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STANDARDIZATION OF CARDIAC CATHETERIZATION IN CHILDREN WITH CONGENITAL HEART DISEASES WITH SYSTEMIC-TO-PULMONARY COMMUNICATIONS

PADRONIZAÇÃO DO CATETERISMO CARDÍACO EM CRIANÇAS PORTADORAS DE CARDIOPATIAS CONGÊNITAS COM COMUNICAÇÕES SISTÊMICO-PULMONARES

ESTANDARIZACIÓN DEL CATETERISMO CARDÍACO EN NIÑOS CON CARDIOPATÍAS CONGÉNITAS CON COMUNICACIONES SISTÉMICO-PULMONARES

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Fernanda Gabrielle Ribeiro[1], Ana Maria Thomaz[2]

ABSTRACT
Cardiac catheterization plays a fundamental role in the evaluation of congenital heart diseases with systemic-to-pulmonary communications, whose main complication is pulmonary arterial hypertension. The lack of consensus in the literature regarding the assessment of pulmonary vascular resistance in pediatrics poses challenges for defining operability and therapeutic management. This cross-sectional and prospective study, conducted at the Heart Institute (InCor HCFMUSP), aimed to describe accurate hemodynamic parameters in patients up to 3 years of age with biventricular physiology and nonrestrictive communications. Data collection was performed under ideal conditions, including baseline measurements and vasoreactivity testing with inhaled nitric oxide. The Fick method was used to calculate flows and vascular resistances through serial blood gas analyses at multiple sites (vena cavae, pulmonary arteries, aorta, and pulmonary vein). The results, consolidated in an automated spreadsheet, provide a reliable basis for the descriptive analysis of intra-procedural events and hemodynamic management strategies, contributing to the standardization of this procedure in the pediatric age group.

Keywords: Congenital Heart Diseases. Cardiac Catheterization. Pulmonary Arterial Hypertension. Pediatrics. Pulmonary Vascular Resistance. Hemodynamics.

RESUMO
O cateterismo cardíaco desempenha papel fundamental na avaliação das cardiopatias congênitas com comunicações sistêmico-pulmonares, cuja principal complicação é a hipertensão arterial pulmonar. A ausência de um consenso na literatura sobre a avaliação da resistência vascular pulmonar em pediatria impõe desafios para a definição de operabilidade e conduta terapêutica. Este estudo transversal e prospectivo, realizado no Instituto do Coração (InCor HCFMUSP), objetivou descrever parâmetros hemodinâmicos acurados em pacientes de até 3 anos com fisiologia biventricular e comunicações não

[1] Medical Doctor. Universidade Nove de Julho (UNINOVE).
[2] Professor at the Pediatrics Unit. Instituto do Coração do Hospital das Clínicas USP (InCor HCFMUSP).

restritivas. A coleta de dados ocorreu em condições ideais, abrangendo medidas basais e testes de vasorreatividade com óxido nítrico inalatório. Utilizou-se o método de Fick para o cálculo de fluxos e resistências vasculares por meio de gasometrias seriadas em múltiplos sítios (veias cavas, artérias pulmonares, aorta e veia pulmonar). Os resultados, consolidados em planilha automatizada, fornecem uma base confiável para a análise descritiva de ocorrências intra-exame e estratégias de manejo hemodinâmico, contribuindo para a padronização deste procedimento na faixa etária pediátrica.

Palavras-chave: Cardiopatias Congênitas. Cateterismo Cardíaco. Hipertensão Arterial Pulmonar. Pediatria. Resistência Vascular Pulmonar. Hemodinâmica.

RESUMEN
El cateterismo cardíaco desempeña un papel fundamental en la evaluación de las cardiopatías congénitas con comunicaciones sistémico-pulmonares, cuya principal complicación es la hipertensión arterial pulmonar. La ausencia de consenso en la literatura sobre la evaluación de la resistencia vascular pulmonar en pediatría plantea desafíos para la definición de la operabilidad y la conducta terapéutica. Este estudio transversal y prospectivo, realizado en el Instituto del Corazón (InCor HCFMUSP), tuvo como objetivo describir parámetros hemodinámicos precisos en pacientes de hasta 3 años con fisiología biventricular y comunicaciones no restrictivas. La recolección de datos se llevó a cabo en condiciones ideales, incluyendo mediciones basales y pruebas de vasorreactividad con óxido nítrico inhalado. Se utilizó el método de Fick para el cálculo de flujos y resistencias vasculares mediante gasometrías seriadas en múltiples sitios (venas cavas, arterias pulmonares, aorta y vena pulmonar). Los resultados, consolidados en una hoja de cálculo automatizada, proporcionan una base confiable para el análisis descriptivo de eventos intraexamen y estrategias de manejo hemodinámico, contribuyendo a la estandarización de este procedimiento en la población pediátrica.

Palabras clave: Cardiopatías Congénitas. Cateterismo Cardíaco. Hipertensión Arterial Pulmonar. Pediatría. Resistencia Vascular Pulmonar. Hemodinámica.

1 INTRODUCTION

Severe congenital heart disease (CHD) has an approximate incidence of 2.5 to 3.0 per 1,000 live births, accounting for about 25% of neonatal deaths related to malformations (Ülgen Tekerek et al., 2023). Over the past three decades, improvements in early diagnosis and therapeutic innovations have substantially increased the survival rates of these patients (Ülgen Tekerek et al., 2023). Cardiac catheterization and angiocardiography have been consolidated as indispensable tools in the preoperative evaluation, allowing precise anatomical definition, quantification of shunts, and measurement of pulmonary vascular resistance (Ülgen Tekerek et al., 2023). Transcatheter interventions, in particular, offer benefits such as shorter hospital stays and the elimination of the need for thoracotomy in various settings (Ülgen Tekerek et al., 2023).

Traditionally, these procedures are conducted under X-ray guidance, which, although effective, exposes the patient and the medical team to risks arising from ionizing radiation and orthopedic injuries due to the use of lead garments (Amin et al., 2022). In this context, interventional cardiac magnetic resonance imaging (iCMR) emerges as a promising alternative, enabling high-definition, three-dimensional visualization without radiation (Amin et al., 2022). At the same time, procedural safety has been reinforced by the use of risk scores, such as the CRISP (Catheterization Risk Score for Pediatrics), which helps in the prediction of serious adverse events and in the planning of care (Santos et al., 2024).

The effectiveness of the procedure is also influenced by technical refinements, such as the use of ultrasound for vascular access, which has higher first-attempt success rates than the anatomical landmark method (Salihu et al., 2024). In addition, gas exchange monitoring via capnography has shown a positive correlation with arterial CO2 in acyanotic patients, although its accuracy is variable in cyanotic heart diseases before definitive correction (Asl et al., 2023). In the specific case of systemic-pulmonary septal defects, accurate hemodynamic assessment is vital to determine operability and prevent the progression of pulmonary arterial hypertension. The present study aims to describe the standardization of this test in ideal physiological and metabolic conditions, aiming to mitigate variations resulting from anesthetic management.

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2 METHODOLOGY

The present study is characterized as a narrative literature review and prospective cross-sectional research, developed with the objective of synthesizing scientific evidence and standardizing the acquisition of hemodynamic parameters in children with congenital heart disease and systemic-pulmonary septal defects. The literature search was conducted in the PubMed database, using MeSH descriptors such as "Congenital Heart Disease", "Cardiac Catheterization" and "Child", integrating information on risk scores and vascular access techniques.

The practical part of the study was carried out at the Pediatric Cardiology Unit of the Heart Institute (InCor HCFMUSP), focusing on patients up to 3 years of age with cardiac or non-restrictive large artery communications and biventricular physiology. Individuals with clinical, radiographic, or echocardiographic signs of increased pulmonary pressure were included. Duplicate studies or studies without a direct relationship with pediatric hemodynamics were excluded from the theoretical synthesis.

Hemodynamic measurements were obtained using the Fick method, using the ratio between oxygen consumption and arteriovenous differences. Data collection followed a strict protocol in two phases: baseline condition and ten minutes after administration of inhaled nitric oxide to assess vasoreactivity. Blood samples were collected at strategic sites, including the superior and inferior vena cavae, pulmonary arteries, aorta, and pulmonary vein. To ensure the reliability of the results, the indexed calculations of systemic vascular and pulmonary resistance were automatically processed in a structured electronic spreadsheet.

2.1 DESCRIPTIVE PRESENTATION OF THE DATA OBTAINED

Twenty-five patients were included, with a mean age of 1.09 (years); average weight of 7kg; average height of 67.72cm; body surface with an average of 0.35m2; and heart rate of 131bpm.

Table 1

Anthropometric data and heart rate

No.	Id	Age (years)	Weight (kg)	Height (cm)	Sup. Corporeal (m2)	FC (bpm)
1	HLMF	2	11,5	90	0,53	120
2	AVNN	0,5	5	58	0,27	120
3	A	0,58	5,4	63	0,29	125

4	NCFS	0,92	6,4	65	0,32	135
5	ELS	1,58	7,99	76	0,4	136
6	MRS	0,39	3,8	52	0,22	115
7	JSSF	0,68	8,7	65	0,37	145
8	MCMF	0,52	5	63	0,29	120
9	ECS	0,65	6,4	65	0,32	111
10	Y	0,81	5,8	64	0,3	142
11	RGF	1,34	7,43	67	0,35	93
12	LRP	1,57	7,6	60	0,3	140
13	GVMB	0,45	5,7	59	0,29	130
14	JPAR	0,79	5,7	64,5	0,3	175
15	AFC	1,22	7,87	69,5	0,37	127
16	RS	0,99	6,63	69	0,34	131
17	AV	1,77	10,38	78	0,46	137
18	JP	0,38	6,1	63	0,31	164
19	NA	1,04	5,4	67	0,31	121
20	EF	2,16	10	83	0,47	151
21	BT	0,98	5,58	65	0,30	125
22	IC	0,75	5,9	63	0,30	132
23	EV	0,59	4,74	59	0,27	137
24	MC	3,08	14,95	98	0,62	124
25	G	1,70	5,22	67	0,30	130

Id: patient identification; Sup. Corpórea: body surface; HR: heart rate

In the baseline condition, the data obtained were: Hb with a mean of 11.36; blood gas data such as pulmonary vein saturation with a mean of 0.96; pulmonary artery with a mean of 0.80; of the aorta, with a mean of 0.92; superior vena cava, with a mean of 0.54; and inferior vena cava, with a mean of 0.64. PO2 of the pulmonary vein, with a mean of 103.24; pulmonary artery with a mean of 50.75; aortic with a mean of 71.82; the superior vena cava, with a mean of 34.92, and the inferior vena cava, with a mean of 38.68. (Table 2)

Table 2

Blood gas analysis data (Hb, saturation and PO2) at baseline

No.	Id	Hb	Sat VP	PO2 VP	Sat AP	PO2 AP	Sat Ao	PO2 To	Sat you guys	PO2 YOU GUYS	Sat VCI	PO2 VCI
1	HLMF	10,8	0,96	75	0,65	42,3	0,88	64,2	0,66	44	0,7	52
2	AVNN	9,5	0,97	78	0,84	42,3	0,94	71	0,43	23,7	0,64	28,5
3	A	11,1	0,97	72,4	0,75	36,6	0,97	73,6	0,50	27,2	0,63	31,2
4	NCFS	10,3	0,95	74	0,78	42,5	0,89	54,5	0,35	26	0,49	30,8
5	ELS	9	1	145	0,87	55	0,94	71,8	0,68	39,1	0,56	35,7
6	MRS	9,1	0,84	53,3	0,71	42,9	0,8	49,5	0,50	31,7	0,53	32,6
7	JSSF	11,5	0,99	129	0,9	61,7	0,96	79,9	0,49	30,9	0,64	37,7
8	MCMF	10	0,99	108	0,82	45,1	0,95	67,7	0,35	23,3	0,60	32,1
9	ECS	11,9	0,99	115	0,88	53,6	0,98	96,7	0,45	28,2	0,72	39,7

10	Y	15,4	1	109	0,91	54	0,96	85	0,36	24,4	0,66	36
11	RGF	12,4	1	154	0,86	47,2	0,94	59,3	0,35	22,3	0,69	34,9
12	LRP	10,3	0,95	78,7	0,78	48,8	0,94	76	0,67	40,6	0,75	39,3
13	GVMB	12,8	0,93	68	0,74	42,7	0,88	53	0,52	31,8	0,52	31,8
14	JPAR	15,2	0,97	78	0,82	45,2	0,86	48,8	0,46	27,8	0,61	33,9
15	AFC	11,9	0,93	67,3	0,78	46,8	0,96	65,7	0,52	32,7	0,64	38
16	RS	13,2	0,94	74	0,81	49,1	0,89	61,25	0,46	30,6	0,61	36,9
17	AV	12,4	0,99	128	0,65	36,7	0,94	75,25	0,63	38	0,68	38,7
18	JP	9	1	130	0,82	55,3	0,90	66,1	0,62	38,2	0,62	38,2
19	NA	10	0,99	130	0,87	60,6	0,94	82,4	0,67	43,9	0,67	43,9
20	EF	12,6	0,96	75	0,82	57,8	0,92	74,4	0,76	50,3	0,74	49,1
21	BT	11,3	0,93	81,2	0,81	56,6	0,91	73,45	0,69	46,6	0,66	44
22	IC	10,6	1	150	0,9	57,7	0,93	64,1	0,41	27,2	0,76	42,9
23	EV	11,6	0,9	70	0,70	46,9	0,87	70	0,54	35	0,54	35
24	MC	12,5	0,98	100	0,84	58,4	0,96	75	0,74	48,3	0,67	42,8
25	G	9,7	0,99	238	0,86	83	0,93	136,7	0,71	61,2	0,71	61,2

Id: patient identification; Hb: hemoglobin; Sat VP: oxygen saturation in the pulmonary vein; PO2 VP: oxygen pressure in pulmonary vein; AP SAT: pulmonary artery oxygen saturation; PO2 AP: oxygen pressure in pulmonary artery; Sat Ao: oxygen saturation in the aorta; PO2 Ao: oxygen pressure in the aorta; Sat VCS: oxygen saturation in superior vena cava; PO2 SVC: oxygen pressure in superior vena cava; Sat IVC: oxygen saturation in the inferior vena cava; PO2 IVC: oxygen pressure in the inferior vena cava.

After using nitric oxide, the following blood gas analysis data were obtained: Hb with a mean of 11.35; pulmonary vein saturation with a mean of 0.97; pulmonary artery saturation with a mean of 0.84; aorta with a mean of 0.94; superior vena cava with a mean of 0.52; and inferior vena cava with a mean of 0.61. PO2 of the pulmonary vein, with a mean of 116.64; pulmonary artery with a mean of 55.16; of the aorta, with a mean of 82.81; the superior vena cava, with a mean of 34.46, and the inferior vena cava, with a mean of 37.82. (Table 3)

Table 3

Blood gas analysis data (Hb, saturation and PO2) after the use of nitric oxide

No.	Id	Hb	Sat VP	PO2 VP	Sat AP	PO2 AP	Sat Ao	PO2 To	Sat you guys	PO2 YOU GUYS	Sat VCI	PO2 VCI
1	HLMF	10,8	0,96	75	0,69	44	0,91	72,3	0,6	40,2	0,61	40,7
2	AVNN	9,5	0,91	58,5	0,81	39,6	0,86	43,8	0,34	21,4	0,42	23,6
3	A	11,1	1	125	0,9	53,5	1	113	0,58	29,4	0,65	32,2
4	NCFS	10,3	0,96	69,1	0,76	40,1	0,88	48,9	0,26	20,8	0,35	23,7
5	ELS	9	1	145	0,89	60,2	0,96	81,3	0,31	26	0,65	38,9
6	MRS	9,1	0,86	56,7	0,77	47,2	0,85	54,5	0,42	28,7	0,51	31,2
7	JSSF	11,5	1	158	0,92	69	1	143	0,61	39,1	0,64	38,6

8	MCMF	10	0,99	180	0,90	57,2	0,98	104	0,33	22,6	0,53	30,8
9	ECS	11,9	1	152	0,92	60	0,99	131	0,43	25,9	0,83	44,5
10	Y	15,4	0,99	129	0,89	58	0,96	79	0,46	30,2	0,63	37,1
11	RGF	12,4	1	133	0,86	43,4	0,92	50,6	0,33	20,1	0,66	30,7
12	LRP	10,3	0,99	158	0,87	61,3	0,98	120	0,68	41,9	0,74	45,6
13	GVMB	12,8	1	132	0,79	47,1	0,92	60	0,45	29,2	0,44	29,2
14	JPAR	15,2	0,98	133	0,83	45,2	0,91	55,9	0,55	29,5	0,60	32,1
15	AFC	11,9	0,95	72,1	0,82	47,8	0,94	70,35	0,46	28,5	0,59	34
16	RS	13,2	0,97	78	0,82	51,2	0,92	68,3	0,55	34,6	0,57	35,1
17	AV	12,4	0,99	128	0,73	40,3	0,96	91,15				
18	JP	9	1	130	0,92	66,8	0,97	99	0,62	38,2	0,62	38,2
19	NA	10	0,88	64,3	0,74	47,3	0,91	70,3	0,67	43,9	0,67	43,9
20	EF	12,6	0,96	75	0,82	49,6	0,93	67,9	0,72	43,1	0,72	43,1
21	BT	11,3	0,94	86,4	0,87	62,8	0,93	79,9	0,69	46,6	0,66	44
22	IC	10,6	1	150	0,91	57,7	0,93	60,3	0,32	22,6	0,62	33,1
23	EV	11,6	0,9	70	0,70	46,7	0,89	62,8	0,58	37,1	0,58	37,1
24	MC	12,5	0,99	120	0,89	64,5	0,98	100	0,8	53,4	0,73	46,2
25	G	9,7	1	238	0,92	118,5	0,96	143	0,71	74,15	0,71	74,15

Id: patient identification; Hb: hemoglobin; Sat VP: oxygen saturation in the pulmonary vein; PO2 VP: oxygen pressure in pulmonary vein; AP SAT: pulmonary artery oxygen saturation; PO2 AP: oxygen pressure in pulmonary artery; Sat Ao: oxygen saturation in the aorta; PO2 Ao: oxygen pressure in the aorta; Sat VCS: oxygen saturation in superior vena cava; PO2 SVC: oxygen pressure in superior vena cava; Sat IVC: oxygen saturation in the inferior vena cava; PO2 IVC: oxygen pressure in the inferior vena cava.

The mean pressures, under baseline conditions, had the following values: The mean pulmonary arterial pressure had a mean of 48.4; the mean pressure in the left atrium had a mean of 13.88; the mean pressure in the aorta had a mean of 60.16; and the mean pressure in the right atrium had a mean of 10.92. (Table 4)

Table 4

Mean pressures at baseline

No.	Id	PMAP	PMAE	PMAo	PMAD
1	HLMF	73	12	90	10
2	AVNN	33	9	38	9
3	A	28	12	53	8
4	NCFS	33	10	51	10
5	ELS	36	16	54	10
6	MRS	43	12	53	12
7	JSSF	35	13	54	9
8	MCMF	33	10	50	8
9	ECS	35	19	47	13
10	Y	52	22	53	18
11	RGF	45	15	56	15
12	LRP	78	12	79	10

13	GVMB	44	12	77	11
14	JPAR	50	10	53	10
15	AFC	41	12	59	12
16	RS	49	18	47	8
17	AV	66	15	76	10
18	JP	42	16	58	8
19	NA	46	12	65	12
20	EF	43	14	68	10
21	BT	52	12	63	10
22	IC	66	18	60	12
23	EV	41	10	47	9
24	MC	67	18	71	12
25	G	79	18	82	17

Id: patient identification; PMAP: mean pulmonary artery pressure; PMAE: mean pressure in the left atrium; PMAo: mean pressure in the aorta; PMAD: mean right atrial pressure

After the use of nitric oxide, the mean pressures obtained the following values: The mean pulmonary arterial pressure had a mean of 43.6; the mean pressure in the left atrium had a mean of 15.68; the mean pressure in the aorta had a mean of 58.42; and the mean pressure in the right atrium had an average of 11.84. (Table 5)

Table 5

Mean pressures after nitric oxide

No.	Id	PMAP	PMAE	PMAo	PMAD
1	HLMF	63	12	80	10
2	AVNN	30	11	50	11
3	A	30	15	48	8
4	NCFS	33	15	50	12
5	ELS	30	16	44	12
6	MRS	35	12	39	12
7	JSSF	33	17	49	12
8	MCMF	39	16	48	12
9	ECS	33	22	49	15
10	Y	46	22	49,5	12
11	RGF	44	14	52	14
12	LRP	55	13	61	9
13	GVMB	43	14	68	14
14	JPAR	50	11	60	11
15	AFC	36	12	58	12
16	RS	44	20	44	10
17	AV	73	18	89	15

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18	JP	33	16	58	8
19	NA	36	16	75	16
20	EF	33	14	62	10
21	BT	53	12	64	10
22	IC	35	18	60	12
23	EV	39	10	50	9
24	MC	64	24	73	12
25	G	80	22	80	18

Id: patient identification; PMAP: mean pulmonary artery pressure; PMAE: mean pressure in the left atrium; PMAo: mean pressure in the aorta; PMAD: mean right atrial pressure

In the baseline condition, the Rpi in the LF&M method had a mean of 5.04; in the Bergstra method it had a mean of 5.21; in the Lindahl method it had a mean of 5.95; in the Lundell method it had a mean of 5.07; and in the Wessel method it had a mean of 5.84. The RSI was also obtained separately by each method, obtaining a mean of 13.84 in the LF&M method; 13.89 in the Bergstra method; 16.6 in the Lindahl method; 14.52 in the Lundell method; and 16.15 under the Wessel method. The parameters of Qp/Qs and Rp/Rs were also calculated by each method previously informed, obtaining mean data of: 2.4 (Qp/Qs) in all methods and 0.37 for Rp/Rs in all methods. (Table 6)

Table 6

Rpi, Rsi, Qp/Qs and Rp/Rs under baseline conditions in each method

No.	Id	Rpi (LF&M)	Rpi (Bergstra)	Rpi (Lindahl)	Rpi (Lundell)	Rpi, Wessel, in the Wessel départeme nt	Rsi (LF&M)	Rsi (Bergstra)	Rsi (Lindahl)	Rsi (Lundell)	Rsi, Wessel, in the Wessel départeme nt
1	HLMF	16,16	16,54	18,37	14,19	18,26	14,3	14,64	16,26	12,55	16,16
2	AVNN	2,19	2,12	2,76	2,74	2,59	8,98	8,68	11,29	11,24	10,59
3	A	2,86	2,42	3,63	3,08	3,35	15,67	13,26	19,91	16,88	18,34
4	NCFS	2,9	3,16	3,5	3,07	3,41	15,4	16,79	18,58	16,32	18,13
5	ELS	2,02	2,04	2,39	1,85	2,34	8,73	8,83	10,36	8,03	10,14
6	MRS	2,71	2,4	3,51	4,04	3,14	7,61	6,74	9,87	11,36	8,84
7	JSSF	1,91	1,81	2,09	2,29	2,36	15,58	14,78	17,01	18,65	19,24
8	MCMF	2,89	2,84	3,84	3,12	3,42	16,2	15,93	21,56	17,5	19,2
9	ECS	1,61	1,37	1,89	1,78	1,84	14,09	12,034	16,5	15,58	16,09
10	Y	3,14	3,41	4	3,29	3,77	20,01	21,73	25,48	20,95	23,99
11	RGF	4,55	4,06	4,69	4,93	4,82	20,74	18,51	21,38	22,45	21,95
12	LRP	8,47	8,39	8,73	10,33	9,74	13,41	13,27	13,82	16,35	15,41
13	GVMB	5,46	5,4	6,8	6,9	6,69	20,66	20,43	25,71	26,1	25,31
14	JPAR	6,22	6,03	8,5	6,19	7,9	15,59	15,13	21,3	15,51	19,8
15	AFC	3,68	3,53	4,11	3,8	4,23	15,29	14,68	17,08	15,8	17,59
16	RS	4,12	3,86	5,04	4,07	4,81	14,77	13,84	18,05	14,59	17,22
17	AV	16,81	19,58	17,91	16,21	19,29	18,84	21,95	20,1	18,16	21,62
18	JP	3	2,67	4	3,32	3,9	8,31	7,39	11,08	9,19	10,79
19	NA	3,34	3,57	4,24	3,18	3,75	10,84	11,58	13,77	10,31	12,19
20	EF	3,73	4,05	4,32	3,37	4,44	8,85	9,62	10,24	7,99	10,53
21	BT	4,2	4,5	5,21	4,23	4,8	9,99	10,69	12,41	10,07	11,37
22	IC	4,28	4,52	5,28	4,7	5,06	15,83	16,73	19,53	17,36	18,73
23	EV	4,95	5,0	6,55	5,62	5,94	10,09	10,25	13,34	11,45	12,11
24	MC	7,2	8,17	7,87	5,31	7,77	14,41	16,35	15,74	11,23	15,54
25	G	7,55	8,69	9,46	4,72	8,25	11,65	13,42	14,59	7,29	12,73

No.	Id	Qp/Qs (LF&M)	Qp/Qs (Bergstra)	Qp/Qs (Lindahl)	Qp/Qs (Lundell)	Qp/Qs (Wessel)	Rp/Rs (LF&M)	Rp/RS (Bergstra)	Rp/RS (Lindahl)	Rp/RS (Lundell)	Rp/RS (Wessel)
1	HLMF	0,67	0,67	0,67	0,67	0,67	1,12	1,13	1,13	1,13	1,13
2	AVNN	3,38	3,38	3,38	3,38	3,38	0,24	0,24	0,24	0,24	0,24
3	A	1,94	1,94	1,94	1,94	1,94	0,18	0,18	0,18	0,18	0,18
4	NCFS	2,97	2,97	2,97	2,97	2,97	0,18	0,18	0,18	0,18	0,18
5	ELS	1,96	1,96	1,96	1,96	1,96	0,23	0,23	0,23	0,23	0,23
6	MRS	2,12	2,12	2,12	2,12	2,12	0,35	0,35	0,35	0,35	0,35
7	JSSF	3,97	3,97	3,97	3,97	3,97	0,12	0,12	0,13	0,12	0,12
8	MCMF	3,07	3,07	3,07	3,07	3,07	0,17	0,17	0,18	0,17	0,17
9	ECS	4,1	4,1	4,1	4,1	4,1	0,11	0,11	0,11	0,11	0,11
10	Y	5,44	5,44	5,44	5,44	5,44	0,15	0,15	0,15	0,15	0,15
11	RGF	3,33	3,33	3,33	3,33	3,33	0,29	0,22	0,22	0,21	0,21
12	LRP	1,51	1,51	1,51	1,51	1,51	0,63	0,63	0,63	0,63	0,63
13	GVMB	1,83	1,83	1,83	1,83	1,83	0,26	0,26	0,26	0,26	0,26
14	JPAR	2,33	2,33	2,33	2,33	2,33	0,4	0,4	0,4	0,34	0,39
15	AFC	2,56	2,56	2,56	2,56	2,56	0,24	0,24	0,24	0,24	0,24
16	RS	2,85	2,85	2,85	2,85	2,85	0,28	0,28	0,28	0,28	0,28
17	AV	0,87	0,87	0,87	0,87	0,87	0,89	0,89	0,89	0,89	0,89
18	JP	1,44	1,44	1,44	1,44	1,44	0,36	0,36	0,36	0,36	0,36
19	NA	2,08	2,08	2,08	2,08	2,08	0,31	0,31	0,31	0,31	0,31
20	EF	1,18	1,18	1,18	1,18	1,18	0,42	0,42	0,42	0,42	0,42
21	BT	1,79	1,79	1,79	1,79	1,79	0,42	0,42	0,42	0,42	0,42
22	IC	3,7	3,7	3,7	3,7	3,7	0,27	0,27	0,27	0,27	0,27
23	EV	1,66	1,66	1,66	1,66	1,66	0,49	0,49	0,49	0,49	0,49
24	MC	1,66	1,66	1,66	1,66	1,66	0,5	0,5	0,5	0,5	0,5
25	G	1,45	1,45	1,45	1,45	1,45	0,65	0,65	0,65	0,65	0,65

Id: patient identification; Rpi: indexed pulmonary resistance; RSI: indexed systemic resistance; Qp/Qs: ratio between pulmonary and systemic flows; Rp/Rs: ratio between pulmonary and systemic resistance; LM&F, Bergstra, Lindahl, Lundell, Wessel: name of methods used

Table 7

Rpi, Rsi, Qp/Qs and Rp/Rs after nitric oxide in each method

No.	Id	Rpi (LF&M)	Rpi (Bergstra)	Rpi (Lindahl)	Rpi (Lundell)	Rpi, Wessel, in the	Rsi (LF&M)	Rsi (Bergstra)	Rsi (Lindahl)	Rsi (Lundell)	Rsi, Wessel, in the

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						Wessel département					**Wessel département**
1	HLMF	11,8	12,07	13,4	10,35	13,32	18,4	18,83	20,9	16,15	20,78
2	AVNN	1,3	1,27	1,65	1,6	1,54	12,88	12,60	16,38	15,93	15,37
3	A	1,35	1,14	1,71	1,45	1,57	13,13	11,12	16,69	14,15	15,37
4	NCFS	2,8	3	3,32	3	3,24	17,20	18,39	20,34	18,40	19,84
5	ELS	1,17	1,16	1,36	1,08	1,33	12,48	12,37	14,5	11,48	14,19
6	MRS	1,31	1,2	1,76	1,84	1,58	6,71	6,14	8,99	9,42	8,05
7	JSSF	1,23	1,17	1,34	1,47	1,52	11,76	11,16	12,85	14,07	14,52
8	MCMF	1,8	1,85	2,5	1,9	2,23	14,98	15,30	20,70	15,77	18,43
9	ECS	0,93	0,8	1,09	1,09	1,06	14,36	12,29	16,85	15,86	16,44
10	Y	2,8	3,08	3,6	2,91	3,34	18,51	20,34	23,84	19,26	22,45
11	RGF	4,4	4,01	4,63	4,72	4,75	18,89	17,24	19,9	20,29	20,43
12	LRP	4,28	4,31	4,49	5,16	5	11,71	11,80	12,29	14,12	13,70
13	GVMB	5,4	5,4	6,8	6,75	6,69	22,16	22,16	27,88	27,69	27,45
14	JPAR	6,8	6,52	9,19	6,8	8,54	17	16,31	22,97	17	21,35
15	AFC	2,92	2,81	3,27	3,02	3,36	18,72	17,98	20,91	19,35	21,54
16	RS	3,32	3,26	4,25	3,24	4,05	11,45	11,22	14,64	11,17	13,97
17	AV	14,61	16,70	15,28	14,08	16,45	21,54	24,31	22,51	20,74	24,24
18	JP	0,95	0,85	1,28	1,05	1,25	10,52	9,43	14,14	11,59	13,76
19	NA	1,89	2,05	2,45	1,78	2,17	9,54	10,38	12,34	9,01	10,93
20	EF	2,59	2,68	2,86	2,32	2,94	10,75	11,13	11,86	9,63	12,19
21	BT	2,71	3	3,48	2,69	3,19	10,97	12,15	14,10	10,89	12,92
22	IC	1,46	1,55	1,80	1,60	1,73	20,87	22,04	25,74	22,89	24,68
23	EV	4,58	4,57	5,94	5,29	5,39	10,5	10,44	13,58	12,41	12,33
24	MC	4,44	5,20	5,01	3,31	4,95	12,47	14,60	14,06	9,28	13,88
25	G	4,22	5,12	5,54	3,7	4,86	11,47	15,15	10,05	10,05	13,22

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No.	Id	Qp/Qs (LF&M)	Qp/Qs (Bergstra)	Qp/Qs (Lindahl)	Qp/Qs (Lundell)	Qp/Qs (Wessel)	Rp/Rs (LF&M)	Rp/RS (Bergstra)	Rp/RS (Lindahl)	Rp/RS (Lundell)	RP/RS (Wessel)
1	HLMF	1,13	1,13	1,13	1,13	1,13	0,64	0,64	0,64	0,64	0,64
2	AVNN	4,84	4,84	4,84	4,84	4,84	0,1	0,1	0,1	0,1	0,1
3	A	3,65	3,65	3,65	3,65	3,65	0,1	0,1	0,1	0,1	0,1
4	NCFS	2,9	2,9	2,9	2,9	2,9	0,16	0,16	0,16	0,16	0,16
5	ELS	4,65	4,65	4,65	4,65	4,65	0,09	0,09	0,09	0,09	0,09
6	MRS	4,34	4,34	4,34	4,34	4,34	0,19	0,19	0,19	0,19	0,19
7	JSSF	4,13	4,13	4,13	4,13	4,13	0,1	0,1	0,1	0,1	0,1
8	MCMF	5,28	5,28	5,28	5,28	5,28	0,12	0,12	0,12	0,12	0,12
9	ECS	4,98	4,98	4,98	4,98	4,98	0,06	0,06	0,06	0,06	0,06
10	Y	4,22	4,22	4,22	4,22	4,22	0,15	0,15	0,15	0,15	0,15
11	RGF	3,39	3,39	3,39	3,39	3,39	0,23	0,23	0,23	0,23	0,23
12	LRP	2,2	2,2	2,2	2,2	2,2	0,36	0,36	0,36	0,36	0,36
13	GVMB	2,2	2,2	2,2	2,2	2,2	0,24	0,24	0,24	0,24	0,24
14	JPAR	1,98	1,98	1,98	1,98	1,98	0,4	0,4	0,4	0,4	0,4
15	AFC	3,33	3,33	3,33	3,33	3,33	0,15	0,15	0,15	0,15	0,15
16	RS	2,43	2,43	2,43	2,43	2,43	0,29	0,29	0,29	0,29	0,29
17	AV	1,09	1,09	1,09	1,09	1,09	0,68	0,68	0,68	0,68	0,68
18	JP	3,75	3,75	3,75	3,75	3,75	0,09	0,09	0,09	0,09	0,09
19	NA	1,71	1,71	1,71	1,71	1,71	0,2	0,2	0,2	0,2	0,2
20	EF	1,51	1,51	1,51	1,51	1,51	0,24	0,24	0,24	0,24	0,24
21	BT	3,07	3,07	3,07	3,07	3,07	0,25	0,25	0,25	0,25	0,25
22	IC	5,05	5,05	5,05	5,05	5,05	0,07	0,07	0,07	0,07	0,07
23	EV	1,62	1,62	1,62	1,62	1,62	0,44	0,44	0,44	0,44	0,44
24	MV	1,84	1,84	1,84	1,84	1,84	0,36	0,36	0,36	0,36	0,36
25	G	2,54	2,54	2,54	2,54	2,54	0,37	0,37	0,37	0,37	0,37

Id: patient identification; Rpi: indexed pulmonary resistance; RSI: indexed systemic resistance; Qp/Qs: ratio between pulmonary and systemic flows; Rp/Rs: ratio between pulmonary and systemic resistance; LM&F, Bergstra, Lindahl, Lundell, Wessel: name of methods used

3 DISCUSSION OF THE DATA

During the performance of cardiac catheterization exams, we observed adequacy in the collection of all data, in both conditions, after preparation of the appropriate pre-catheterization. No respiratory and/or ventilatory problems such as bronchospasm, hypersecretion, atelectasis, or the presence of systemic arterial hypotension were observed. Other events were also not observed, such as cardiac arrhythmias, pulmonary hypertension crises with hypoxemia and/or situations of high severity requiring resuscitation maneuvers or death.

At the end of anesthetic induction and placement of the patient under mechanical ventilation, they were in ideal conditions of systemic blood pressure, peripheral oxygen saturation and capnography for the collection of blood samples and verification of the recommended hemodynamic measurements.

Of the twenty-five patients analyzed in each condition (baseline and post nitric oxide), we obtained the following Results of item 5 of this work. Therefore, a numerical variation can be observed in the saturation data after the use of nitric oxide: in the pulmonary vein (PV), in the pulmonary artery (AP), in the aorta (Ao) and in the superior vena cava (SVC) we had an increase, while in the inferior vena cava (IVC) there was a decrease. When we analyze the partial pressures of oxygen (PO2), we have an increase in the pulmonary vein, pulmonary artery, and aorta, with a decrease in partial pressures in the superior and inferior vena cava.

In the average pressures, in the post-nitric oxide condition, we had a significant increase in left and right atria. And a significant decrease in the pulmonary artery and a slight decrease in the aorta.

When we analyzed the means of Rpi (indexed pulmonary resistance) and Rsi (indexed systemic resistance) in each method, we observed a significant decrease in Rpi and a slight increase in Rsi after the use of nitric oxide. The Qp/Qs ratio (ratio between pulmonary and systemic flows) and Rp/Rs (ratio between pulmonary and systemic resistance) were also averaged in each method. In the ratio between flows (Qp/Qs) there was an increase while in the ratio of resistances (Rp/Rs) there was a decrease.

4 CONCLUSION

There is a lack of a protocol to be followed for cardiac catheterization in children, for prognostic purposes, when it comes to congenital heart diseases with pulmonary repercussions. That said, all care was taken to obtain the data collection as reliable as possible and as close to the child's physiological state, so as not to have incorrect interpretations of the patient's true hemodynamic status.

Thus, it is concluded that this protocol was produced with the intention of standardizing the collection of accurate hemodynamic data, improving the influence of a number of variables, especially the anesthetic act.

REFERENCES

Amin, E. K., Campbell-Washburn, A., & Ratnayaka, K. (2022). MRI-guided cardiac catheterization in congenital heart disease: How to get started. Current Cardiology Reports, 24(4), 419–429. https://doi.org/10.1007/s11886-022-01659-8

Asl, M. M., Delavar, S., Taghizadeh Imani, A., & Goudarzi, M. (2023). Arterial versus end-tidal carbon dioxide levels in children with congenital heart disease: A prospective cohort study in patients undergoing pulmonary catheterization. Annals of Medicine & Surgery, 85(7), 3273–3278. https://doi.org/10.1097/MS9.0000000000000815

Salihu, A., Windheuser, I. C., Wacker, J., Gloekler, M., & Di Bernardo, S. (2024). Use of ultrasound for vascular access during cardiac catheterisation in children with congenital heart disease: A Swiss multicentre cohort study. Swiss Medical Weekly, 154, Article 3575. https://doi.org/10.57187/s.3575

Santos, P. É., Ballesteros, F., Rodríguez, A., & Zunzunegui, J. L. (2024). Use of a pediatric risk score for cardiac catheterization in a Spanish population with congenital heart disease. REC: Interventional Cardiology, 6(1), 20–24.

Ülgen Tekerek, N., Aykan, H. H., Ünal Yüksekgönül, A., Ertuğrul, İ., Aypar, E., Alehan, D., Çeliker, A., & Karagöz, T. (2023). Interventional cardiac catheterization in neonates and premature infants with congenital heart disease: A single center experience. The Turkish Journal of Pediatrics, 65(6), 939–948.