Research Article

Cerebral oxygenation monitoring in critically congenital heart neonates during cardiac catheterization

Mohammed Samir Eid[1], Hala Mounir Agha[1], Shereen Esam Maher[2] and Khaled Mahrous Khaled Saleh[2]

[1] Department of Pediatric Faculty of Medicine, Cairo University.
[2] Department of Pediatric Faculty of Medicine, Minia University.

Abstract
Background: NIRS and cerebral oximetry are only two terms for the same technology. The reason they rely on it is that oxyhemoglobin, deoxyhemoglobin, and cytochrome aa3 all have distinct absorption patterns in the 700 to 900 nm region of near infrared light, and biological tissue is rather transparent to this light. The redox status of cytochrome aa3, amounts of oxy- and deoxyhemoglobin, and ScO2 can be determined by analysing light signals at many wavelengths. **Aim of the work:** The goal is to assess brain oxygenation in cases of severe congenital heart defects undergoing cardiac catheterization using near-infrared spectroscopy (NIRS). Reduced brain injury, including alterations in neurocognitive function and blood biomarkers, is a result of using NIRS cerebral oximetry. Transfusion rates, mortality, and resource utilisation are all decreased, and injuries to other organs, such as the brain and heart, are also decreased. **Patients and methods:** The catheterization laboratory of the paediatric cardiology section at Cairo University Hospital was the site of. beginning on November 1, 2021, and continuing until November 30, 2023, the research will be conducted. Fifty individuals in direct need of an invasive cardiac catheterization due to critical congenital heart disease were enrolled in this trial. **Conclusions:** We may conclude from this study that INVOS has been beneficial when used within 6 months of cardiac catheterization procedures in critically ill youngsters. **Recommendations:** Therefore, to compare our results, we propose further studies on the same infant cohorts.

Keywords: Neonates- critical congenital heart diseases, INVOS, Cardiac catheterization- Desaturation, Echocardiography

Introduction
Cerebral Oximetry:
NIRS and cerebral oximetry are only two terms for the same technology. The reason they rely on it is that oxyhemoglobin, deoxyhemoglobin, and cytochrome aa3 all have distinct absorption patterns in the 700 to 900 nm region of near infrared light, and biological tissue is rather transparent to this light. The redox status of cytochrome aa3, amounts of oxy- and deoxyhemoglobin, and ScO_2 can be determined by analysing light signals at many wavelengths [1].

At this time, the gadgets use either frequency-domain or continuous-wave technology. The intensity of the detected light in relation to the emitted light is measured by continuous wave devices, which have been available for sale for some time. These devices monitor changes in oxygenation levels over time, beginning with an unknown initial value[2].

One new technology that can measure the phase-shift and intensity of detected light relative to emitted light is frequency-domain

devices. These gadgets can find the initial oxygenation level and track its evolution over time [3].

There are clear distinctions between pulse-oximetry and cerebral oximetry. Cerebral oximetry measures the non-pulsatile signal component that represents the circulation of tissues, such as arterioles, capillaries, and venules, in contrast to pulse oximetry, which measures the pulsatile signal component that represents the arterial circulation. Around 85% of the signal from venules contributes to the cerebral oximetry "weighted average" of blood flow in brain tissue. Subtracting the amount of ScO_2 from SaO_2 yields the estimated cerebral oxygen extraction (CEO_2), since ScO_2 is a good approximation of venous SO_2. Brain oximetry shows a banana-shaped amount of tissue around 2 cm below the optical probe [1].

A sensor is placed on the skin across the temporal and frontal lobes of the brain in this noninvasive method. This method involves penetrating the brain with a low-intensity near-infrared light beam in order to detect changes in tissue chromophores like haemoglobin [4].

The spectral absorption of oxygenated and deoxygenated haemoglobin in the brain can be determined by detecting light at two distinct distances from its source. Analysing the data is as simple as comparing the relative changes over time. The result is shown as an oxygen saturation index (rS02) of the cerebral cortex's combined arterial and venous blood [5].

Nearly 70% of the signal originates in the venous compartment, 20% in capillaries, and 10% in arterioles [6].

Aim of the work
The goal is to assess brain oxygenation in cases of severe congenital heart defects undergoing cardiac catheterization using near-infrared spectroscopy (NIRS).

Reduced brain injury, including alterations in neurocognitive function and blood biomarkers, is a result of using NIRS cerebral oximetry. Transfusion rates, mortality, and resource utilisation are all decreased, and injuries to

other organs, such as the brain and heart, are also decreased.

Patients and methods
The catheterization laboratory of the paediatric cardiology section at Cairo University Hospital was the site of. beginning on November 1, 2021, and continuing until November 30, 2023, the research will be conducted.
Fifty individuals in direct need of an invasive cardiac catheterization due to critical congenital heart disease were enrolled in this trial.

Patients : (Cases & Controls)
Since every patient admitted to the cardiac catheterization unit at Abo El Resh Medical Center's tertiary cardiac and newborn intensive care unit (NICU) had a record from the time of admission until their discharge, we rely on their (Registration) sector.

Five categories were established from the study population based on the results of the echocardiography:
Class 1: TGA (Great Arteries Transposition)
Class 2: Duct-dependent systemic circulation; Coarctation of the aorta (CoA) with ventricular septal defect (VSD), interrupted aortic arch (IAA) with VSD, and functional single ventricle (FSV) with CoA
As a third group, we have duct-dependent pulmonary circulation, tetralogy of fallot with pulmonary atresia (PA) or pulmonary stenosis (PS), and FSV with PA or PS.
Class 4: Ebstein abnormality, tricuspid dysplasia, and regurgitation lesions
Class 5: Combination lesion, truncus arteriosus, and total abnormal pulmonary venous return ("TAPVR"). In **2018, Merck** was based in Kenilworth, New Jersey.

Inclusion criteria for the patients:
1) All youngsters hospitalized to the Abo El Resh medical center had serious congenital heart disease.
2) 1–90 days of age
3) Received admission between November 2021 and November 2023. Operated on both Saturday and Tuesday.
4) Echocardiography confirmed the diagnosis of critical congenital heart disease.
5) The parent's legal approval and written authorization

Exclusion criteria for the patients:

1-Hemorrhagic Ischemic Cerebrovascular Disease

Two, abnormalities of the central nervous system that occur during birth

3- Kernicterus

4- Illnesses related to biochemistry (Neurometabolic disorders)

5- Disorders affecting brain development

6- Seizures in patients

Results

Table (1): Demographic data between cases and controls

Baseline characteristics	Cases (n=50)	Controls (n=50)	P value
Age (days) Mean ± SD Median (Range)	18.5±19 10.5(2:75)	30.5±23.5 23.5(2:90)	0.002*
Sex Male Female	35(70%) 15(30%)	26(52%) 24(48%)	0.06

-* significant at p value <0.05

As shown in table 1, there are statistically significant difference between cases and control regarding age (p value<0.05) as mean age of cases was 18.5 days which is significantly lower than control (mean age was 30.5 days).

While there are non-statistically significant difference regarding sex (p value>0.05) as 70% of cases were males compared to 52% of controls.

Table (2): Comparison of ECHO diagnosis between cases and controls

ECHO diagnosis	Case (N=50)	Controls (N=50)	Total (N=100)	P value
TOF PA	9(18%)	4(8%)	13(13%)	
TOF- PS	1(2%)	0	1(1%)	
Critical PS	17(3%)	20(40%)	37(237%)	
Critical AS	2(4%)	2(4%)	4(4%)	0.30
PA Intact IVS	6(12%)	11(22%)	17(17%)	
TA intact IVS	1(2%)	1(2%)	2(2%)	
D-TGA intact IVS	3(6%)	8(16%)	11(22%)	
Single ventricle PA	4(8%)	0	4(4%)	
D-TGA PS	1(2%)	0	1(1%)	
D-TGA- PA- VSD	2(4%)	2(4%)	4(4%)	
L TGA PA	2(4%)	2(4%)	4(4%)	
Severe COA myopathic LV	1(2%)	0	1(1%)	
Severe Aortic Stenosis – COA	1(2%)	0	1(1%)	

TOF (Tetralogy of Fallout)- PS (Pulmonary stenosis)- PA (Pulmonary Atresia) –
IVS (Interventricular septum) - TA (Tricuspid Atresia) – TGA (Transposition of Great Arteries) –
VSD (Ventricular septal defect) - COA (Coarctation of Aorta) – LV (Left ventricle)

*Regarding echo diagnosis of studied cases and control, there are non- statistically significant difference between cases and controls regarding echo finding (Diagnosis) (p value>0.05).
*As the most common clinical finding among cases and controls was critical PS (34% and 40% respectively) and the next common among cases was TOF PA (18%) while the second common finding among controls was PA intact IVS (22%) and the least common among cases and controls were Severe COA myopathic LV, Severe Aortic Stenosis – COA, D-TGA PS and TOF- PS.

Table (3): Comparison of Catheterization maneuvers between cases and controls

Catheterization maneuvers	Case (N=50)	Controls (N=50)	Total (N=100)	P value
PDA stent	20(40%)	18(36%)	38(38%)	0.24
Pulmonary ballon dilatation	7(14%)	20(40%)	37(37%)	
Aortic ballon dilatation	4(8%)	2(4%)	6(6%)	
Rashkind	5(10%)	10(20%)	15(15%)	
RVOT stent	2(4%)	0	2(2%)	
RF PDA stent	2(4%)	0	2(2%)	

PDA (Patent ductus arteriosus)–RVOT (Right Ventricle Outflow Tract)-RF (Radiofrequency)
Regarding catheterization maneuvers which were done for studied cases and controls, there are non-statistically significant difference between cases and controls regarding catheter maneuvers (p value>0.05).

As 40% of cases had PDA stent compared to 36% of controls, also 40% of controls had pulmonary balloon dilatation compared to 14% of cases.
While the least common maneuver done for cases and controls was RVOT stent and RF PDA stent (percentage was 4% for cases compared to 0% of controls).

Table (4): Descriptive statistics of INVOS and area under curve of studied cases

INVOS value and AUC	Cases (n=50)
INVOS value Mean ± SD Median (Range)	60.3±14.7 65(35:80)
Area under curve Flat line Less than 25% More than 25%	22(44%) 13(26%) 15(30%)

As regard INVOS values of studied cases, it was ranging from 35 to 80 with a mean of 60.3, also foe area under curve, it was estimated that majority of cases 44% had no area under curve (Flat line), then 30% had area under curve more than 25% and 26% had area under curve less than 25%.

Discussion

A critical congenital heart defect is one that is obvious at birth and requires medical attention within a year of life due to structural abnormalities in the heart. Out of all the newborn deaths due by birth defects, congenital heart disease makes up 30-50%. There were more than 13,000 infant fatalities in the US attributable to congenital heart defects between 1999 and 2006, prior to the implementation of

essential congenital heart disease newborn screening [7].

Any form of congenital heart defect (CHD) requiring medical intervention within the first year of a person's life is considered serious, according to the American Heart Association (AHA). The more realistic way to put it is that it's Congenital Heart Disease (CHD) if it required medical treatment or caused death within the first 28 days of life. Eckersley et al., (2016) used this categorization to choose the forms of congenital heart disease (CHD) that may benefit from a screening module used in the early stages [8].

Patients with coronary heart disease are at increased risk for brain damage during and after cardiac treatments such as catheterization or surgery. Cognitive abilities, physical skills, social interaction, behaviour, language, focus, and executive function are just few of the areas that might be impacted by neurodevelopmental disability.[9] is a reference to a study that was carried out by Kim and colleagues in the year 2021. [10] is about a study that was carried out by Zhu and colleagues in the year 2020.

In the catheterization lab of the pediatric cardiology division at Cairo University Hospital, researchers carried out a prospective observational cohort study. The research will run from November 1, 2021, to November 30, 2023. Fifty infants and newborns in serious need of invasive cardiac catheterization due to congenital heart defects were enrolled in this study [15].

With an emphasis on the advantages of INVOS and an assessment of the immediate prognosis within 6 months after the procedure, this prospective study sought to examine the short-term fate of critically sick babies undergoing cardiac catheterization.

Fifty people took part in the study. Fifty neonates who needed an invasive cardiac catheterization immediately due to a serious congenital heart defect were the subjects of the study. The procedures were conducted on Saturdays and Tuesdays during the study period, which lasted from November 2021 to November 2023. Fifty instances served as a control group that did not receive INVOS

monitoring; these patients were compared to them. In the perspective of just one center experience, this amount is substantial, particularly when contrasted with others[16].

Echocardiography diagnoses were used to classify the study population into five groups.
First category: TGA, or transposition of the main arteries.
Condition such as functional single ventricle (FSV) with coarctation of the aorta (CoA) or interrupted aortic arch (IAA) with ventricular septal defect (VSD) is part of Group 2, which includes situations where the duct is dependent on the systemic circulation.[17]

Group 3 includes situations where the pulmonary circulation is dependent on a duct, such as tetralogy of Fallot (TOF) with pulmonary atresia (PA) or pulmonary stenosis (PS), or functional single ventricle (FSV) with PA or PS[18].

Regurgitation lesions, tricuspid dysplasia, and Ebstein's abnormalities are all part of Group 4.
The fifth category includes lesions that cause blood to mix, such as truncus arteriosus and total anomalous pulmonary venous return, or TAPVR. The 2018 Merck headquarters are in Kenilworth, New Jersey[20].

Both NIRS and cerebral oximetry mean the same thing. The absorption spectra of oxyhemoglobin, deoxyhemoglobin, and cytochrome aa3 are different, and their reliance on the relative transparency of biological tissue to near-infrared light (700-900 nm) is crucial. Various light signals at different wavelengths can be used to evaluate cytochrome aa3 redox status, oxy-and deoxyhemoglobin levels, and ScO_2 concentrations [11].

At this time, the devices use either continuous-wave or frequency-domain technology. Because they compare the amount of light that is detected to the amount of light that is emitted, continuous wave devices have been available for a while. Over time, relative to an unknown initial point, the authors [12] show variations in oxygenation levels.

Cerebral oximetry and pulse-oximetry differ in a number of important ways. The use of near-infrared light signals is common in both

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cerebral oximetry and pulse oximetry. The non-pulsatile signal component, which indicates circulation in tissues including venules, capillaries, and arterials, is especially monitored by cerebral oximetry. Conversely, pulse oximetry measures arterial blood flow by monitoring the pulsatile signal component. A "weighted average" of tissue circulation is produced by cerebral oximetry, which shows that 85% of the signal comes from venules. Since ScO_2 is similar to venous SO_2, the difference between SaO_2 and ScO_2 (CEO$_2$ 5 SaO$_2$ 2 ScO$_2$) can be used as a sign of cerebral O_2 extraction (CEO$_2$). Using cerebral oximetry, a banana-shaped tissue compartment with a diameter of about 2 cm is illuminated [13].

Conclusions

- We may conclude from this study that INVOS has been beneficial when used within 6 months of cardiac catheterization procedures in critically ill youngsters.
- Patients with severely sick congenital cardiac problems can spend less time in the ICU with the use of INVOS, an efficient approach.
- In individuals with severe congenital cardiac defects, INVOS is an effective way to shorten the duration of inotropic support medication use.
- When it comes to severely sick patients with duct dependent congenital heart defects, INVOS is an efficient way to shorten the duration of prostaglandin infusion (Prostin) medication.
- Critically sick patients with congenital heart disorders who need urgent cardiac catheterization procedures can be accurately predicted to improve with the INVOS, thanks to its excellent sensitivity and specificity.
- Patients in critical care who have congenital cardiac disorders can benefit from using the INVOS to forecast their short- and intermediate-term prognoses.

Recommendations

- Therefore, to compare our results, we propose further studies on the same infant cohorts.
- Additional research on very sick congenital heart defects in newborns and adolescents

should be undertaken to compare it with our current findings.

- We recommend further research on the short- and long-term effects of treating newborns with serious congenital heart defects so that we may compare these outcomes to those in children and adolescents.
- To determine the impact of many factors on the course of patients with severely sick congenital cardiac diseases, such as the amount of time spent in the hospital intensive care unit, the length of time on inotropic medication, and the length of time on prostin therapy, additional research is required.

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