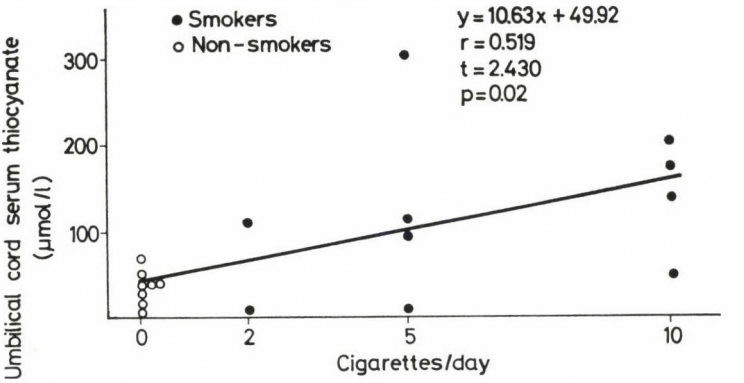


FIG. 1. Cigarette consumption and thiocyanate level in cord blood

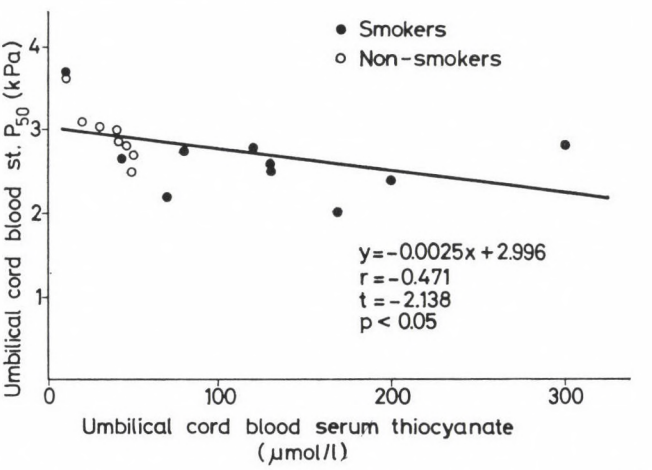


FIG. 2. Correlation between cord blood thiocyanate level and blood oxygen affinity

intrauterine hypoxia [10, 24], in which blood oxygen affinity changes play an important role. The results are both intrauterine (e.g. somatic retardation) and extrauterine (e.g. disturbed adaptation). Among the effects of cigarette smoke, earlier those of carbon monoxide on hb were stressed, with an increase in blood oxygen affinity in both fetal [4, 10] and adult blood [6, 8, 19, 23]. The role of thiocyanate with its 7-day half-life has also been shown to be important [18] and as its metabolism involves hb [3], so we examined the blood oxygen affinity and thiocyanate level of smoking mothers and their newborns.

The low birthweight of newborns of smoking mothers was noteworthy [7, 12, 16], but we could not find any effect of smoking on the length of the umbilical cord [15] nor an increase in maternal blood oxygen affinity, which other authors have reported [19, 23]; the latter was perhaps explained by

the absence of smoking during several hours prior to delivery [8]. The 2,3-DPG content of maternal blood was in agreement with earlier data [19, 23], but a prolonged maternal hypoxia was not apparent from the hb and htc values. The thiocyanate level of maternal blood agreed with previous data [11, 12, 18, 27] and so did the close correlation between the daily number of cigarettes and the cord blood thiocyanate level as well as of its concentration in maternal and cord blood [12, 18].

A new finding was the direct relationship between the increased oxygen affinity of cord blood and its thiocyanate level and the connection between blood carboxy-hb and thiocyanate, which has been suggested to operate in adults [27].

From the present findings it would appear that the increased blood oxygen affinity was not accompanied by an increased fetal 2,3-DPG production while the cord blood hb and htc values failed to indicate the activation of some other compensatory mechanisms [13]. The st.$P_{50}$ value of 3 and 5 day old newborns pointed either to the postnatal occurrence of cyanate detoxication and elimination [20] or of some other mechanism affecting blood oxygen affinity, such as 2,3-DPG production, relative reduction of fetal hb, etc.

The present results together with some previous and recent findings [5, 9, 14, 17, 20, 22, 25] all indicate the importance of avoiding smoking during pregnancy in view of its harmful effects on the fetus.

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