Cerebral Oxygenation Determined by the INVOS 5100 During Infant Cardiac Surgery under Circulatory Arrest and Low Flow Bypass

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Introduction: Near-infrared spectroscopy (NIRS) is used to monitor cerebral oxygenation during pediatric cardiac surgery (1). In a survival piglet model of hypothermic circulatory arrest, the nadir time of the oxyhemoglobin signal has been correlated with neurologic outcome (2). The INVOS 5100 (Somanetics, Troy, MI) has been approved by the FDA for use as a trend monitor of cerebral oxygenation, and this study evaluated the rate of change and time to nadir of the regional cerebral oxygen saturation index (rSO_2) during deep hypothermic circulatory arrest (DHCA) in infant cardiac surgery. We also compared the changes in rSO_2 under circulatory arrest and continuous low-flow bypass (LF) conditions.

Methods: After IRB approval and parental informed consent, 62 neonates and infants undergoing hypothermic cardiopulmonary bypass (CPB) were prospectively studied. Standardized perfusion (pH stat) and anesthetic techniques were used. Diagnosis and surgeon preference determined whether DHCA or LF was used. Pediatric SomaSensors® were placed on the right and left forehead following induction, and the rSO_2 was recorded continuously. Data were analyzed by paired t-tests and presented as mean ± SD.

Results: Demographic and intraoperative data are shown in Table 1. Right-sided cerebral oxygen saturation (rSO_2) data are shown in Table 2. We analyzed the decline in rSO_2 during DHCA in patients who had more than 10 minutes of arrest (n=19, range (median) 11-59 (28) mins). The rSO_2 declined from 86 ± 10 at the onset of DHCA to 57 ± 11 after 25 mins of arrest. Rate of decline (Δ) of rSO_2 (absolute value from baseline) was –11 at 5 mins, –16 at 10 mins, –22 at 15 mins, –26 at 20 mins, and –29 at 25 mins of DHCA. No early post-operative adverse clinical outcomes were noted.

Discussion: Cerebral oxygenation measured by the INVOS 5100 was comparable to that reported using other instruments, i.e. rSO_2 increased during CPB cooling, decreased during DHCA, and was restored on recirculation. A nadir rSO_2 could not be obtained because the number of patients with DHCA beyond 25 minutes was too small for analysis. The significant difference in rSO_2 between the DHCA and LF groups during rewarming is consistent with the delay in recovery of cerebral oxygen consumption and extraction following DHCA (3). A limitation of the INVOS 5100, particularly with high rSO_2 during hypothermia, is that it cannot distinguish between O_2 staying bound to Hb and intracellular utilization of O_2. The INVOS 5100 holds promise as a monitor of cerebral oxygenation during pediatric cardiac surgery, but normal and critical values need to be defined and the relationship with neurologic outcome data is lacking.

Table 1. Demographic and Intraoperative Data

	LF	DHCA
N	36	26
Age (days)	102 ± 64	9 ± 15*
Weight (kg)	5.2 ± 1.1	3.7 ± 5.7*
Diagnostic Group (n)		
TGA	2	23
Conotruncal abnormalities	18	2
VSD	16	1
Total CPB time (min)	83 ± 19	133 ± 29*
Lowest tymp. temp. (°C)	25 ± 3	16 ± 1*
Minutes of DHCA	0	23 ± 13

Data are mean ± SD; **P*=0.001

Table 2. Saturation Data (Right rSO_2)

Perfusion Phase	LF (n=36)	DHCA (n=26)	*P*
Post induction	68 ± 14	63 ± 11	0.16
On CPB	63 ± 13	65 ± 12	0.68
10 min after cooling	80 ± 9	90 ± 8	<0.001
Onset of LFB	79 ± 9	89 ± 11	<0.001
Onset of DHCA	-	88 ± 11	
Resume LFB	-	64 ± 14	
Start rewarming (SW)	82 ± 12	81 ± 14	0.66
10 min after SW	68 ± 13	92 ± 8	<0.001
Warm flow (35˚C)	66 ± 10	86 ± 8	<0.001
Off CPB	65 ± 11	83 ± 9	<0.001
60 min post CPB	70 ± 13	78 ± 12	0.03
6 h post CPB	61 ± 8	65 ± 10	0.14

Refs:

1. Austin E.H. et al, J Thorac Cardiovasc Surg, 1997
2. Sakamoto T. et al, J Thorac Cardiovasc Surg, 2001
3. Greeley W.J. et al, Circulation, 1991