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# Developmental assessment of infants with congenital heart disease: a cross-sectional study

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## Abstract

**Background:** Recently, marked improvement of medical and surgical care for infants with congenital heart disease led to a growing population with a high risk of developmental delay. We aimed to identify developmental delay in these infants and its risk factors. So, we performed a cross-sectional study on 100 infants with congenital heart disease to assess their development by using Vineland Adaptive Behaviour Scale. We searched for risk factors for developmental delay in these infants. Correlations were conducted between the degree of developmental delay and the potential risk factors. To our knowledge, this study has not been conducted in developing countries before.

**Results:** The median age of the study group is 12.5 months, but it is equivalent to 9.5 months by using Vineland Adaptive Behaviour Scale. There was a statistically significant developmental delay in infants who had risk factors such as prematurity, history of neonatal intensive care unit admission, anemia, stunted growth, underweight, central cyanosis, or abnormal electroencephalographic.

**Conclusions:** Developmental delay is a common complication in infants with congenital heart disease. It has many risk factors; some of them could be modifiable as anemia, stunted growth, and underweight. Thus, early screening for developmental delay and its risk factors is of a great value. This could help in applying preventive measures and early intervention programs. Vineland Adaptive Behaviour Scale is a reliable tool in determination of developmental delay in infants with congenital heart disease.

**Keywords:** Congenital heart disease, Developmental delay, Vineland Adaptive Behaviour Scale, Risk factors of developmental delay

## Background

Congenital heart disease (CHD) is considered one of the commonest congenital anomalies in neonates with a birth prevalence of 8–12/1000 per live births [1, 2]. Surviving infants are at a great risk for developmental delay and could affect up to 75% of them [3]. Many risk factors are related to this developmental delay, including defective perfusion, acid-base abnormalities, low oxygen supply to the brain, and stunted growth. Also, some risk factors are biological as syndromes, genetic, developmental diseases, circulatory disorders related to the CHD, medical treatment, and/or surgical interventions performed [2, 4]. Also, developmental impairment occurs due to events that happen intrauterine, later in life, or during surgical intervention. Recently, the high survival rates in pediatric CHD raise the importance of the integrity of the brain and neurodevelopmental outcome instead of heart-related morbidity and death [4]. They have developmental and behavioral abnormalities as impairment of cognitive, social, and communication skills. Also, they have impairment in academic performance, language, perception, visual, and motor development. Developmental screening tools are used to confirm

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developmental delay requiring highly trained personnel [2]. These tools must be sensitive, valid, and reliable in order to determine the developmental delay and its management [5]. Application of preventive measures and early intervention programs is needed to achieve a positive effect on these infant's development and future academic achievement [6]. We aimed to identify developmental delay in these infants and its risk factors using Vineland Adaptive Behaviour Scale (VABS).

## Methods

We conducted a cross-sectional study aiming to identify developmental delay in infants with CHD and its risk factors using VABS. One-hundred patients were voluntarily enrolled in this study in the period starting from January 2020 to August 2020. They were included during their regular follow-up at cardiology outpatient clinic, children's hospital. Written informed consent was obtained. Enrolment of participants was after approval of the ethical and scientific committee of the institution according to relevant guidelines and regulations (approval code: S-25-2019). Inclusion criteria were as follows: non syndromic infant with CHD, age range from 6 to 24 months, and before surgical correction or cardiac catheter intervention. Exclusion criteria ere as follows: infants with genetic syndromes, neurological diseases, or post cardiac surgery.

### Sample size calculation

The primary outcome of the study is to identify developmental delay in infants with CHD and its risk factors. Mussatto et al. reported that developmental delay is common among children in the first 3 years of life and found most of them (75%) had risk or delay in $\geq 1$ of developmental domains [3]. $\alpha$ was set as 0.05, confidence level as 95%, and an acceptable error as $\pm 0.05$. The following formula was used to determine the required sample size:

$$n = \frac{Z^2(\alpha/2)P(1-P)}{e^2}$$

where:

$Z^2$ = for 95% confidence (i.e., $\alpha = 0.05$), $P$ = "best guess" for prevalence, and $e$ = maximum tolerable error for the prevalence estimate (e.g., $\pm 0.05$).

The minimum required sample size for detecting developmental delay in infants with CHD was 72.

### Medical history

The following data were collected from the parent of each infant as follows:

- History of neonatal intensive care unit (NICU) admission
- Prematurity
- Physical developmental milestone (head support, sitting, and walking)
- Language development (monosyllables and few words)

### General examination

- Central cyanosis (to assess the type of CHD: cyanotic or acyanotic CHD)
- Pallor

Anthropometric measurements (body weight and length or height measurements) were plotted on Egyptian growth curves performed by Ghalli et al. (2008) [7]. If the body weight percentile was below 3rd percentile, the infant was considered to be underweight. If the length percentile was below 3rd percentile, the infant was considered to be stunted [8].

All patients were investigated by 2-dimensional echocardiography for diagnosis of CHD.

*Psychometric assessment* was done by using the Arabic version of VABS [9, 10]. Its primary purpose was to assess the social abilities of an infant and diagnose various disabilities. It consists of four main domains: communication, daily living skills, socialization, and motor skills. Each domain consists of subdomains with age equivalent for each skill. We used assessment of skills for infants until the age of 2 years. The communication domain assesses the receptive and expressive communication development. The daily living skills domain assesses behavior, domestic, and community interaction development. The socialization domain assesses play, leisure time, interpersonal relationships, and coping development. The motor skills domain assesses fine and gross motor development [11].

We calculated the equivalent age of each infant in the study group according to each developmental skill using results of VABS. Then, we compared each field of developmental delay detected by the results of VABS with each potential risk factor of developmental delay. These potential risk factors included prematurity, cyanotic CHD [2], history of NICU admission, anemia (defined as hemoglobin level lower than normal reference range for infant with the same age [12] and it was retrieved from the patients' files), stunted growth, underweight, or abnormal electroencephalography (EEG). EEG record was performed for each infant to detect any abnormal record.

We classified the infants according to the degree of developmental delay into the following:

- Infants with severe developmental delay, as they had ≥ 3 affected developmental domains.
- Infants with moderate developmental delay, as they had 1 or 2 affected developmental domains
- Relation between the potential risk factors and the severity of developmental delay was done.

Logistic regression analysis for occurrence of developmental delay was conducted to detect the correlations between the degree of developmental delay and the potential risk factors and detect if the presence of one of these risk factors was significant over the others as regard the degree of developmental delay.

### Statistical analysis

The collected data were revised, coded, tabulated, and introduced to a PC using the Statistical Package for Social Science (SPSS) software program version 22. The chi-square test was used for calculating differences and comparing data between categories. Comparisons between groups were done using analysis of variance (ANOVA) with multiple comparisons post hoc test in normally distributed quantitative variables, while non-parametric Kruskal-Wallis test and Mann-Whitney test were used for non-normally distributed quantitative variables (Chan, 2003a). Exact test was used instead when the expected frequency is less than 5 (Chan, 2003b). *p*-value level of significance was considered non-significant if $p > 0.05$ and significant if $p \leq 0.05$.

## Results

This cross-sectional study included 100 infants with CHD (62 males and 38 females). A total of 22% of the infants had cyanotic CHD, and 78% had acyanotic CHD confirmed by 2-dimensional echocardiography. The infants' median age was 12.5 months with interquartile range (IQR) 8–17 months.

### Anthropometric measurements

The median length was 72 cm (*IQR* 66–77 cm), and 8% of the infants were stunted. The median body weight was 8.5 kg (*IQR* 7–10 kg), and 14% of the infants were underweight.

According to VABS results, the median equivalent age was 9.5 months (*IQR* 6–13 months), which was lower than the median chronological age of infants included in the study (12.5 months). The median equivalent age of the study group for each developmental skill according to results of VABS is shown in Table 1.

**Table 1** The median equivalent age of study group according to each developmental skill as regard the results of VABS

| Field of developmental delay | Median (IQR) | Delayed (%) |
|---|---|---|
| Receptive behavior | 10 (7:15) | 67 |
| Expressive behavior | 10 (6:12) | 84 |
| **Total communication** | 9.5 (7:14) | 72 |
| Personal behavior | 16 (16:16) | 62 |
| Community | 5 (5:17) | 85 |
| **Total daily life skills** | 11 (9:15) | 46 |
| Interpersonal relationships | 5 (4–16) | 77 |
| Play and leisure time | 5 (2.5:15) | 67 |
| Coping skills | 11 (10–11) | 58 |
| **Total of socialization field** | 7 (4:15) | 72 |
| Gross motor skills | 8 (4:12) | 87 |
| Fine motor skills | 8 (8:12) | 80 |
| **Total motor skills** | 8 (6:11.5) | 90 |
| Average equivalent age | 9.5 (6:13) | 90 |

*VABS* Vineland Adaptive Behavior Scale, *IQR* interquartile range

### VABS results comparing infants with different risk factors as shown in Tables 2, 3, and 4

#### *Prematurity*

The study included 19 preterm infants; all of them (100%) were statistically delayed in both total motor skills and average equivalent age (*p-value 0.035*). A total of 89.5% of them were statistically delayed in receptive behavior (*p-value 0.021*) (Table 2).

#### *History of NICU admission*

Thirty-eight infants had a history of NICU admission; all of them (100%) were statistically delayed in average equivalent age (*p-value 0.001*).

A total of 97.4% of them were statistically delayed in total motor skills (*p-value 0.036*). A total of 86.8% of them were statistically delayed in receptive behavior (*p-value 0.001*) and total communication skills (*p-value 0.010*). A total of 84.2% of them were statistically delayed in both personal behavior (*p-value 0.001*) and total socialization field (*p-value 0.033*). A total of 78.9% of them were statistically delayed in play and leisure time (*p*-value 0.047) (Table 2).

#### *Anemia*

Also, twenty-three infants had anemia; 87% of them were statistically delayed in play and leisure time (*p-value 0.02*) (Table 3).

#### *Growth parameters*

Eight infants were stunted in growth and showed statistically developmental delay in interpersonal relationship

**Table 2** Comparison between the presence of prematurity or history of NICU as regard results of VABS

| Field of developmental delay | Full term ($n = 81$) | Preterm ($n = 19$) | *P* value | No History of NICU ($n = 62$) | History of NICU ($n = 38$) | *p*-value |
|---|---|---|---|---|---|---|
| | Number (%) | Number (%) | | Number (%) | Number (%) | |
| Receptive behavior | 50 (61.7) | 17 (89.5) | **0.021*** | 34 (54.8) | 33 (86.8) | **0.001*** |
| Expressive behavior | 66 (81.5) | 18 (94.7) | 0.116 | 49 (79) | 35 (92.1) | 0.071 |
| **Total communication** | 55 (67.9) | 17 (89.5) | 0.059 | 39 (62.9) | 33 (86.8) | **0.010*** |
| Personal behavior | 48 (59.3) | 14 (73.7) | 0.244 | 30 (48.4) | 32 (84.2) | **0.001*** |
| Community | 68 (84) | 17 (89.5) | 0.529 | 50 (80.6) | 35 (92.1) | 0.105 |
| **Total daily life skills** | 34 (42) | 12 (63.2) | 0.095 | 24 (38.7) | 22 (57.9) | 0.062 |
| Interpersonal relationships | 63 (77.8) | 14 (73.7) | 0.706 | 44 (71) | 33 (86.8) | 0.067 |
| Play and leisure time | 53 (65.4) | 14 (73.7) | 0.491 | 37 (59.7) | 30 (78.9) | **0.047*** |
| Coping skills | 49 (60.5) | 9 (47.4) | 0.297 | 40 (64.5) | 18 (47.4) | 0.092 |
| **Total of socialization field** | 58 (71.6) | 14 (73.7) | 0.856 | 40 (64.5) | 32 (84.2) | **0.033*** |
| Gross motor skills | 69 (85.2) | 18 (94.7) | 0.223 | 52 (83.9) | 35 (92.1) | 0.220 |
| Fine motor skills | 64 (79) | 16 (84.2) | 0.602 | 46 (74.2) | 34 (89.5) | 0.064 |
| **Total motor skills** | 71 (87.7) | 19 (100) | **0.035*** | 53 (85.5) | 37 (97.4) | **0.036*** |
| Average equivalent age | 71 (87.7) | 19 (100) | **0.035*** | 52 (83.9) | 38 (100) | **0.001*** |

*VABS* Vineland Adaptive Behavior Scale, *NICU* Neonatal intensive care unit

*Statistically significant

**Table 3** Comparison between the presence of anemia, stunted growth, or underweight as regard results of VABS

| Field of developmental delay | No Anemia ($n = 77$) | Anemia ($n = 23$) | *p*-value | Normal ($n = 92$) | Stunted growth ($n = 8$) | *p*-value | Normal body weight ($n = 86$) | Underweight ($n = 14$) | *p*-value |
|---|---|---|---|---|---|---|---|---|---|
| | Number (%) | Number (%) | | Number (%) | Number (%) | | Number (%) | Number (%) | |
| Receptive behavior | 50 (64.9) | 17 (73.9) | 0.422 | 63 (68.5) | 4 (50) | 0.300 | 58 (67.4) | 9 (64.3) | 0.817 |
| Expressive behavior | 64 (83.1) | 20 (87) | 0.653 | 77 (83.7) | 7 (87.5) | 0.772 | 70 (81.4) | 14 (100) | **0.021*** |
| **Total communication** | 54 (70.1) | 18 (78.3) | 0.446 | 68 (73.9) | 4 (50) | 0.169 | 62 (72.1) | 10 (71.4) | 0.959 |
| Personal behavior | 46 (59.7) | 16 (69.6) | 0.394 | 56 (60.9) | 6 (75) | 0.417 | 52 (60.5) | 10 (71.4) | 0.433 |
| Community | 65 (84.4) | 20 (87) | 0.762 | 77 (83.7) | 8 (100) | 0.099 | 72 (83.7) | 13 (92.9) | 0.337 |
| **Total daily life skills** | 34 (44.2) | 12 (52.2) | 0.498 | 41 (44.6) | 5 (62.5) | 0.329 | 38 (44.2) | 8 (57.1) | 0.368 |
| Interpersonal relationships | 57 (749) | 20 (87) | 0.196 | 69 (75) | 8(100) | **0.036*** | 66 (76.7) | 11 (78.6) | 0.879 |
| Play and leisure time | 47 (61) | 20 (87) | **0.020*** | 60 (65.2) | 7 (87.5) | 0.165 | 56 (65.1) | 11 (78.6) | 0.305 |
| Coping skills | 44 (57.1) | 14 (60.9) | 0.751 | 53 (57.6) | 5 (62.5) | 0.787 | 51 (59.3) | 7 (50) | 0.513 |
| **Total of Socialization field** | 52 (67.5) | 20 (87) | 0.069 | 64 (69.6) | 8 (100) | **0.019*** | 61 (70.9) | 11 (78.6) | 0.546 |
| Gross motor skills | 66 (85.7) | 21 (91.3) | 0.467 | 80 (87) | 7 (87.5) | 0.965 | 73 (84.9) | 14 (100) | **0.040*** |
| Fine motor skills | 60 (77.9) | 20 (87) | 0.324 | 72 (78.3) | 8 (100) | 0.053 | 68 (79.1) | 12 (85.7) | 0.551 |
| **Total motor skills** | 68 (88.3) | 22 (95.7) | 0.264 | 82 (89.1) | 8 (100) | 0.184 | 76 (88.4) | 14 (100) | 0.074 |
| Average equivalent age | 68 (88.3) | 22 (95.7) | 0.264 | 82 (89.1) | 8 (100) | 0.184 | 76 (88.4) | 14 (100) | 0.074 |

*VABS* Vineland Adaptive Behavior Scale

*Statistically significant

**Table 4** Comparison between the type of CHD or abnormal EEG as regard results of VABS

| Field of developmental delay | Acyanotic CHD ($n = 78$) | Cyanotic CHD ($n = 22$) | *p*-value | Normal EEG records ($n = 77$) | Abnormal EEG records ($n = 23$) | *p*-value |
|---|---|---|---|---|---|---|
| | Number (%) | Number (%) | | Number (%) | Number (%) | |
| Receptive behavior | 48 (61.5) | 19 (86.4) | **0.029*** | 46 (59.7) | 21 (91.3) | **0.005*** |
| Expressive behavior | 64 (82.1) | 20 (90.9) | 0.291 | 63 (81.8) | 21 (91.3) | 0.249 |
| **Total communication** | 53 (67.9) | 19 (86.4) | **0.021*** | 52 (67.5) | 20 (87) | 0.069 |
| Personal behavior | 42 (53.8) | 20 (90.9) | **0.002*** | 45 (58.4) | 17 (73.9) | 0.180 |
| Community | 64 (82.1) | 21 (95.5) | 0.084 | 64 (83.1) | 21 (91.3) | 0.310 |
| **Total daily life skills** | 34 (43.6) | 12 (54.5) | 0.363 | 29 (37.7) | 17 (73.9) | **0.002*** |
| Interpersonal relationships | 56 (71.8) | 21 (95.5) | **0.020*** | 61 (79.2) | 16 (69.6) | 0.334 |
| Play and leisure time | 49 (62.8) | 18 (81.8) | 0.094 | 53 (68.8) | 14 (60.9) | 0.476 |
| Coping skills | 49 (62.8) | 9 (40.9) | 0.066 | 42 (54.5) | 16 (69.6) | 0.200 |
| **Total of socialization field** | 52 (66.7) | 20 (90.9) | **0.025*** | 57 (74) | 15 (65.2) | 0.409 |
| Gross motor skills | 66 (84.6) | 21 (95.5) | 0.141 | 66 (85.7) | 21 (91.3) | 0.467 |
| Fine motor skills | 59 (75.6) | 21 (95.5) | **0.021*** | 60 (77.9) | 20 (87) | 0.324 |
| **Total motor skills** | 68 (87.2) | 22 (100) | **0.022*** | 69 (89.6) | 21 (91.3) | 0.809 |
| Average equivalent age | 68 (87.2) | 22 (100) | **0.022*** | 67 (87) | 23 (100) | **0.018*** |

*VABS* Vineland Adaptive Behavior Scale, *CHD* Congenital heart disease, *EEG* Electroencephalographic

*Statistically significant

and total socialization field with *p-values 0.36 and 0.019*, respectively (Table 3), while 14 infants were underweight and statistically delayed in expressive behavior and gross motor skills with *p-values 0.021 and 0.04*, respectively (Table 3).

#### *Type of congenital heart disease*

Twenty-two infants had congenital cyanotic heart disease. All of them (100%) were statistically delayed in both total motor skills and average equivalent age (*p-value 0.022*). A total of 95.5% of them were statistically delayed in interpersonal relationships (*p-value 0.02*) and fine motor skills (*p-value 0.021*). A total of 90.9% of them were statistically delayed in both personal behavior (*p-value 0.002*) and total socialization field (*p-value 0.025*). A total of 86.4% of them were statistically delayed in receptive behavior (*p-value 0.029*) (Table 4).

#### *Abnormal EEG records*

Twenty-three infants had abnormal EEG records; all of them (100%) were statistically delayed in average equivalent age (*p-value 0.018*). A total of 91.4% of them were statistically delayed in receptive behavior (*p-value 0.005*). A total of 73.9% of them were statistically delayed in total daily life skills (*p-value 0.002*) (Table 4).

### Classification of the infants according to the degree of developmental delay

In the current study, 69% of the infants were classified as having severe developmental delay, as they had $\geq 3$ affected developmental domains, while 30 infants were classified as having moderate developmental delay, as they had 1 or 2 affected developmental domains. Relation between the potential risk factors and the severity of developmental delay was shown in Fig. 1.

Risk analysis for occurrence of developmental delay was conducted to detect the correlations between the degree of developmental delay and the potential risk factors as shown in Table 5 and Fig. 2 and revealed no statistical difference between the presence of one of these risk factors over the others as regard the degree of developmental delay.

## Discussion

The aim of the current study was to assess the development of infants with CHD using VABS focusing on four main domains: communication, daily life skills, socialization, and motor skills.

We compared the results of VABS and the different risk factors that may affect their developmental status such as prematurity, history of NICU admission, anemia, underweight, stunted growth, cyanotic CHD, and abnormal EEG.

Previous studies conducted by Khalil et al. demonstrated that there is a high risk of neurodevelopmental delay in form of convulsions, feeding difficulties, cranial nerve, motor abnormalities, and\or lethargy in infants with CHD [13].

As regards results of VABS, almost all infants (99%) included in the current study demonstrated developmental delay in its all domains: communication, daily life, socialization, and motor skills (Table 1).

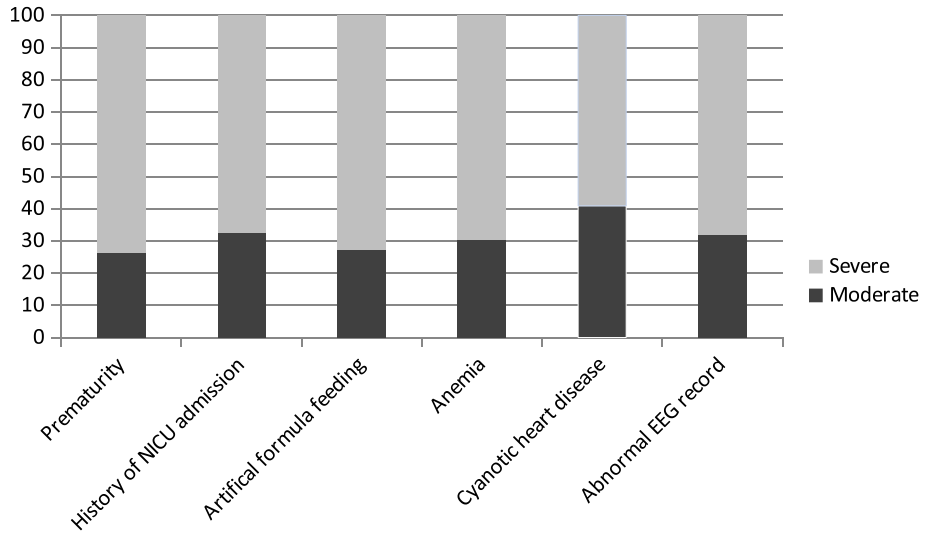


**Fig. 1** Relation between potential risk factors and severity of developmental delay

**Table 5** Risk analysis for occurrence of severe developmental delay

| | Moderate developmental delay | | Severe developmental delay | | Odds ratio | | | |
|---|---|---|---|---|---|---|---|---|
| **Risk factor** | ***N*** | **Row %** | ***N*** | **Row %** | **P value** | **OR** | **Lower 95% CI** | **Upper 95% CI** |
| History of prematurity | 5 | 26.3% | 14 | 73.7% | 0.674 | 1.27 | 0.41 | 3.92 |
| History of NICU admission | 12 | 32.4% | 25 | 67.6% | 0.722 | 0.85 | 0.35 | 2.05 |
| History of artificial formula feeding | 6 | 27.3% | 16 | 72.7% | 0.726 | 1.21 | 0.42 | 3.47 |
| Cyanotic heart disease | 9 | 40.9% | 13 | 59.1% | 0.220 | 0.54 | 0.20 | 1.45 |
| Anemia | 7 | 30.4% | 16 | 69.6% | 0.987 | 0.99 | 0.36 | 2.73 |
| Abnormal EEG records | 7 | 31.8% | 15 | 68.2% | 0.861 | 0.91 | 0.33 | 2.53 |

*N* Number, *OR* Odds ratio, *NICU* Neonatal intensive care unit, *EEG* Electroencephalographic

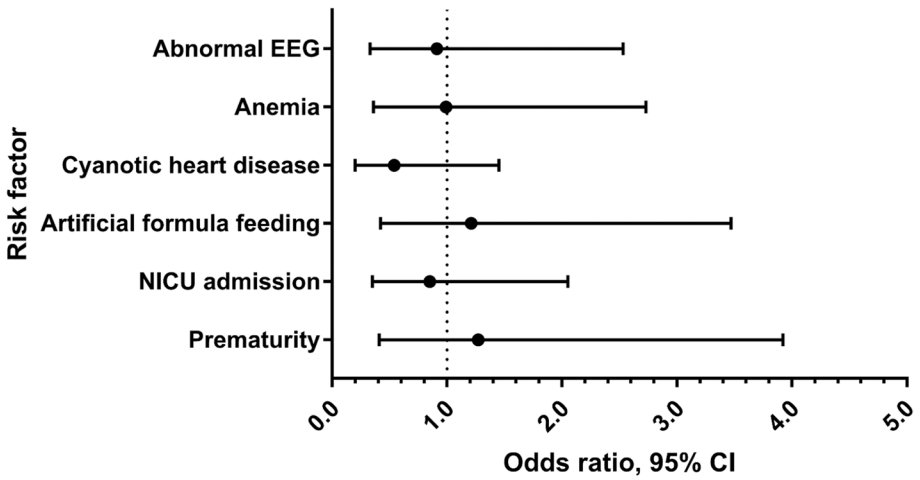


**Fig. 2** Odds ratio for various risk factors. Rounded markers represent estimates. Error bars represent 95% confidence limits. Dotted vertical line represents line of equality (odds ratio of 1.0). A total of 95% confidence limits including the value 1.0 are not statistically significant

This is in agreement with Mebius et al., who found that there is a risk of neurodevelopmental delay in infants with CHD due to many factors as injury to multiple cerebral regions and alternation of cerebral blood flow that lead to impairment of oxygen and nutrient supply to the brain [14]. Also, Marino et al. found that they had developmental and behavioral abnormalities as impairment of cognitive, social, and communication skills. Also, they have impairment in academic performance, language, perception, visual, and motor development as a result of multiple risk factors including the circulatory disorders related to the CHD, medical treatment, and surgical interventions performed [2].

The current study goes in concordance with Butler et al., who demonstrated that infants with CHD had detective interaction with their environment as they have abnormalities in attention [15].

### VABS results comparing infants with different risk factors

#### *Prematurity*

Prematurity was revealed to be a significant risk factor for developmental delay in infants with CHD especially in receptive behavior (*p*-value 0.021), total motor skills (*p*-value 0.035), and average equivalent age with (*p*-value 0.035). This is in line with Woythaler et al., who followed 950 preterm infants and detected that preterm infants had significant developmental delay in different fields such as expressive language at 24 months and may increase to be severe at school age. It is due to many reasons such as events occurred at prenatal period affecting the growing brain that may have a risk of injury compared with full-term infants [16].

It is concordant with Mebius et al., who demonstrated that preterm infants are at risk for acquiring brain injury. Their brains have immature vasculature, vulnerable white matter, and affected autoregulation. This brain injury is associated with developmental delay [14].

Also, Jarjour found that there is a high prevalence of adverse developmental outcomes in the majority of very preterm infants. These included almost all developmental aspects. Early recognition of the neurolo-developmental disability is important in counseling of the families. Also, this helps in referring these infants to early suitable intervention programs and appropriate medical care [17].

Thus, we attributed our results not only due to prematurity but also due to circulatory changes in infants with CHD that could impair cerebral blood flow and lead to decrease of oxygen and nutrient supply to the brain.

#### *History of NICU admission*

History of NICU admission among our infants (38%) was a significant risk factor of developmental delay regarding receptive behavior (*p-value 0.001*), total communication (*p-value 0.010*), personal behavior (*p-value 0.001*), play and leisure time (*p-value 0.047*), total socialization field (*p-value 0.033*), total motor skills (*p-value 0.039*), and average equivalent age (*p-value 0.001*).

This corresponds to Philpott-Robinson et al., who noted NICU admission had risk of exposure to sounds of alarms that affect functions of the tactile system. Also, painful procedures and exposures to bright lights affect motor and cognitive development negatively [18].

Also, Fallah et al. found that infants admitted to the NICU showed degrees of developmental delay at the ages of 6 and 12 months, especially in the gross motor and personal-social developmental domains [19].

#### *Anemia*

It was detected in 23% of the infants, and it was a significant risk factor for developmental delay in play and leisure time subdomain (*p*-value 0.02).

Similarly, Ozmen et al. detected a significant relation between anemia and developmental delay [20].

#### *Growth parameters*

Stunted infants (8%) were a significant risk factor of developmental delay in interpersonal relationship and total socialization field with *p-value 0.036 and 0.019*, respectively.

Ravishankar et al. detected that stunting in 37% of their patients correlated with decreased size of the brain. This results from changes in concentration of growth factor, structural proteins, and neurotransmitter production. So, these infants have affected developmental functions and school performance [21].

Also, in current study, underweight infants (14%) showed a statistically significant developmental delay in expressive behavior and gross motor skills with *p-value 0.021 and 0.04*, respectively.

This is in agreement with Lata et al., who found that 57% of infants with CHD were underweight attributing that to malnutrition and inadequate caloric intake [4]. In addition, Luo et al. detected that in his study group, 1.2% were underweight, 1.6% were wasted, 20% of the infants had delayed cognitive development, while 32.3% had delayed in psychomotor development, thus highlighting the significant relation between infant nutrition and their development. Micronutrient deficiency plays an important role in developmental delay [22].

#### *Type of congenital heart disease*

Infants with cyanotic CHD (22%) in the current study had more statistically significant developmental delayed than infants with acyanotic heart disease regarding receptive behavior (*p-value 0.029*), personal behavior (*p-value 0.002*), interpersonal relationship (*p-value*

*0.02*), total of socialization field (*p-value 0.025*), fine motor skills (*p-value 0.021*), total motor skills (*p-value 0.022*), and average equivalent age with *p-value 0.022*). Our results are in agreement with Lata et al., who noted that children who had cyanotic CHD were at high risk of developmental delay as they had chronic hypoxaemia [4].

### *Abnormal EEG records*

Infants with abnormal EEG records (23%) had a significant developmental delay compared with infants with normal EEG records in receptive behavior (*p-value 0.005*), total daily life skills (*p-value 0.002*), and in average equivalent age (*p-value 0.018*).

Mulkey et al. study detected 60% of infants with CHD had abnormal EEG patterns. It may give data about the infants' neurological status that may affect their developmental [23].

Also, Limperopoulos et al. conducted a study on infants with CHD, suggesting that EEG abnormalities may increase the risk of persistent neurologic deficits [24].

There was no statistically difference between the presence of one risk factor over the other as regard the degree of developmental delay. This could be explained as 99 out of 100 infants had some degree of developmental delay. So, we could not reach which risk factor was the most significant. Yet, these risk factors should be considered during the assessment of infants with CHD.

## Conclusions

Developmental delay is a common complication in infants with CHD. It has many risk factors such as anemia, malnutrition, prematurity, cyanosis, and NICU admission. Some of these risk factors could be modifiable as anemia, stunted growth, and underweight due to malnutrition. So, nutritional management and proper nutritional supplementation for these infants are very important and crucial for improving their development. The Vineland Adaptive Behaviour Scale is a reliable tool in determination of developmental delay in infants with CHD. Early screening for developmental delay and its risk factors is of a great value. This could help in applying preventive measures and early intervention programs to achieve positive effect on these infants' development.

#### Abbreviations

CHD: Congenital heart disease; EEG: Electroencephalographic; IQR: Interquartile range; NICU: Neonatal intensive care unit; VABS: Vineland Adaptive Behaviour Scale.

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#### Authors' contributions

SSh revised and critically reviewed the manuscript. ORA designed the study and reviewed the manuscript. AE collected the data. NE revised the English editing of the manuscript. ShS designed the study, drafted the initial manuscript, revised the manuscript, and critically reviewed the manuscript. The authors read and approved the final manuscript.

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#### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Declarations

#### Ethics approval and consent to participate

The study had been approved by the Research Ethical Committee of Faculty of Medicine, Cairo University (approval code: S-25-2019), according to relevant guidelines and regulations. A written informed consent was obtained from the parents or legal guardians of the infants.

#### Consent for publication

Not applicable

#### Competing interests

The authors declare that they have no competing interests.

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