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Research Article

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The Effect of Maternal Oxygen Inhalation upon Fetal Oxygenation

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ABSTRACT In eight sheep, uterine and umbilical blood flows and oxygen uptakes, the transplacental flow-limited clearance of an inert molecule, pH values, and oxygen pressures, saturations, and capacities in the main placental vessels have been measured during maternal air breathing and oxygen inhalation. The mean ± SEM percentage changes during oxygen inhalation were + 4.6 ± 8.4 for the umbilical flow, + 2.8 ± 8.7 for the uterine flow, and + 4.6 ± 6.2 for the clearance. None of these changes are statistically significant. Oxygen uptake rose slightly in two cases and remained unchanged in the others. In all cases the oxygen pressures, saturations, and contents rose significantly in the uterine and umbilical vessels with oxygen inhalation.

INTRODUCTION

Observations on the effects of high oxygen concentrations in the inspired air of the mother upon aspects of fetal oxygenation have been fairly numerous in man and in experimental animals, principally sheep and monkeys. In many studies, variables that are not closely related, such as the O_2 pressures in maternal and fetal arteries, have been compared, but there has been no comparison of uterine and umbilical vein oxygen pressures, nor simultaneous measurements of uterine and umbilical blood flows and oxygen uptakes. Furthermore, in some experiments, air breathing and oxygen inhalation were not randomized in order to discriminate between the effect of hyperoxia and deterioration of the preparation. Perhaps because of these limitations, the data in the literature show discrepant results and interpretations. Some authors have claimed adverse effects of O_2 inhalation, such as decreased umbilical blood flow (1, 2), decreased fetal oxygen consumption (2), and decreased surface area of the placental capillaries (3). No increase, and even a decrease of O_2 pressure in the fetal arteries after O_2 inhalation have been reported (1, 3, 4). We have only to consider the limited therapeutic measures available to the obstetrician dealing with fetal hypoxia to realize the implications of these results and to appreciate the need for further investigation.

The experiments presented in this paper have been designed to give a comprehensive description of fetal oxygenation during acute maternal oxygen inhalation. Simultaneous measurements of uterine and umbilical blood flows, the transplacental flow-limited clearance of an inert molecule, uterine and fetal oxygen consumptions, pH values, and oxygen pressures, saturations, and capacities in the main vessels supplying the placenta were done during a control period and during oxygen inhalation.

METHODS

Eight pregnant Dorset sheep of known gestation were starved for about 72 hr before surgery. They had free access to water. The sheep were given 6 mg of Pontocaine intrathecally for spinal anesthesia supplemented by intravenous Nembutal sufficient for sedation. The animals were breathing spontaneously throughout. The surgical procedure was similar to that described previously (5) with three catheters placed in a maternal

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peripheral artery, uterine vein, and umbilical artery, respectively and a double lumen catheter in the umbilical vein. The fetal catheters were inserted in small branches of the umbilical circulation and threaded toward the cord. There was no manipulation of the fetus and the cord at any time nor any loss of intrauterine fluids. First, the umbilical vein double lumen catheter was positioned, and an infusion of 10 g/100 ml of antipyrine was begun at a constant and known rate(about 10 mg/min) through the tip of the double lumen catheter. Approximately 50 min after starting the infusion, the transplacental diffusion rate of antipyrine become constant and equal to the infusion rate, except for minor corrections. Under these conditions, referred to as "the steady state," measurements of antipyrine concentration in the four placental vessels were used to calculate uterine and umbilical blood flows by the Fick principle, i.e., as ratios of the transplacental diffusion rate over the arteriovenous differences in the two circulations. In addition, the data were used to calculate the transplacental clearance of antipyrine which is defined as the ratio of the transplacental diffusion rate to the difference between the concentrations of antipyrine in umbilical arterial blood and maternal arterial blood. The exact details of these calculations have been published elsewhere (5, 6).

Each experiment was divided into two periods. In the first period, the ewe was given either room air or 100% O_2 to breathe, and in the second period, the other gas. The sequence of O_2 and air inhalation was reversed in successive experiments in order to randomize the effect that a deterioration of the preparation might have on the results. The animal was breathing through a tracheal cannula joined to a set of respiratory valves. During O_2 inhalation, the inspiratory valve was connected to a rubber bag filled with 100% O_2. Five sets of blood samples were drawn simultaneously at about 5-min intervals from the maternal artery, uterine vein, and umbilical artery, and vein. The samples in the first and fifth set were 0.2 ml each; they were used for antipyrine analysis only. The samples in the second, third, and fourth sets were 1.2 ml each and were used for measurements of antipyrine, pH, oxygen content and capacity, per cent of O_2 saturation, and Po_2.

In the second period a minimum of 15 min was allowed to elapse between the time the ewe began inhaling a different gas mixture and the first sampling. Then five sets of samples were taken according to the protocol given above for the same measurements as the first period.

Antipyrine was analyzed colorimetrically on the Technican AutoAnalyzer (Technicon Co., Chauncey, N. Y.), Po_2 was measured polarographically with the Beckman macroelectrode (Beckman Instruments, Inc., Fullerton, Calif.), O_2 and CO_2 contents were measured by gas chromatography (Beckman GC2A gas chromatograph), and pH was measured with a Radiometer microelectrode type E5020 (Renn Corp. Chicago, Ill.). O_2 saturation was determined by optical density measurements at two wavelengths with the Radiometer oximeter on hemolyzed packed red cells. Previously, comparisons of oxygen saturations determined colorimetrically vs. those determined by gas chromatography as the ratio, O_2 content/O_2 capacity, had been carried out for adult and fetal blood of sheep. On the basis of those data, no corrections were found necessary for oxygen saturations determined colorimetrically on adult sheep blood. However, using the calibration nomogram supplied with the instrument, we found there was a significant correction required for fetal blood at low oxygen saturations. The equation for the regression line used in this correction, valid from 10 to 100%, is given below:

$$S_{OXIM.} - S_{G.C.} = 4.77 - 0.058\ S_{G.C},$$

where $S_{OXIM.}$ = per cent of O_2 saturation determined with Radiometer oximeter, and $S_{G.C.}$ = per cent of O_2 saturation determined with Beckman gas chromatograph as the ratio, O_2 content/O_2 capacity.

The Po_2 and pH measurements were done at 38°C. The gas chromatograph was standardized by injection of known amounts of oxygen in the reaction chamber and with bicarbonate solutions. Hemoglobin was determined colorimetrically as cyanmethemoglobin. The colorimeter was standardized in each experiment with blood samples of known O_2 combining capacities as determined by chromatographic analysis. Pressures were estimated from the CO_2 content of whole blood, pH, and hemoglobin concentration by means of the Van Slyke-Sendroy nomograms (7).

Arteriovenous differences of oxygen were estimated independently by two methods: (*a*) by direct chromatographic analysis of oxygen; and (*b*) as the sum of the arteriovenous difference in saturation times O_2 capacity plus the arteriovenous difference of Po_2 times the solubility coefficient.

Each arteriovenous difference was multiplied by the appropriate flow to give a total of six estimates of uterine and fetal oxygen consumptions in each of the two periods of observation.

RESULTS

The mean oxygen tensions and saturations in each of the four placental vessels in the control period and during O_2 inhalation are presented in Table I. In two of the eight animals it was found at autopsy that the uterine vein catheter had been placed by mistake in a small branch of the uterine vein. These uterine vein data have been omitted from Table I. In every experiment, the Po_2 and O_2 saturations were higher in the uterine vein, umbilical vein, and umbilical artery when the mother was breathing 100% oxygen. The Po_2 in the umbilical vein rose markedly but never exceeded the uterine vein Po_2. In four of the eight fetuses, the umbilical vein oxygen saturation was 95% or greater during maternal O_2 inhalation. The increased O_2 pressure did not produce significant changes in O_2 capacity in fetal and maternal blood.

TABLE I

Oxygen Pressures and Saturations in the Placental Vessels during Air Breathing and Oxygen Inhalation

Animal	Fetal age	Inspired gas	O_2 pressures				% O_2 saturations			
			Mat. art.	Ut. vein	Umb. vein	Umb. art.	Mat. art.	Ut. vein	Umb. vein	Umb. art.
	days		*mm Hg*							
253	131	Air	68.0		18.2	14.5	85.7 ± 2.6		55.5 ± 1.5	36.6 ± 0.6
		O_2	270.0		29.4	21.6	99.9 ± 0.1		85.0 ± 0.7	61.1 ± 1.9
2	140	O_2	303.0	57.5	40.9	22.0	99.1 ± 0.7	67.2 ± 1.3	92.1 ± 4.0	58.7 ± 3.8
		Air	59.7	38.9	20.8	14.0	85.6 ± 3.7	46.9 ± 1.6	62.4 ± 1.1	33.4 ± 2.3
26	140	Air	51.5	38.9	16.1	11.2	71.2 ± 3.2	52.2 ± 3.1	36.8 ± 0.8	14.3 ± 0.4
		O_2	315.0	68.8	50.4	23.9	99.9 ± 0.1	85.6 ± 1.8	93.9 ± 2.7	60.0 ± 1.4
66	90	O_2	222.0	75.5	49.6	20.7	99.8 ± 0.6	90.6 ± 0.4	97.7 ± 2.4	58.0 ± 3.4
		Air	64.2	46.7	25.9	11.9	84.1 ± 1.0	72.7 ± 1.0	75.9 ± 2.3	21.4 ± 2.8
136	120	Air	64.5	46.1	28.4	21.4	83.6 ± 0.9	66.8 ± 0.5	83.6 ± 1.2	63.6 ± 1.5
		O_2	215.0	72.7	44.7	27.1	100.0 ± 1.7	85.2 ± 1.3	95.6 ± 1.1	75.9 ± 1.1
33	120	O_2	243.0	43.5	30.3	20.3	100.0 ± 0.4	56.5 ± 1.8	80.0 ± 2.2	52.2 ± 2.7
		Air	54.9	33.0	18.9	13.5	78.6 ± 0.9	43.0 ± 2.5	52.6 ± 3.9	30.2 ± 3.0
1778	143	Air	57.1	46.0	25.3	18.3	79.4 ± 0.7	65.4 ± 0.5	79.1 ± 0.5	52.5 ± 0.6
		O_2	190.0	76.7	42.2	24.7	99.7 ± 0.9	88.8 ± 0.5	95.1 ± 1.2	71.0 ± 0.5
73	143	O_2	80.0		48.3	22.8	90.7 ± 1.9		96.8 ± 1.1	68.4 ± 1.3
		Air	48.2		28.6	17.3	68.5 ± 0.6		82.9 ± 0.9	50.1 ± 1.1

Each oxygen pressure represents the mean of three measurements and each saturation of the mean of six measurements by two different methods ± the standard error of the mean.

Fig. 1 presents the oxygen tensions and saturations measured in each of the four placental vessels of a single animal experiment. It is evident that the changes in umbilical vein Po_2 follow the changes in uterine vein Po_2closely. The marked increases in both umbilical venous and arterial oxygen tensions and saturations when the mother is breathing high concentrations of oxygen are clearly shown.

The mean pH and Pco_2 in each of the four vessels are presented in Table II. Oxygen inhalation coincided with a small but statistically significant fall of pH in the placental vessels. The mean decrease in pH of the maternal artery, uterine vein, and umbilical vein and artery were 0.05, 0.05, 0.03, and 0.02 respectively, due principally to an increase in Pco_2. Table III presents the umbilical and uterine blood flows and clearance of antipyrine during O_2 inhalation and in the control period together with their percentage changes from air breathing to O_2 breathing. Each number represents the integrated flow over the 15 min period in which samples for O_2 analysis were taken. The changes in umbilical and uterine flows and in placental clearance of antipyrine were not related to O_2 pressure changes. The mean ± SEM percentage changes during O_2 inhalation were + 4.6 ± 8.4 for the umbilical flow, + 2.8 ± 8.7 for the uterine flow, and + 4.6 ± 6.2 for the clearance. None of these means is significantly different from zero. It is clear, therefore, that oxygen inhalation had no demonstrable effect either on uterine and umbilical blood flows or on placental clearance of antipyrine.

Table IV presents the fetal and total uterine oxygen consumptions (mean ± SEM in ml of STP/min) as well as the umbilical oxygen uptakes per kg of fetus. In six of the eight fetuses, the administration of oxygen to the mother neither increased nor decreased fetal oxygen uptake significantly. In two of the fetuses (Nos. 2 and 73) there was a statistically significant increase in umbilical oxygen uptake when the mother was breathing oxygen. In animal 2, the uterine oxygen consumption also showed an increase during O_2 inhalation. The mean percentage change of fetal consumption during the O_2 inhalation was + 9.6 ± 6.2 SEM in ml of STP/min. This change is of borderline

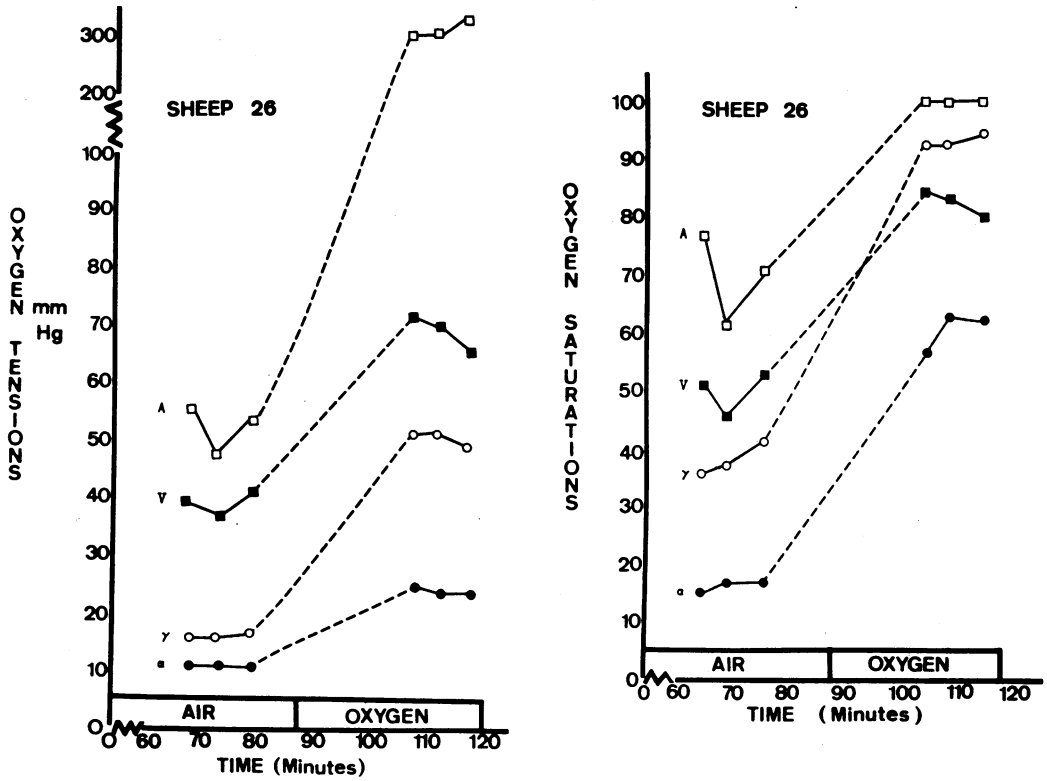

FIGURE 1 Oxygen tensions and saturations in maternal artery (A □), uterine vein (V ■), umbilical vein (γ ○), and umbilical artery (α ●) are presented during periods of air and oxygen inhalation.

TABLE II

pH and P_{CO_2} *in the Placental Vessel during Air Breathing and Oxygen Inhalation*

Animal	Inspired gas	pH				P_{CO_2}			
		Mat. art.	Ut. vein	Umb. vein	Umb. art.	Mat. art.	Ut. vein	Umb. vein	Umb. art.
						mm Hg			
253	Air	7.391		7.247	7.223	36.5		53.1	58.0
	O_2	7.293		7.218	7.195	45.7		58.8	65.2
2	O_2	7.262	7.202	7.201	7.163	43.6	54.8	60.4	70.6
	Air	7.319	7.263	7.278	7.230	36.6	45.2	50.8	62.3
26	Air	7.426	7.372	7.183	7.157	37.0	43.0	49.4	56.0
	O_2	7.382	7.333	7.167	7.136	40.5	47.0	53.5	63.3
66	O_2	7.326	7.290	7.254	7.176	34.1	38.1	46.5	60.8
	Air	7.371	7.349	7.263	7.159	29.6	34.4	40.8	62.3
136	Air	7.387	7.354	7.293	7.268	33.8	37.6	46.0	50.5
	O_2	7.374	7.318	7.286	7.252	36.6	42.8	50.5	54.3
33	O_2	7.373	7.309	7.244	7.227	44.7	58.6	62.5	71.2
	Air	7.436	7.375	7.262	7.231	39.6	48.0	59.3	67.8
1778	Air	7.406	7.381	7.420	7.388	30.3	32.7	35.2	40.6
	O_2	7.348	7.322	7.354	7.332	36.8	39.5	42.8	46.2
73	O_2	7.417		7.381	7.359	33.8		38.3	42.6
	Air	7.437		7.403	7.369	31.3		36.3	41.7

Each number represents the mean of three observations over a 15 min period.

TABLE III

Uterine and Umbilical Flows and Transplacental Clearances of Antipyrine during Air Breathing and Oxygen Inhalation

I Animal	II Inspired gas	III Uterine flow	IV % Change	V Umb. flow	VI % Change	VII Antipyrine clearance	VIII % Change
		ml/min		*ml/min*		*ml/min*	
253	Air			275	−13	124	−3
	O_2			240		121	
2	O_2	548	+15	453	+12	190	+8
	Air	478		406		175	
26	Air	632	+1	351	−21	139	−7
	O_2	636		277		129	
66	O_2	559	+6	62	+41	43	+32
	Air	530		44		33	
136	Air	1130	−10	357	−1	181	0
	O_2	1020		354		181	
33	O_2	227	−29	291	−22	101	−22
	Air	319		373		130	
1778	Air	1320	+34	546	+7	300	+3
	O_2	1770		583		309	
73	O_2			724	+34	392	+26
	Air			539		312	

Each number represents the average over a 15 min period in which samples for oxygen analysis were taken. In columns IV, VI, and VII are reported the per cent changes of flow and clearance from air breathing to oxygen breathing.

TABLE IV

Uterine and Umbilical Oxygen Uptakes during Air Breathing and Oxygen Inhalation ±*1* SEM

I Animal	II Fetal weight	III Inspired gas	IV Uterine O_2 uptake	V % Change	VI Umb. O_2 uptake	VII % Change	VIII Umb. O_2 uptake
	g		*ml of STP/min*		*ml of STP/min*		*ml of STP/min per kg*
253	2034	Air			7.6 ± 0.9	+10	3.7
		O_2			8.4 ± 0.7		4.1
2	2700	O_2	30.9 ± 0.8	+22*	24.4 ± 1.5	+32*	9.0
		Air	25.4 ± 1.4		18.5 ± 1.1		6.9
26	2165	Air	18.6 ± 3.0	−11	10.7 ± 0.7	+17	4.9
		O_2	16.5 ± 1.7		12.5 ± 0.9		5.8
66	475	O_2	9.2 ± 0.7	+15	2.6 ± 0.2	+8	5.5
		Air	8.0 ± 0.9		2.4 ± 0.1		5.1
136	1828	Air	27.1 ± 1.3	+2	12.3 ± 1.4	−8	6.7
		O_2	27.6 ± 1.7		11.3 ± 1.1		6.2
33	2233	O_2	18.7 ± 0.5	−12	13.6 ± 0.6	−4	6.1
		Air	21.3 ± 2.5		14.1 ± 0.2		6.3
1778	3504	Air	30.6 ± 1.9	+19	22.3 ± 0.5	−2	6.4
		O_2	36.5 ± 2.2		21.8 ± 0.8		6.2
73	4809	O_2			34.1 ± 2.3	+24*	7.1
		Air			27.5 ± 0.9		5.7

Columns V and VII present the percentage change from air breathing to oxygen inhalation of these variables. In column VIII are listed the umbilical rates of O_2 uptake per kg of fetal body weight.

* Signifies $P < 0.05$ for these changes.

significance ($0.1 < P < 0.2$). It should be pointed out that the significance of a change of oxygen uptake in a single experiment must be interpreted with caution. It could be due to some undetected non-random error in the flow measurements. On the other hand, the mean change of oxygen uptake by the eight fetuses is free from that type of systematic error.

In animals 136 and 33, of the same gestational age, there was a range of uterine flows from 227 to 1130 ml/min. Despite this fivefold difference in uterine flows and large differences of saturation and Po_2 in the maternal and fetal vessels, the fetuses had similar rates of oxygen consumption.

DISCUSSION

The data presented in this report show no significant effect of acute changes of O_2 pressure in the arterial blood from 50 to 300 mm Hg upon uterine and umbilical blood flows and the transplacental clearance of antipyrine. It has been shown (6) that the transplacental clearance of antipyrine is flow limited, i.e., it is a function of the maternal and fetal blood flow rates through the placenta, the relative direction of flows, and the degree of uneven perfusion. Thus, our data indicate no gross effect of acute O_2 inhalation at the microcirculatory level, such as the opening of shunts and changes in the perfusion pattern.

Maternal O_2 inhalation did not change the fetal O_2 consumption significantly in six out of eight cases. In two instances there were about 25% increases of fetal O_2 consumptions that appear to be significant. Taken as a whole, the data show a large degree of independence between fetal O_2 consumption and O_2 pressure and saturation in the umbilical vessels. These observations are at variance with the results of Acheson, Dawes, and Mott (8) on fetal lambs with low umbilical blood flows. According to these authors, fetal oxygen consumption decreased significantly when umbilical artery saturation fell below 50%. In this respect the present observations are in agreement with subsequent experiments by Dawes and Mott (9) in which relatively high rates of O_2 consumption were found with low umbilical artery saturations in lambs with umbilical blood flows higher than 100 ml/min. It appears, therefore, that placental flows and O_2 pressures may vary widely above certain critical levels without reaching a point at which placental O_2 transfer limits fetal O_2 consumption.

Oxygen inhalation markedly increased the O_2 saturations and pressures in the uterine vein and in the umbilical vein and artery. The rise of O_2 pressure in the uterine vein was due primarily to the fact that uterine blood flow, maternal blood O_2 capacity, and uterine O_2 consumption did not change significantly in hyperoxia. The shift of pH that occurred during O_2 inhalation (-0.05 units) accounts for only a 5% increase of uterine venous Po_2 (in adult sheep blood $\Delta \log Po_2/\Delta$ pH = 0.4 at constant saturation) (10).

The rise of umbilical venous Po_2 with acute O_2 inhalation was physiologically significant; the O_2 tension became 1.5 to 3 times the control value. Yet the rise was small in comparison with the maternal artery. This phenomenon is explained by the recent demonstration that the sheep placenta simulates a concurrent system of exchange (5, 6). As a consequence, the umbilical venous Po_2 cannot be higher than the Po_2 in the maternal placental veins, and it will be very much lower than maternal arterial Po_2 when the uterine arterial venous difference of Po_2 is very large, as in the case of O_2 inhalation. A demonstration that the Po_2 in the umbilical vein is directly proportional to the uterine vein Po_2 is given in Fig. 2. In this figure the present data as well as data from a series of observations on unanesthetized sheep exposed to 5000 and 14,000 ft altitude are given (11). Previous attempts at a rational description of the respiratory function of the placenta were

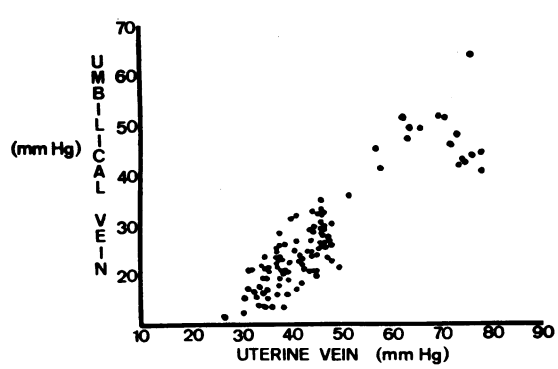

FIGURE 2 Oxygen tensions in the uterine and umbilical venous blood of pregnant sheep including observations at various altitudes (10) and with maternal hyperoxia.

based on the concept that the rate of transplacental oxygen diffusion is proportional to the mean oxygen pressure difference across the placenta. Experimentally it becomes increasingly difficult to measure the mean oxygen pressure difference across the placenta as one moves away from permeability-limited diffusion to flow-limited diffusion. Thus, in hyperoxia, considerations of flows and flow patterns are more important. According to recent evidence (12) transplacental oxygen diffusion might be flow limited even at normal levels of maternal oxygen pressure. Kirschbaum, Lucas, De Haven, and Assali (2) have criticized Krogh's equation on the basis of the fact that umbilical blood oxygen tension does not increase proportionally to maternal arterial oxygen tension. This criticism is unjustified because correct use of the equation requires the calculation of mean oxygen pressures.

There are several reasons not mutually exclusive why umbilical vein saturation should be lower than 100%: (*a*) equilibration within the cotyledonary capillary bed with a Po_2 lower than that measured in the uterine vein; (*b*) an inadequate exposure time in the placental capillaries for equilibration; (*c*) uneven perfusion ratios of the placental cotyledons; and (*d*) an admixture in the umbilical vein of blood that comes from the respiratory portion of the placenta with blood coming from the other areas, i.e., "shunting." The relative importance of these factors under different physiologic conditions cannot be assessed at present. Our data provide some interesting clues. In the six fetuses in which umbilical vein saturation rose above 90% with O_2 inhalation, we may assume, for the purpose of discussion, that umbilical vein blood was a mixture of 100% saturated blood with the same O_2 pressure as the uterine vein and blood that did not exchange oxygen within the placenta. In that case the amount of umbilical blood shunted away from the sites of respiratory exchange was 15.3 ± 2 SEM of the umbilical blood flow. In studying CO diffusion across the sheep placenta, perfused artificially on the fetal side, Metcalfe, Moll, Bartels, Hilpert, and Parer (13) estimated that 19% ± 1 SEM of the umbilical flow is shunted. The difference between the two estimates is not significant. It is clear that shunting of this magnitude could not account completely for the unsaturation of umbilical venous blood when the mother was breathing air. Thus, mechanisms other than shunting must account for some of the unsaturation of umbilical venous blood under ordinary circumstances.

The increased O_2 saturation and pressure in the umbilical artery during O_2 inhalation was a direct consequence of increased O_2 saturation in the umbilical vein and near constancy of umbilical flow and O_2 uptake. The shift of pH that occurred with O_2 inhalation (−0.02 units) contributed a negligible 2% of the O_2 pressure rise in the umbilical artery.

These observations are of practical interest because the use of high oxygen concentrations in the inspired air to relieve fetal hypoxia is a common clinical practice. Nyberg and Westin (14) have suggested, on the basis of their placental perfusion experiments, that high oxygen tensions might lead to vasoconstriction of the placental vessels. Given the fact that the placenta simulates a concurrent system, it is difficult to see how normobaric oxygen inhalation could ever produce in the fetus oxygen pressures as high as those used in perfusion experiments. James (15) could demonstrate no increase in umbilical cord oxygen saturations in pregnant patients given oxygen concentrations before delivery. Towel (4) reported data on two pregnant rhesus monkeys in which the oxygen pressure in the descending aorta of the fetus did not increase with oxygen inhalation. Rivard, Motoyama, Acheson, Cook, and Reynolds (1) also observed in some fetal sheep that maternal oxygen inhalation produced no increase in carotid arterial Po_2. These observations suggest circulatory and metabolic changes concomitant with oxygen inhalation. However, it is doubtful, in view of the data presented in this paper, that these changes were causally related to the high oxygen pressure in the maternal blood.

Recently, Kirschbaum and associates (2) claimed to have observed a decreased rate of umbilical oxygen uptake during maternal oxygen inhalation. They ascribe this paradox to some yet undiscovered ability of the placenta to limit net oxygen transfer during hyperoxia. We have been unable to confirm the existence of such a paradox. In addition, it is not clear to us how the placenta could simultaneously increase the oxygen content of the umbilical vein blood, produce no physiologically significant change in umbilical blood flow,

and yet reduce the rate of oxygen transfer to the fetus.

It should be emphasized that there was no indication in our data that acute oxygen inhalation had any adverse effect on the placenta or on the fetus. The effect of maternal oxygen inhalation on the fetus can be described as equivalent to that of increasing uterine blood flow. This point is brought out clearly by a comparison of animals 136 and 33.

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