EVALUATION OF THE THERMAL MAP OF HUMAN PLACENTA AS THE FIRST STEP TO *IN VIVO* APPLICATION OF INFRARED THERMOMETRY

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INTRODUCTION

Capacity of fetus to regulate thermogenesis is limited. About 85% of fetal heat, produced as a result of fetal metabolism, is lost through the placenta, and 15% is moved across the other fetal membranes. The elimination of heat is strongly tied to the placental transport of oxygen, carbon dioxide and metabolic substrates. The fetus has to adjust umbilical blood flow according to thermo-regulatory requirements (Schroeder and Power, 1994). Thermal gradient between mother and fetus has been suggested to be an index of intra-uterine fetal condition (Morishima *et al.,* 1977). Allocation of areas of effective placental heat dissipation, e.g. percentage (%) of areas with increased ability to heat loss/exchange, might be used as indicators of placental efficiency as radiator and oxygen/nutrient exchanger. Tissue's oxygen consumption could be calculated, based on Fick principle (Hunter *et al.*, 2003): tissue oxygen consumption (μ mol g^{-1} min^{-1}) = ΔT (T(tissue)-T(blood)x arterial blood flow (ml $min^{-1}g^{-1}$) x 3.68 Jg^{-1} $^{o}C^{-1}$ /0.473 (J). Placental heat conductance is high, estimated as $0.16Wx10^{6}X^{o}C^{-1}Kg^{-1}$ (Schroeder *et al.,* 1988).

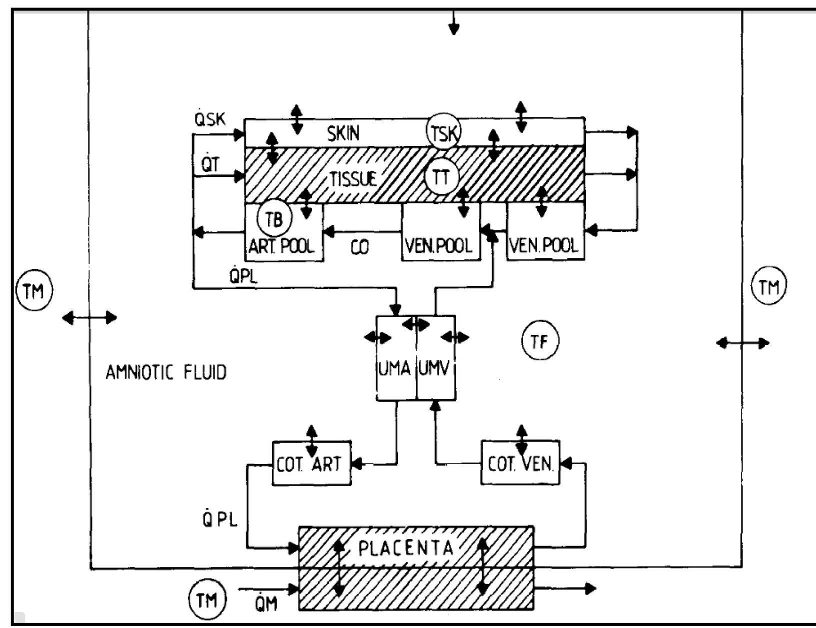

FIG. 1. Structure of fetal heat exchange model. ↔, Conductive heat transfer; →, convective transfer by maternal ($\dot{Q}_M$) and fetal ($\dot{Q}_{PL}$) placental blood flow, tissue ($\dot{Q}_T$) and skin ($\dot{Q}_{SK}$) blood flow, and cardiac output (CO). T_M, maternal temperature; T_B, fetal arterial blood temperature; T_F, amniotic fluid temperature; T_T, fetal tissue temperature; T_{SK}, fetal skin temperature; ART POOL, arterial vessels; VEN POOL, venous vessels; UMA, umbilical arteries; UMV, umbilical veins; COT ART, cotyledonary arteries; COT VEN, cotyledonary veins. ▨, Sites of heat production. (Schroeder et al., 1988).

OBJECTIVE

To evaluate placental thermal map, using infrared thermography (Figures 2 and 3).

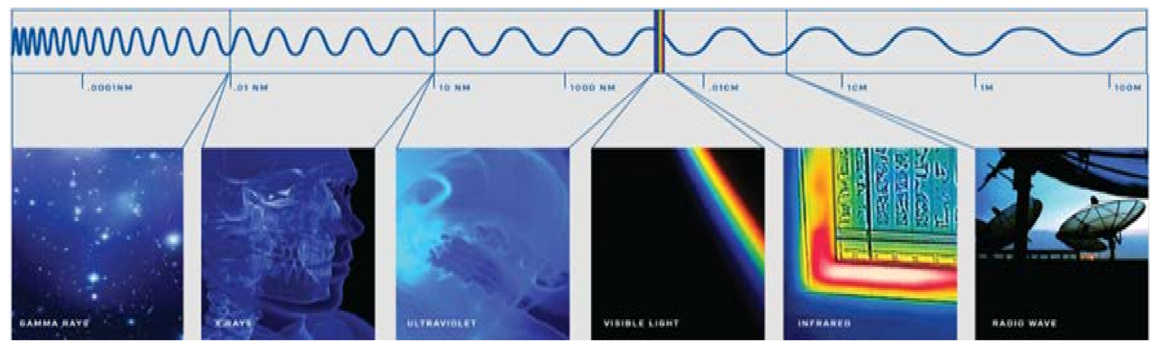

Figure 2: The electromagnetic spectrum describes the various types of electromagnetic energy based on wavelength.

Figure 3: FLIR ONE attached to a smartphone.

MATERIALS AND METHODS

Distance (cm)	5	10	15	20	25	30
Temperature (⁰C)	39.5	38.2	37.6	37.1	37.5	37
	39	38.5	37.7	37.4	37.2	36.9
	38.8	38.1	37.9	37.5	36.5	37
	38.6	37.8	38	37.6	37	37.4
	39.3	38	37.8	37.7	36.7	36.9
Mean	39.04±0.36	38.12±0.25	37.8±0.15	37.46±0.23	36.98±0.39	37.08±0.20
SD	0.364	0.258	0.158	0.23	0.396	0.207
CV%	0.934	0.679	0.418	0.614	1.071	0.559
CV	0.009	0.006	0.004	0.006	0.01	0.005

Table 1: FLIR ONE temperature readings from various distances at 36.6⁰C temperature setting (stable heat source).

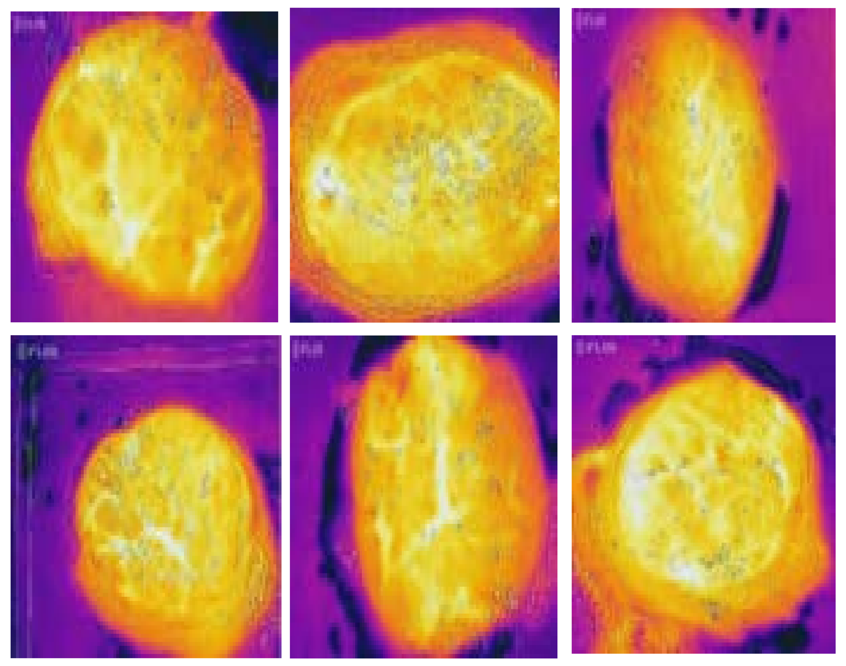

Figure 4: Thermal imaging of placenta, after delivery.

Figure 5:
Temperature of placentas (n=6) was measured 5 minutes after delivery, using infrared thermometry (FLIR ONE). The placenta was spread out with the maternal side visible. Two measuring tapes were placed along the x and y axis. The image was analyzed through the program to select points for temperature of the particular color. The percentage (%) of areas, corresponding to each color were estimated using "*Image J Program*".

RESULTS

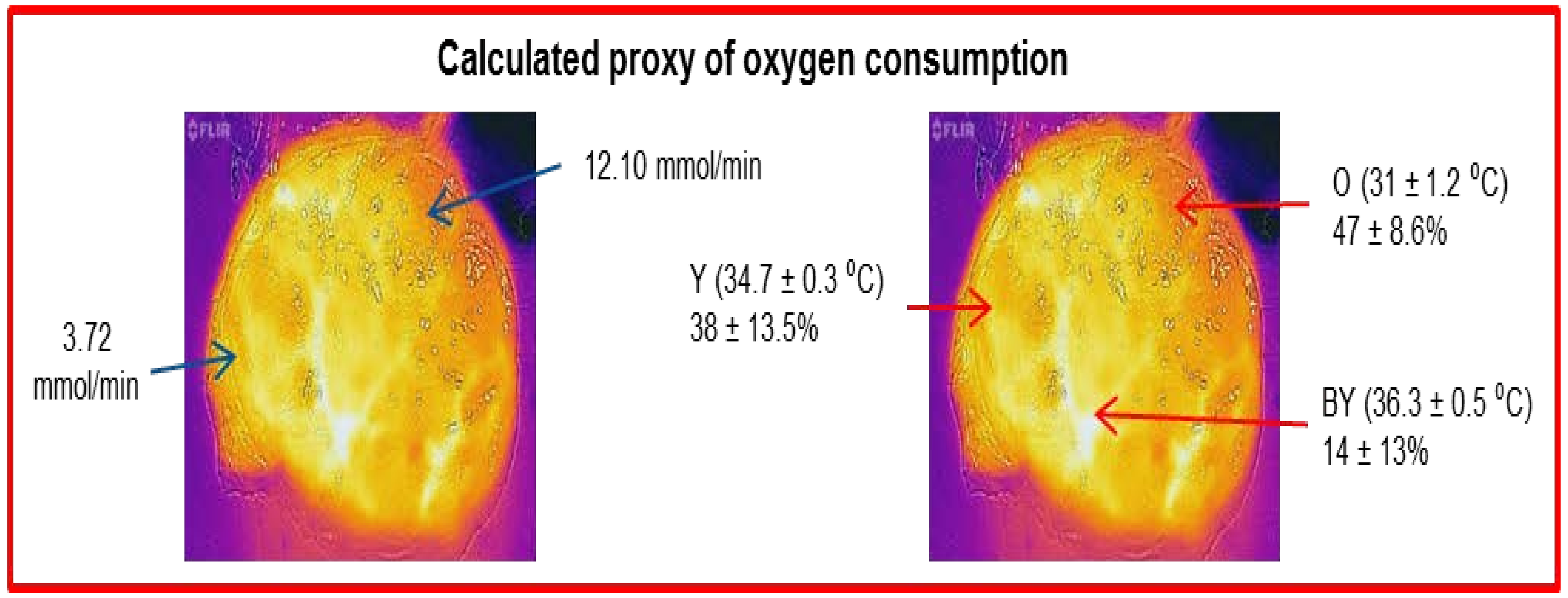

Figure 6: The average temperature of the regions were 36.3 ± 0.5 ⁰C, 34.7 ± 0.3 ⁰C, and 31 ± 1.2 ⁰C for BY, Y and O respectfully. The thermal areas were distributed as followed 14% ± 13% (BY), 38% ± 13.5 % (Y) and 47 ± 8.6% (O). The absolute surface areas were 20 ± 8 cm^2, 89 ± 39 cm^2 and 119 ± 21 cm^2.

DISCUSSIONS

In the perfusion experiments *in vitro* the placental tissue oxygen consumption was reported to be 2.92-10.9 ml/min/kg vs estimated *in vivo* 0.58 m mol/min (13 ml/min) placental oxygen uptake (rev. in Schneider, 2000 and Carter, 2000). In our study, thermal difference (tissue to blood) of the placenta after delivery has been used to calculate placental oxygen consumption, assuming, that the flow rate of the umbilical cord would remain constant (Figure 7). The estimated oxygen consumption exceeded the range reported in vivo, but was less, than calculated in *in vitro* (assuming placental weight = 500 g).

Placental oxygen consumption and heat exchange capacities differ within this organ and in line with reported differences, shown on MRI evaluation of primate placentae *in vivo* (Frias **et al.**, 2015).

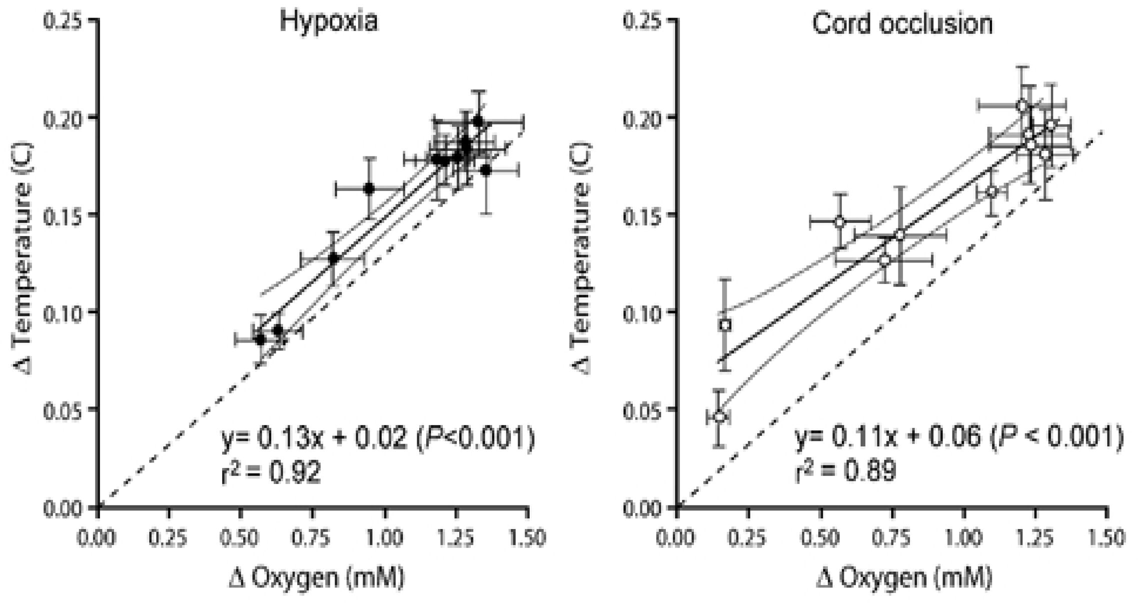

Figure 7: The arterio-tissue temperature difference for the parietal cortex (Δ Temperature (C)) and the arterio-venous oxygen content difference (Δ Oxygen (mM)) in animals treated with either moderate hypoxia (n=11) or severe asphyxia induced by cord occlusion (n=9) (Hunter C *et al.,* 2003)

CONCLUSIONS

The heat map of the placenta might provide useful tool for evaluation metabolically active placental tissue in utero.

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