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Interventional catheterization in pediatric patients after Fontan procedure

Cateterismo intervencionista en pacientes pediátricos tras cirugía de Fontan

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To the Editor,

The advances made in surgical techniques followed by the best candidate selection process possible and optimal preparation of patients eligible for surgery have contributed to reducing early postoperative mortality in patients treated with the Fontan procedure.[1] However, the balance provided by the Fontan procedure is precarious and can fail for multiple reasons that can be resolved through interventional catheterizations (IC).[2-4]

This study describes the experience of our center performing IC and focuses on the type of interventional procedures performed and predictors of these.

We conducted a retrospective study of all patients < 18 years-old who underwent a Fontan procedure from January 2000 through December 2021 and were treated with IC due to suspected anatomical injury detected by echocardiography (annually) or magnetic resonance imaging (at 10 years and then every 3 years) or complications like protein-losing enteropathy, plastic bronchitis or hepatopathy. Since 2017, scheduled catheterizations are performed 10 years after the Fontan procedure.

All patients gave their prior written informed consent, and the study was approved by the hospital ethics committee. Possible sex and gender variables have been considered in accordance with the SAGER guidelines.

Descriptive statistics of the demographic, anatomical, hemodynamic, and surgical variables was used. Normally distributed variables were expressed as mean and standard deviation while those without a normal distribution were expressed as median and interquartile range [IQR]. Kaplan-Meier curves were drawn to estimate the IC-free survival rate. To identify predictors of the need for IC, univariate Cox logistics regression analysis was conducted. Variables with significance levels < .2 were included in the multivariate analysis. Also, hazard ratios (HR) with a 95% confidence interval (95%CI) were estimated.

A total of 74 patients treated with a Fontan procedure were identified. Their demographic, anatomical, and pre-catheterization characteristics are shown on table 1. After a median follow-up of 10.3 years [IQR, 5.3-13.3], a total of 59 IC were performed on 35 patients (47%) for a total 79 interventional procedures. The most common ones were embolization of collaterals between systemic and pulmonary veins (26.6%), stent implantation or dilation into the pulmonary branches (20.3%), closure of fenestration (19%), and embolization of aortopulmonary collaterals (16.5%). Other interventional procedures included fenestration dilation (5.1%), Fontan stent implantation or dilation (5.1%), aortic stent implantation or dilation (3.8%), endocavitary pacemaker implantation (1.3%), embolectomy (1.3%), and embolization of antegrade flow (1.3%). A total of 20, 9, 4, 1, and 1 patients were treated with 1, 2, 3, 4, and 5 IC, respectively.

The IC-free survival rate was 63% and 45% at 5 and 10 years, respectively (figure 1A). No deaths were reported associated with cardiac catheterizations. A total of 4 patients (5%) experienced complications associated with the catheterizations (pulmonary thromboembolism, brachial neuropraxia, vasoactive drug administration during the procedure, and pulmonary atelectasis).

The diagnosis of hypoplastic left heart syndrome (HR, 2.62; 95%CI, 1.18-5.78), and the values of mean pulmonary artery pressure (HR, 1.2; 95%CI, 1.02-1.41), the transpulmonary gradient (HR, 1.64; 95%CI, 1.21-2.22), and the McGoon index (HR, 0.18; 95%CI, 0.07-0.44) prior to the Fontan procedure behaved as independent predictors of the need for IC after this surgery (figure 1B).

In our patients, the rate of interventional procedures performed (47%) is similar to that reported in the series by Downing et al.[3] with an IC-free survival rate of 53% at 15 years. Although the number of procedures performed is quite similar, in their case, the closure of fenestration was the most common procedure of all due to their high rate of fenestrated Fontan (90%) compared to ours (35%).

Nonetheless, when our series was compared to others with older patients, significant differences were found. A total of 49% of the patients from the series of Van Dorn et al.[4] (1978 through 2002) were treated with a traditional atriopulmonary connection. Most interventional procedures were pacemaker implantation or replacement (26%) or arrhythmia ablation (20%).

Our clinical practice attempts the closure of the fenestration 6 months after the Fontan procedure if the patient's disease progression is favorable, pressure remains < 16 mmHg during the

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Table 1. Characteristics of patients, types of interventional procedures, and time elapsed since the Fontan procedure

Characteristics	Age at the Fontan procedure
Type of heart disease	
Hypoplastic left heart syndrome	19 (25.6)
Tricuspid atresia	15 (20.3)
Complex heart disease with functionally univentricular heart	13 (17.5)
Double-inlet left ventricle	12 (16.2)
Pulmonary atresia with intact septum	9 (12.2)
Ebstein anomaly	3 (4.1)
Heterotaxy	3 (4.1)
Dominant right ventricle	25 (33.8)
Masculine sex	40 (54.1)
Norwood surgery	20 (27)
Age at the Fontan procedure (months)	62.8 ± 27.6
Weight at the Fontan procedure (kg)	17.3 ± 5.4
Type of Fontan procedure	
Extracardiac	67 (90.5)
Lateral tunnel	7 (9.5)
Fenestrated	26 (35.1)
Pre-Fontan catheterization data	
mPAP (mmHg)	12.2 ± 2.3
TPG (mmHg)	3.6 ± 1.6
iPVR (WU·m^2)	1.1 ± 0.5
EDVP (mmHg)	10.4 ± 2.7
Qp/Qs	0.5 ± 0.1
Nakata index (mm^2/m^2)	243.8 ± 85.2
McGoon index	2 ± 0.5
Type of interventional procedure	**Time elapsed since the Fontan procedure, months**
Embolization of SV-PV collaterals	72.3 [35-90.5]
Stent implantation/dilation into the pulmonary branches	46.3 [3-81.6]
Fenestration closure	15.6 [9.3-23.3]
Embolization of aortopulmonary collaterals	25.4 [6.7-93.1]
Fenestration dilation	3.9 [0.2-63.3]
Stent implantation/dilation into Fontan. SVC or IVC	138.4 [34.3-152.4]
Stent implantation/dilation into the aorta	85.4 [4.4-122.2]
Endocavitary pacemaker implantation	82.4*
Embolectomy	0.26*
Embolization of antegrade flow	1.43*

EDVP, end-diastolic ventricular pressure; iPVR, indexed pulmonary vascular resistances; IVC, inferior vena cava; mPAP, mean pulmonary artery pressure; Qp/Qs, pulmonary to systemic flow ratio; SV-PV, systemic vein-pulmonary vein; SVC, superior vena cava; TPG: transpulmonary pressure gradient; WU, Wood units.
Data are expressed as no. (%), mean ± standard deviation, and median [interquartile range]; those with only 1 value express absolute time in months.
* 1 patient only.

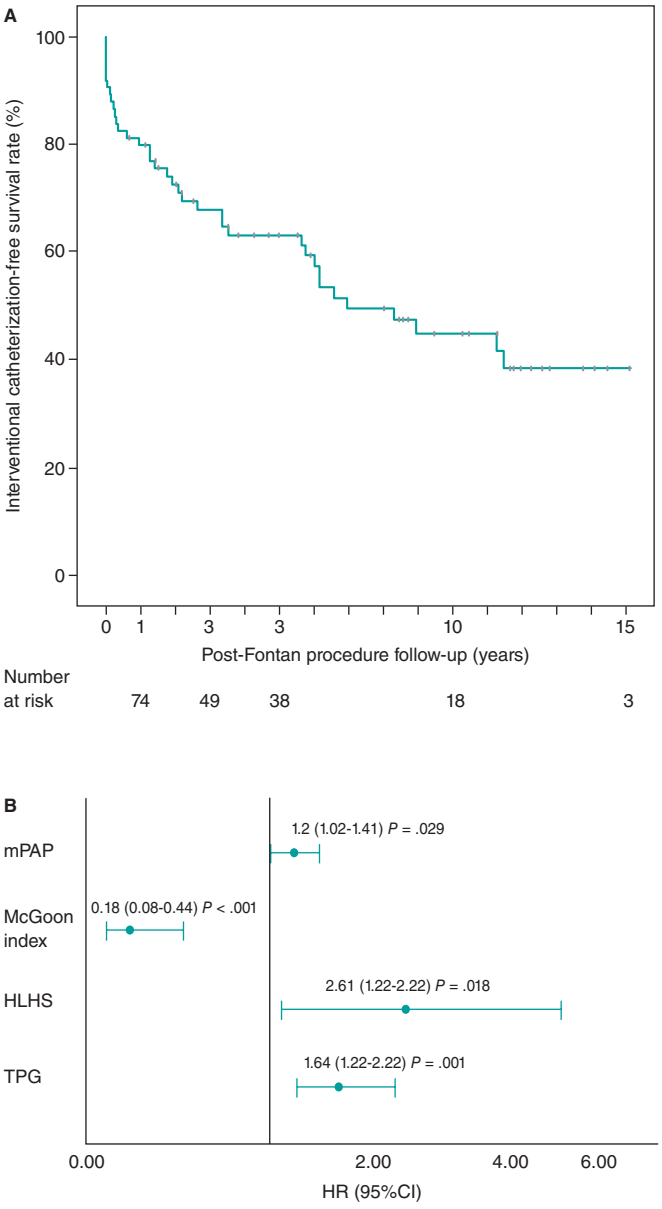

Figure 1. **A:** Kaplan-Meier curve of interventional catheterization-free survival after Fontan procedure. **B:** Independent predictors of the risk of interventional catheterization. 95%CI, 95% confidence interval; HLHS: hypoplastic left heart syndrome; HR, hazard ratio; mPAP, mean pulmonary artery pressure; TPG: transpulmonary pressure gradient.

occlusion test, and proper cardiac output is preserved (> 2 L/min/m^2 with a decrease of < 20% compared to baseline levels).

The presence of aortopulmonary collaterals has proven to have a negative effect on Fontan circulation, thus extending the duration of pleural effusions and causing ventricular volume overload. Therefore, we delve into an aggressive search and embolization of these collaterals in the catheterizations performed before and after the Fontan procedure.

The lack of stenosis in the Fontan conduit and pulmonary branches is essential to keep proper hemodynamics in Fontan circulation. Therefore, it seems logical to treat stenoses even in asymptomatic patients.

Regarding the risk factors associated with performing IC, the diagnosis of hypoplastic left heart syndrome was seen as an

independent predictor of this event in both the series of Downing et al.[3] and our own. Elevated pulmonary pressures and resistances, and smaller pulmonary arteries are known factors of poor prognosis in this population.

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ETHICAL CONSIDERATIONS

All patients signed the informed consent and the study was approved by the hospital's ethics committee. Possible sex and gender variables have been considered in accordance with the SAGER guidelines.

DECLARATION OF USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence has not been used during the preparation of this manuscript.

AUTHORS' CONTRIBUTIONS

A. Mendoza, and L. Albert: study idea, and data mining and analysis. M. Flores, D. Herrera, B. Toral, and A. Caro: manuscript review and edition.

CONFLICTS OF INTEREST

None whatsoever.

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Relationship between membranous septum length and need for pacemaker implantation after transcatheter aortic valve implantation

Relación entre longitud del septo membranoso y necesidad de marcapasos tras implante de válvula aórtica

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To the Editor,

Transcatheter aortic valve implantation (TAVI) can trigger significant conduction disorders due to the mechanical compression caused by the transcatheter heart valve. This is because of the proximity between the aortic annulus, the atrioventricular node, and the membranous septum (MS) of the left ventricular outflow tract. The rate of pacemaker implantation after TAVI ranges from 4% to 33%.[1]

This retrospective analytical study included symptomatic patients with severe aortic stenosis referred for multidetector computed tomography as part of the TAVI protocol from December 2012 through October 2022. Written informed consent was obtained from all patients prior to the tomography scan by obtaining approval to conduct the study. We excluded patients with bicuspid aortic valve anatomy, pacemaker carriers, and those with previous surgical bioprosthetic valve. The aim of this study was to determine whether MS length is associated with the need for pacemaker implantation after TAVI. MS length was measured as the maximum distance from the plane of the aortic annulus to the top of the muscular portion of the ventricular septum in the coronal plane during systole (figure 1A,B).[2] Qualitative variables were analyzed using the chi-square test or Fisher exact test, while quantitative variables were analyzed using the Mann-Whitney *U* test. *P* values < .005 were considered statistically significant. A receiver operating characteristic (ROC) curve was constructed to assess the predictive accuracy of MS length for pacemaker implantation. Data were analyzed using the IBM SPSS statistical software package, version 26 (United States).

A total of 134 consecutive patients were assessed: 71 (53%) were men and the mean age was 75.5 ± 7.6 years.

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