Original Article

Can Pulmonary Arterial Pressure Exceeding 15 mm Hg Predict Prognosis in Patients With a Single-Ventricle Defect Undergoing the Glenn Procedure?

Reza Abbaszadeh[1], MD; Behrouz Azari[1*], MD; Mahmoud Meraji[1], MD; Gholamreza Azari[2], PhD; Yasaman Khalili[1], MD; Akbar Nikpajouh[1], MD

ABSTRACT

Background: The primary goal of the Fontan reconstructive surgery is not only to achieve optimal systemic blood flow and simultaneous controlled pulmonary balance but also to prevent the blood from returning to the ventricles. Such measures as the use of systemic-pulmonary shunts can help achieve the desired outcome in this type of surgery. It appears that reducing the resistance of pulmonary arteries and maintaining pulmonary arterial pressure (PAP) could serve as prognostic factors in patients undergoing this surgery. We sought to test the hypothesis that preserved PAP in patients with a single-ventricle defect undergoing the Fontan procedure via the Glenn shunt implantation could confer a better prognosis.

Methods: This retrospective cohort study was conducted on 54 consecutive patients with a single-ventricle defect who underwent the Glenn procedure in Rajaie Cardiovascular Medical and Research Center in Tehran in 2019. Based on PAP assessed by angiography, the patients were classified into 2 groups: PAP equal to or less than 15 mm Hg (n=27) and PAP above 15 mm Hg (n=27). Information on the surgical outcome was compared between the 2 groups.

Results: No difference was observed between the groups in the rate of cardiac arrhythmia (*P*=0.192), but the prevalence rates of ascites (7.4% vs 48.1%; *P*=0.001) and pleural effusion (33.3% vs 85.2%; *P*=0.001) were higher in the high-PAP group. The mean length of hospital stay (6.00±2.37 d vs 9.48±6.86 d; *P*=0.16) and the mean length of ICU stay (3.93±1.07 d vs 5.30±2.30 d; *P*=0.008) were longer in the high-PAP group.

Conclusions: High PAP is regarded as a prognostic factor in patients undergoing the Glenn procedure since it places patients at risk for postoperative ascites and pleural effusion and, thus, the need for long-term hospitalization. ***(Iranian Heart Journal 2022; 23(1): 112-117)***

KEYWORDS: Coronavirus disease 2019 (COVID-19), Deep vein thrombosis (DVT), Incidence rate, SARS-CoV-2

[1] Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran.
[2] Department of Basic Sciences, University of Social Welfare and Rehabilitation Sciences (USWRS), Tehran, IR Iran.

*** Corresponding Author:** Behrouz Azari, MD; Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, IR Iran.
Email: behrouzazari@yahoo.com **Tel:** +989148294407

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In some anatomical defects of the heart, only 1 ventricle is functional, and it pumps the blood jointly into the aortic artery and the pulmonary artery. The amount of drainage into each of these 2 vascular beds depends on the degree of the obstruction of their outflow tract. If the outflow tract obstruction is of the same severity, more blood enters the pulmonary circulatory system due to less vascular resistance. Patients with a single ventricle will have a poor prognosis if they do not undergo reconstructive surgery. Overall, the prognosis of patients with single ventricular function is poor. [1] The Fontan procedure as the treatment of choice for a single-ventricle defect has always been associated with good results. [2-7] The bidirectional Glenn shunt is always considered a palliative and supportive method before performing the Fontan procedure. The benefits of this supportive surgery include relief from ventricular volume overload, reduction of ventricular atrial valve insufficiency, and prevention of pulmonary artery distension. [8-13] The bidirectional Glenn shunt surgery plays a key role in improving the surgical outcome in patients undergoing the Fontan procedure, to the extent that it significantly reduces the risk of mortality in high-risk patients. [14-19] Nonetheless, several factors affect the mortality resulting from the aforementioned surgery, including abnormal pulmonary artery structure, high pulmonary hypertension, heterotaxy syndrome, systemic right ventricle, and abnormal pulmonary venous drainage. [20] In this regard, the role of high pulmonary arterial pressure (PAP) as a prognostic factor is prominent. Many studies have considered a PAP below 15 mm Hg an indication for the Fontan procedure and defined a PAP below 20 mm Hg, along with a ventricular end-diastolic pressure of less than 15 mm Hg, as indications for that surgery. [21] Nevertheless, there are still conflicting results regarding the effects of basal PAP on the outcome of the Glenn procedure. Pulmonary artery hypertension also appears to be a significant factor in the prognosis of the Fontan procedure. Accordingly, in the present study, we sought to determine the early outcome following the Glenn procedure in patients with a single-ventricle defect with a PAP exceeding 15 mm Hg and compare the findings with those in patients with a PAP equal to or below 15 mm Hg to determine the influence of pulmonary artery hypertension on the consequences of Glenn procedure.

METHODS

This retrospective cohort study was conducted on 54 consecutive patients with a single-ventricle defect referred to Rajaie Cardiovascular Medical and Research Center in Tehran in 2019 who underwent the Glenn procedure. Patients with incomplete file data were not included. Additionally, concurrent cardiac procedures were considered the exclusion criteria. First, with a comprehensive review of the recorded files of patients with single ventricular heart undergoing the bidirectional Glenn shunt surgery, background information (eg, demographic characteristics, medical history, and surgical history), angiographic information, and echocardiographic data were collected and included in the study checklist. In addition, information on the consequences of the Glenn reconstructive surgery, including postoperative complications, hospital mortality, the need for mechanical ventilation, the use of inotropes, the need for reintubation, the level of cardiac biomarkers before and after surgery, the length of hospital stay in the intensive care unit (ICU), and the total length of hospital stay, was extracted from the patients' files. Based on PAP assessed by angiography, the patients were classified into 2 groups: PAP equal to or less than 15 mm Hg (n=27) and PAP exceeding 15 mm Hg (n=27). Information on the outcome after surgery was compared between the 2 groups.

For statistical analysis, the results were presented as the mean ± the standard deviation (SD) for quantitative variables and were summarized as frequencies (percentages) for categorical variables. Continuous variables were compared using the *t* test or the Mann–Whitney test whenever the data did not appear to have normal distribution or when the assumption of equal variances was violated across the study groups. Categorical variables were, on the other hand, compared using the χ^2 test. The differences in the study outcomes between the 2 groups were adjusted for baseline variables, and multivariable regression modeling was employed. For the statistical analyses, the statistical software SPSS, version 23.0, for Windows (IBM, Armonk, New York) was used.

RESULTS

The baseline characteristics in the 2 groups are summarized in Table 1. The 2 groups were matched for sex and mean age; still, significantly lower body weight, lower height, and lower serum levels of hemoglobin and hematocrit were reported in the high-PAP group than in the low-PAP group. The mean heart rate was also higher in the former group. There were no differences in the mean balloon pump time and aortic cross-clamp time between the 2 groups. No differences were found between the groups in terms of the average injection dose of milrinone and epinephrine. There were also no associations between the mean PAP and body mass index (r=0.144, P=0.410) and the inotrope score (r=0.003, P=0.984).

With respect to the postoperative outcome (Table 2), no difference was noted in the rate of cardiac arrhythmia between the 2 groups (P=0.192); however, the prevalence rates of ascites (7.4% vs 48.1%; P=0.001) and pleural effusion (33.3% vs 85.2%; P=0.001) were higher in the high-PAP group. The mean length of hospital stay (6.00±2.37 d vs 9.48±6.86 d; P=0.16) and the mean length of ICU stay (3.93±1.07 d vs 5.30±2.30 d; P=0.008) were also longer in the high-PAP group. In the multivariate linear regression model and in the presence of the baseline characteristics, there was still a difference in the length of hospital stay in the ward between the 2 groups (β coefficient =3.898; P=0.022). Additionally, in the same linear regression model, there was a difference in the length of ICU stay between the 2 groups (β coefficient =1.341, P=0.021). In the multivariate logistic regression model and in the presence of the baseline characteristics, the difference in the prevalence of ascites between the 2 groups was significant (odds ratio [OR]=116.900, P=0.003). Moreover, in another multivariate logistic regression model, the difference in the prevalence of pleural effusion was significantly different between the 2 groups (OR=27.891, P=0.001).

Table 1. Baseline and intraoperative characteristics in the study population

Characteristics	PAP≤15 mm Hg	PAP>15 mm Hg	*P* value
Male sex	19 (70.4)	16 (59.3)	0.393
Mean age, y	5.43±0.84	3.97±0.92	0.247
Mean weight, kg	18.88±12.68	12.91±6.91	0.036
Mean height, cm	108.41±28.28	91.31±23.94	0.019
Mean hemoglobin level	16.72±2.53	15.32±2.58	0.049
Mean hematocrit level	51.99±8.57	47.41±8.37	0.050
Mean heart rate	127.70±20.64	143.63±20.79	0.007
Mean pump time, min	75.54±35.44	83.08±50.71	0.540
Mean cross-clamp time, min	35.14±25.76	35.75±30.12	0.967
Mean milrinone use	0.75±0.35	0.86±0.22	0.967
Mean epinephrine use	0.08±0.04	0.13±0.05	0.379

PAP, Pulmonary arterial pressure

Table 2. Postoperative outcome in the study population

Characteristics	PAP≤15 mm Hg	PAP>15 mm Hg	*P* value
Cardiac arrhythmia	1 (3.7)	5 (18.5)	0.192
Ascites	2 (7.4)	13 (48.1)	0.001
Pleural effusion	9 (33.3)	23 (85.2)	0.001
Mean hospital stay, d	6.00±2.37	9.48±6.86	0.016
Mean ICU stay, d	3.93±1.07	5.30±2.30	0.008

PAP, Pulmonary arterial pressure; ICU, Intensive care unit

DISCUSSION

The primary goal of the Fontan reconstructive surgery is not only to achieve optimal systemic blood flow and simultaneous controlled pulmonary balance but also to prevent the blood from returning to the ventricles. Some measures such as the use of systemic-pulmonary shunts could confer the desired prognosis of this surgery. It appears that reducing the resistance of pulmonary arteries and maintaining PAP can be considered prognostic factors in patients undergoing this surgery. The main goal of the present study was to assess the hypothesis that preserved PAP in patients with a single-ventricle defect undergoing the Fontan procedure with the use of the Glenn surgical technique (Glenn shunt implantation) could confer a better prognosis. High baseline PAP is regarded as a risk factor for a poor prognosis following the Glenn procedure. Therefore, in this study, we compared the clinical consequences of the Glenn procedure between 2 groups of patients with a single-ventricle defect: a group with PAP exceeding 15 mm Hg and a group with PAP equal to or less than 15 mm Hg (the control group). The main clinical outcomes assessed were complications such as arrhythmia, pleural effusion, ascites, and a prolonged hospital and ICU stay. We found that not only high PAP was associated with an increased risk of ascites and pleural effusion but also, because of these serious postoperative complications, the need for a prolonged hospital and ICU stay was predictable. Consequently, before the Glenn procedure and with the aim of preventing postoperative side effects, continuous and stable evaluation and control of PAP in such patients seems vital.

Previous investigations have described mechanisms for the relationship between the prognosis of the Glenn procedure and increased PAP and pulmonary vascular resistance. The use of small shunts to prevent single-ventricular volume overload is a very desirable measure in reducing peripheral vascular resistance. It can be argued that the optimal outcome of the Fontan reconstructive surgery in patients with a single-ventricle defect depends on the balance between the optimal development of the pulmonary vascular bed and the reduction of pulmonary vascular resistance. [22] Overall, one of the best ways to balance the above would be to optimize pulmonary vascular resistance by creating shunts such as the bidirectional Glenn shunt, which could improve the postoperative outcome.

In this regard, the relationship between the reduction and maintenance of PAP and better performance in patients undergoing the Fontan procedure has been shown in some studies. In an investigation by Silvilairat et al [21] on patients with single ventricular hearts undergoing the Glenn procedure, the factors predicting the long-term mortality of the patients included age at surgery, the arterial oxygen saturation level, history of previous surgery, and pulmonary artery hypertension. Tanoue et al [23] concluded that the predictors of mortality following the Glenn procedure were high preoperative PAP and the presence of heterotaxy syndrome. In a study by Mendelsohn et al, [24] the Glenn procedure

resulted in a significant increase in the total pulmonary blood flow and the mean pulmonary hypertension, indicating that not only was pulmonary artery hypertension a predictive factor for adverse consequences of the Glenn procedure but also, following this surgery, a significant improvement in the vascular index was predictable. Pridjian et al [25] reported that increased pulmonary vascular resistance and pulmonary artery distension were risk factors associated with mortality in patients undergoing the Glenn procedure. According to Hussain et al, [26] the most important contraindication to the Glenn procedure was a pulmonary vascular resistance index exceeding 3.5, which led to adverse outcomes due to surgery. In a recent study by Tran et al, [27] the mean PAP exceeding 16 mm Hg was associated with hospital mortality. The maintenance of PAP and pulmonary artery resistance is essential to prevent postoperative complications, especially pleural effusion and ascites, which lead to a longer hospital stay and, thus, greater hospital costs.

CONCLUSIONS

According to the results of the present study, high PAP was a prognostic factor in patients undergoing the Glenn procedure. Generally, high blood pressure in the pulmonary arteries places patients at risk for postoperative ascites and pleural effusion and, thus, the need for long-term hospitalization.

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