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ORIGINAL ARTICLE

Current practice of the Conduct of Perfusion in adult cardiac surgery in Spanish-speaking Latin America

Práctica actual de la conducción de la Perfusión Latinoamericana de habla hispana

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RESUMEN

Introduction: Perfusion management involves multiple interventions to maintain optimal tissue oxygenation during cardiac surgery. Currently there is no consensus in Latin America on the management of variables that comprise the conduct of perfusion.

Objectives: To describe the conduct of current perfusion in adults of Spanish-speaking Latin American perfusionists.

Methods: Prospective descriptive study through a survey of thirty-four questions according to variables: demographic and occupational, devices, equipment and disposables, techniques, parameters, safety and concepts, with evidence from 2021, 2019, European guidelines and scientific articles.

Results: 53.2% of the perfusionists work alone. Less than 50% have a diversity of technological resources and devices. Most of them are adapted to the recommendations proposed in the international guidelines for perfusion conduction (>50%) in terms of both techniques and devices and parameters. 97.22% maintain temperature gradients of 5-10 °C in the rewarming phase, with a time/temperature rate of 1°C/5 min, not specified in the guidelines. 42.59% have security devices, and 11.59% do not have any. Most disassemble the circuit with the patient's chest closed.

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Conclusions: Performance of perfusion, a term that does not appear in the bibliography as such as there is terminological divergence in concepts, absence of definitions of variables, ranges, placement of security systems due to little or no world theoretical production from perfusionists. Current practice in Spanish-speaking Latin America for perfusion in adult cardiac surgery is in accordance with guidelines and when it does not occur, it is due to a lack of recommendations.

Key words: **Extracorporeal Circulation, Conduct of Perfusion, Latinamerica, Cardiac Surgery, Adults, Perfusionist.**

RESUMEN

Introducción: Conducción de la perfusión implica múltiples intervenciones para mantener óptima oxigenación de los tejidos durante cirugía cardíaca. Actualmente no existe consenso en Latinoamérica del manejo de variables que comprenden la conducción de la perfusión.

Objectivos: Describir la conducción de la perfusión actual en adultos de perfusionistas latinoamericanos de habla hispana.

Métodos: Estudio descriptivo prospectivo mediante encuesta de treinta y cuatro preguntas según variables: demográficas y laborales, dispositivos, equipos y desechables, técnicas, parámetros, seguridad y conceptos, en comparación con la evidencia publicada en las guías de perfusión americanas del 2021, las europeas del 2019, las guías de manejo de sangre americanas del 2021, las guías europeas del 2017 y editorial titulado Guidelines for Conduct of Cardiopulmonary Bypass.

Resultados: 53,2% de los perfusionistas trabajan solos. Menos del 50% cuentan con diversidad de recursos tecnológicos y dispositivos. La mayoría se adapta a recomendaciones propuestas en las guías internacionales de la conducción de la perfusión (>50%) tanto en técnicas como dispositivos y parámetros. El 97.22% mantiene gradientes de temperatura 5-10 °C en fase recalentamiento, con tasa tiempo /temperatura 1 °C /5 min, no especificado en las guías. El 42.59% cuentan con dispositivos de seguridad, y 11.59% no tiene ninguno. La mayoría desmonta el circuito con tórax del paciente cerrado.

Conclusiones: Conducción de la Perfusión, término que no figura en la bibliografía como tal y hay divergencia terminológica en conceptos, ausencia de definiciones de variables, rangos, colocación de sistemas de seguridad por escasa o nula producción teórica mundial de los perfusionistas. La práctica actual en América Latina de habla hispana para la perfusión en cirugía cardíaca de adultos muestra una tendencia a adecuarse a las guías internacionales y cuando no ocurre es por falta de recomendaciones.

Palabras Clave: **Circulación Extracorpórea, Conducción de la Perfusión, Latinoamérica, Cirugía Cardiaca, Adultos, Perfusionista**

INTRODUCTION

Ever since the first successful use of extracorporeal circulation (ECC) on May 6, 1953, technology has evolved to support the ever-wider range of cardiac surgery. "Successful ECC entails close communication among the heart surgeon, perfusionist, and anesthesiologist." Perfusionists play a crucial role in the decision-making process during the complex procedures involved in ECC.[1] Performance of perfusion (PP) is a term often used in Spanish-speaking countries. By consensus, it is defined as a set of actions, interventions and strategies carried out by the perfusionist with the objective of maintaining optimal oxygen delivery to the tissues during cardiovascular surgery. The parameters that define optimal perfusion are hemodilutional volume, cardiac output or pumping deficiency, perfusion pressure, heparinization, hypothermia, myocardial protection, regulation, and control of sprinklers and integration of blood analytics. These parameters vary depending on body surface, heart disease, and the patient's associated conditions in addition to the surgical moment. Together, they define "PP."[2] The PP process includes continuous monitoring and implementation of maneuvers based on scientific evidence to maintain several hemodynamic, gas, and metabolic parameters within normal values. However, to achieve this, the operator, in this case, the perfusionist, should have appropriate training and logistic support. However, after consulting the medical literature available, Scielo, Pubmed, Medline, and Cochrane there is very little information describing PP and we detected that it has been replaced by conduction of cardiopulmonary bypass (CPB) since most of the literature available comes from the field of cardiovascular surgery or anesthesiology. In the English language, this term appears in several books as Conduct of perfusion.

In the Journal of Cardiothoracic and Vascular Anesthesia, 2021, Hessel and Groom3 published an interesting editorial entitled Guidelines for Conduct of Cardiopulmonary Bypass (Ed. Guidelines CPB), where they describe the multiple variables that make up PP making reference to the updated classes of international recommendations and levels of evidence published in several guidelines with special emphasis on the European Guidelines on Cardiopulmonary Bypass in Adult Cardiac Surgery of 2019 published by the EACTS/EACTA/EBCP medical societies (2019 EACTS/EACTA/EBCP). Some of the variables referred to in these guidelines are included in the following categories: training, equipment, devices and monitoring, disposable material, procedures during ECC, and weaning from ECC. In addition, articles by the Spanish Association of Perfusionists[2] (AEP) and others endorse the definitions of the variables that make up PP. Given the fact that most literature comes from abroad and from professional societies different from perfusion societies, the following question came up: how is the current performance of perfusion in adult ECC by Spanish-speaking Latin-American perfusionists? Specifically in these aspects: 1. demographics and work; 2. devices, equipment, and disposable materials, 3. Techniques, 4. Parameters, 5. Safety, 6. Concepts, just as they will be described when discussing the variables. We thought it timely to compare the results of the guidelines to those of this study to reach conclusions with scientific foundation.

With this and other studies we are beginning a necessary stage in the development of our profession which is the production of theoretical material and the unification of linguistic variability to develop a terminology that would characterize us.

MAIN OBJECTIVE

To describe Spanish-speaking Latin American performance of perfusion in adult cardiac surgery.

SPECIFIC OBJECTIVES

Demographic and labor objectives: To determine the demographic characteristics of Latin American perfusionists based on their geographic distribution, type of healthcare system where they work at (public or o private), and operative perfusionist personnel in performance of perfusion.

Devices, equipment, and disposable materials: To analyze the availability and routine use of devices, equipment, and disposable material.

Techniques: To determine the different techniques involved when performing perfusion: occlusiveness, partial oxygen pressure (paO_2), reduction of hemodilution (HD), ultrafiltration (UF), temperature, arterial line pressure, and location of arterial line pressure measurement.

Parameters: To present the ranges used by Latin American perfusionists associated with perfusion parameters: mean arterial pressure (MAP), arterial line pressure, hematocrit (HTC), tissue perfusion, and temperature.

Safety: To identify what safety devices are used by perfusionists and up to what surgical moment they can maintain ECC circuit integrity.

Concepts: To specify what Latin American perfusionists understand by normovolemic hemodilution (NHD) in association with the definitions from other medical fields such as anesthesiology or cardiac surgery considering the absence of theoretical material particular to the field of perfusion.

To establish the objectives of this research considering that it is on Spanish-speaking Latin American perfusionists and adult cardiac surgery. We grouped the variables into 6 categories, which we call first-degree categorization and we located the levels of evidence according to the corresponding variable and the recommendation existing in the clinical guidelines on the management of perfusion of 2019 EACTS/EACTA/

EBCP, Ed. Guidelines CPB, 2021 STS/SCA/AmSECT/SABM Update to the Clinical Practice Guidelines on Patients Blood Management (2021STS/ (2021STS/ SCA/AmSECT/SABM) and 2015 STS/SCA/AmSECT: Clinical Practices Guidelines for Cardiopulmonary Bypass-Temperature Management During Cardiopulmonary Bypass (2015 STS/ SCA/AmSECT) to later compare the results of this study to the evidence published.

Table 1. First-degree categorization with their respective sub variables based on evidence and recommendation corresponding to PP.

Variable (1st categorization)	**Performance of perfusion guidelines. Journal of Cardiothoracic and Vascular Anesthesia 2021, 2019 /EACTS Guideline, 2021 STS/ SCA/AmSECT/SABM, 2015 STS/ SCA/AmSECT**	**Level of Evidence Recommendation**
1. Demographic and working	a) N + 1 perfusionist per case	Standard #15
2. Devices, equipment, and disposable materials	a) Routine use of red blood cell recovery through useful configuration of blood preservation. b) Centrifugation of blood recovered with pump is reasonable to minimize transfusion of allogenic red blood cells after ECC. c) Continuously monitor SVO_2 and HTC levels during ECC. d) Blood gas test monitoring is advised at regular intervals or continuous observation during ECC. e) Use of NIRS-guided algorithms can be considered to improve clinical results. f) Use of arterial filter is advised to reduce the number of microembolisms. g) The concentrations of escape gases from the oxygenator should be monitored during ECC. h) Use of low molecular weight starches is ill-advised in primary and non-primary solutions to reduce bleeding and transfusions. i) Use of routine hemoconcentrators.	a) IA b) IIaA c) IB d) IC e) IIbB f) IIbC g)IIaB h) IIIC i) S/R
3. Techniques	a) Leukocyte filtration or hyperoxia are ill-advised to protect the lungs during ECC. b) Retrograde and antegrade autologous priming are advised as part of a blood conservation strategy to reduce transfusions. c) Retrograde autologous priming of the ECC circuit should be considered whenever possible. d) Reduce priming volume in the ECC circuit reduces hemodilution and is indicated for blood preservation. e) Hemodilution limitation is advised as part of the blood preservation strategy to reduce bleeding and transfusions. f) Use of routine ultrafiltration technique. g) MUF and selective pulmonary arterial perfusion can be considered to improve postoperative respiratory function. h) The use of MUF can be reasonable regarding blood preservation. i) Patient-centered myocardial protection strategies based on the clinical condition and procedural complexity are advised instead of fixed institutional cardioplegic solution. j) Consider blood cardioplegia in selected patients to reduce hemodilution. k) Method of cardioplegia infusion.	a) IIIA b) IA c) IB d) IB e) IB f) S g) IIbB h)IIbB i) IC j) IIaB
4. Parameters	a) Ranges of arterial linear pressure. b) Keep MAP between 50 and 80 mmHg and use of vasodilators and vasoconstrictors if necessary. c) Use of vasopressors to force MAP values > 80 mmHg during ECC is ill-advised. d) Adjusting MAP during ECC with use of arterial vasodilators if MAP > 80 mmHg or vasoconstrictors if MAP < 50 mmHg is ill-advised after anesthesia depth is verified and with a supposedly enough directed pump flow. e) The suitability of pump volume flow during ECC should be checked depending on metabolic parameters (SvO_2, O_2ER, NIRS, VCO_2, and lactates). f) Pump volume flow should be adjusted depending on the content of arterial oxygen to keep a minimum threshold of DO_2 in moderate hypothermia. g) Red blood cell transfusion is ill-advised with Hb concentrations > 10g/dL. h) Temperature gradients between arterial outlet and venous entry in the oxygenator during cooling and reheating should not exceed 10^{0} C. i) The maximum gradient should be 10^{0} C between arterial blood outlet temperature from oxygenator and venous entry of the cardiotomy reservoir with temperatures < 30^{0} C. j) When arterial blood outlet temperature is > 30^{0} C, a reheating rate of ≤ 5^{0} C or 4^{0} C gradient should be kept. k) Definition of hypothermia ranges. l) Ranges of line pressure values.	a) S/R b) IA c) IC d) IC e) IIaB f) IIaB g) IIIB h) IC i) IIaC j) IIaB k) S/R l) SR
5. Safety	a) Bubbles, temperature, pressure, and level sensors are advised. b) Using a level sensor during the ECC procedures (hard-shell reservoirs). c) Using a bubble detector in all ECC procedures in the entry line of the oxygenator is advised. e) Keeping the ECC circuit functional until the patient's thorax has been closed is advised. h) Continuous monitoring of pre- and post-oxygenator arterial line pressure. l) Monitoring the parameters of ECC performance is the pillar of patient care for perfusionists.	a) IC b) IC c) IC e) IC h) IC l) IC
6. Concepts	a) Acute normovolemic hemodilution is a reasonable method to reduce bleeding and transfusion.	a) IIaA

METHODS

A descriptive prospective study was carried out through a 34-question survey (see annex), which covered the topics discussed in the PICOT question whose objective was to know the perfusionist's daily practice regarding performance of perfusion in Latin America in adult cardiac surgery. The reference values used in the survey were taken from the 2019 EACTS/EACTA/EBCP guidelines. The survey was validated by the quality section of the Latin American Perfusion Board. After it had been validated, the next step was to create its digital version on the QuestionPro platform, https://www.questionpro.com and it was distributed through the Latin American Association of Perfusion (ALAP) database as mass e-mail and different digital platforms. The instrument was distributed throughout the Spanish-speaking Latin American countries. The survey remained open for one week during the month of March 2022. To better analyze and understand the results, we built a table called second-degree categorization where variables were grouped by the topics surveyed. (Table 2). The answers that came from Brazil were excluded because the language barrier deviated from the objectives of this study. In addition, we excluded answers from countries outside of Latin America. The survey was distributed to a universe of approximately 1100 perfusionists. Since it was such a large survey, we asked the Latin American Perfusion Board for help and they granted two (2) training credits (TC) for certified clinical perfusionists (PCC) who answered the survey, which can be used in the recertification process.

Statistical analysis: To determine sample size, we calculated 95% confidence interval (CI) and a sample proportion of 0.5 based on this. A total of 175 respondents are needed to obtain an margin of error of 5%. Results were processed on an Excel spreadsheet and expressed in proportions; tables were also made with frequency and percentages.

Table 2: Categorization of second-degree variables regarding performance of perfusion

VARIABLE (2nd categorization)	STUDY ENDPOINTS	VARIABLE IN LATIN AMERICA
1. Demographic and working	Determine the demographic characteristics of Latin American perfusionists by geographic distribution, type of healthcare sector, and operative perfusion personnel performing perfusion procedures.	1. Country where perfusionists work. 2. Type of center they work at. 3. Number of perfusionist per surgical case.
2. Devices, equipment, and disposable materials	Analyze availability and routine use of devices, equipment, and disposable material in Latin American perfusionists.	1. Blood cell savers. 2. Monitoring line gases/estimating DO_2. 3. Hemoconcentrators. 4. Vaporizer. 5. NIRS. 6. Priming solutions. 7. Oxygenators with built-in arterial filter. 8. Arterial filter added to built-in filter.
3. Techniques	Verify the technical differences involved when performing perfusion among Latin American perfusionists.	1. Type of occlusiveness implemented: dynamic, static 2. Partial oxygen pressure level. 3. Techniques used to reduce hemodilution. 4. Use of ultrafiltration. 5. Use of MUF in adults. 6. Goal of CUF. 7. Use of Z-BUF. 8. Type of cardioplegia implemented. 9. Technique of cardioplegia infusion. 10. Site of perfusion pressure measurement.
4. Parameters	Locate the management parameters when performing perfusion regarding pressure, tissue perfusion, and temperature considered within the limits by Latin American perfusionists.	1. Line pressure/perfusion pressure ranges. 2. MAP ranges. 3. PaO_2 ranges in normothermia. 4. DO_2: estimate, measurement, and use of App. 5. Hematocrit limit regarding transfusion. 6. Perfusion pressure or line pressure measurement. 7. Temperature gradient between heat exchanger and the patient's temperature. 8. Reheating phase: rate (temperature/time). 9. Temperature ranges implemented.
5. Safety	Identify safety devices used by Latin American perfusionists and up to what surgical moment they keep ECC circuit integrity.	1. Safety systems. 2. Bubble sensors. 3. Temperature sensors. 4. Level sensors. 5. Gases in line. 6. Arterial line pressure. 7. Disassembling the ECC circuit.
6. Concepts	Analyze the concept of normovolemic hemodilution used in Latin America.	1. Normovolemic dilution

RESULTS AND DISCUSSION

In just 1 week the survey was e-mailed to 1100 perfusionists registered in the ALAP database and from other digital platforms. A total of 700 out of these 1100 perfusionists are from Brazil and 400 from the rest of Latin America (source: ALAP). The survey was answered by 245 people. Regarding the exclusion criteria, 27 surveys answered from Brazil, 1 from the United States and 1 from Spain were excluded. A total sample of 216 fully answered samples remained. Because this study is limited to the adult population, by consensus among the authors, we assumed that, out of the entire sample, 80 perfusionists are entirely pediatric perfusionists in Latin America. Therefore, the total population of this survey includes 320 Latin American adult perfusionists. The response rate obtained is 67.5% (Figure 1).

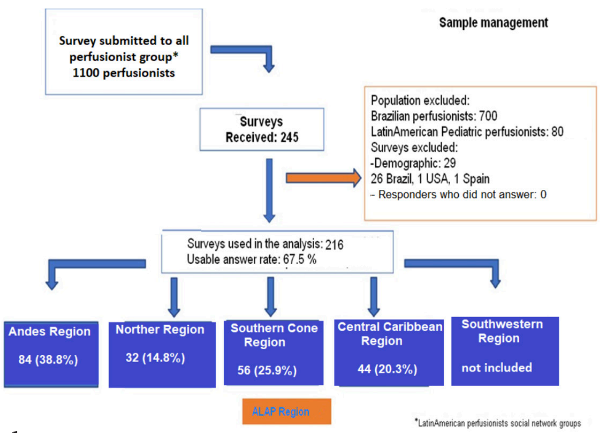

Figure 1

From the information collected in the surveys conducted among Latin American perfusionists, we conducted the variables analysis according to their subvariables, and compared them to international guidelines obtaining the following results.

1. Demographic and work-related:

According to the classification of the 5 regions proposed by ALAP, the greatest density of answers by perfusionists came from the Andes region, which corresponds to the overall number of several countries of which Colombia was the greatest responder (20.37%). Northern region is only made up of Mexico which has a larger number of perfusionists compared to the rest of the Spanish-speaking countries with 14.81% of the answers.

Regarding the working sector; they are distributed in the following manner, 38.9% work in the private sector, 34.7% at public institutions while only 26.4% are employed in both sectors. (Figure 3).

Regarding personnel distribution, perfusion departments should be sufficiently staffed and have adequate experience. The daily amount of certified perfusion personnel should be n + 1, where n is the number of consecutive functioning operating rooms and 1 is considered an unassigned perfusionist per OR who should be available for relief and /or support.4 Although it is true, as shown on figure 3, that in Latin America 46.7% of perfusionists work with a perfusion partner within the operating room or can count on a perfusionist outside the OR who is available, 53.2% of perfusionists work on their own inside the OR. Therefore, at present the n + 1 requirement is not met in most perfusion departments surveyed. (Standard 15: American Society of Extracorporeal Technology Standards and Guidelines for Perfusion Practice) (Figure 3)

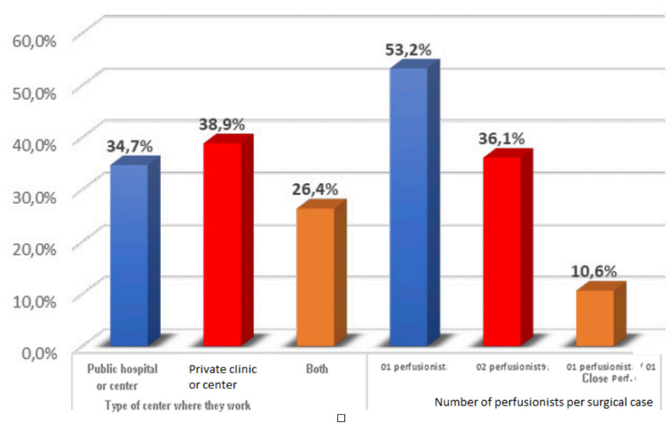

Figure 2

2. Devices, equipment and disposable materials

A- Red blood cell saver and hemoconcentrators

Blood conservation methods are part of the intraoperative procedures and restrictive transfusional policy in blood saving programs. The PBM program (Patient Blood Management) aims to improve clinical results with the updated guidelines recommending routine use of red blood cell saving systems by centrifugation as an aid in blood conservation in cardiac surgeries with ECC (Class I Level A), as well as centrifugation of blood recovered from the pump to minimize allogenic red blood cells transfusion post-ECC (Class IIa Level A).5 In Latin America, 31.48% of perfusionists surveyed answered that they routinely use the cell saver in their practice and 42.59% use it in specific cases. The remaining respondents, 25.93%, said that they do not use it (Table 3).

Table 3. Use of hemoconcentrator and red cell saver.

		N	%
Use of Hemoconcentrator	Yes	146	67.59%
	No	21	9.72%
	Specific cases	49	22.69%
Use of Cell Saver	Yes	68	31.48%
	No	56	25.93%
	Specific cases	92	42.59%

UF techniques are used to revert HD and improve hemoglobin figures (Hb). The hemoconcentrator is routinely used in ECC by 67.59% of the perfusionists surveyed; 22.69 % of the respondents use it in specific cases and 9.72% of them simply don't use it. Probably the cost is involved in these decisions.

B- Line Gases Monitoring and NIRS

Intermittent sampling for blood gas test has been the most common form of blood gas management in ECC. Perfusionist societies in Ireland and the UK, in their recommendations for monitoring standards indicate that blood gas tests should become available for each patient and the frequency of the sampling is determined by the local protocols.6 Since 2000,[7] there has been an increase in the use of this technology called "real time" continuous monitoring which registers different variables: pH, partial pressure of carbon dioxide ($paCO_2$), paO_2, SvO_2 and arterial oxygen saturation (SaO_2), HTC, electrolytes, bicarbonate, among others. The 2019 EACTS/EACTA/EBCP guidelines recommend continuously monitoring SvO_2 and HCT levels during ECC (Class I Level B). Also, monitor blood gas test at regular intervals or continuous observation during ECC (Class I Level C). According to reported data, 40.74% of perfusionists use line gas monitoring in all their surgeries whereas 47.22% do not use it and only 12.04 % reports using it in specific cases (Table 4).

Table 4. Use of line gas monitoring and NIRS.

		N	%
Use of line gases monitoring	Yes	88	40.74%
	No	102	47.22%
	Specific cases	26	12.04%
Use of NIRS	Resource unavailable	85	39.35%
	Selected and discussed cases	60	27.78%
	All surgical cases	71	32.87%

NIRS monitoring measures regional oxygen saturation at brain level, thus reflecting the balance between delivery and consumption in this organ.[8]

The 2019 EACTS/EACTA/EBCP guidelines consider the use of NIRS guided algorithms to improve clinical results (Class IIb Level B).

In the survey, 39.35% indicated that the resource is not available to them, 32.87% indicated that they use it in all their surgical cases, and 27.78% that they only use it in the aforementioned selected cases.

C- Oxygenators and Arterial Filter

According to the recommendation established by the 2019 EACTS/ EACTA/EBCP clinical guidelines, AF should be considered to reduce the number of microembolisms (Class IIb Level C).

The industry integrated this component into the architecture of the oxygenating membrane although external AF is still being used.9 A total of 62.50% of respondents say that they use oxygenators with built-in AF. Therefore, we saw a tendency towards the use of oxygenators with built-in AF in Latin America (Table 5); 14.81% said that they do not use them, and 22.69% that they have access to both kinds of disposable

Table 5. Use of Oxygenators and arterial filter

		N	%
Use of oxygenator with built-in filter	Yes	135	62.50%
	No	32	14.81%
	Both	49	22.69%
Use of arterial filter + oxygenator with built-in filter	Yes	27	12.50%
	No	189	87.50%

materials. Regarding the use of an additional AF added to the oxygenator with a built-in AF, 87.90% answered that they did not follow this practice and a smaller percentage (12.50%) said that they did actually add an external AF in addition to the one built-in and integrated in the membrane.

The analysis of the availability and routine use of devices, equipment, and disposable materials makes us think that the cost factor and lack of resources availability are the most important factors for the lack of use, although we find numbers that surpass our early expectations.

D- Anesthetic vaporizer

Regarding the use of volatile anesthetics in ECC different metanalyses have revealed that patients anesthetized with volatile agents tend to show lower troponin levels in the postoperative period compared to the IV infusion of anesthesia. Therefore, cardioprotective effects have been attributed to volatile agents, thus having an impact on lower postoperative morbidity and mortality rates, which can also be extrapolated to non-cardiac surgeries.[10]

85.19% of perfusionists surveyed use anesthetic vaporizers in between their circuit. Although this is not a routine practice, it is necessary to evaluate the number of gases administered during ECC through the analyzers in the membrane exit gas port. To this end, the 2019 EACTS/EACTA/EBCP guidelines recommend that escape gas concentrations from the oxygenator should be monitored during ECC (Class IIa Level B).

E- Priming Solution

As ECC systems have developed, priming solutions have also been modified and changed over time: from priming that is mostly hematic in content to the use of crystalloid solutions to improve blood flow and oxygen delivery at capillary level. A digital survey conducted in 18 European countries whose objective was to know the current management practice of perioperative fluids in patients treated with cardiac surgery revealed that there was a preference for using crystalloid solutions with synthetic colloid or albumin.[11]

Table 6. Use of solutions for priming the circuit

		N	%
Type of Solution for priming the extra- corporeal circuit	Plasmalyte, Normosol, Multylitos R	67	31.02%
	Ringer lactate	82	37.96%
	Ringer without lactate	5	2.31%
	0.9% sodium chloride	62	28.70%

There is no consensus regarding the determination of the type of solution considered "ideal" for extracorporeal priming even when the solution used is a determining factor in the patient's metabolic behavior, which also impacts postoperative recovery. The 2019 EACTS/EACTA/EBCP guidelines on modern priming solutions recommend not using low-molecular weight starches as primary and non-primary priming to reduce bleeding and transfusions (Level III class C). Both balanced solutions (Plasmalyte, Normosol, Multylitos R) are used in 31.02%; 0.9% sodium chloride is used equally by respondents (28.70%) while Ringer's lactate (RL) is used by 37.96% of Latin American perfusionists while 2.31% use it without lactate for priming (Table 6). The predominant use of these solutions is probably due to the fact that balanced solutions are not available to all perfusionists surveyed since they involve greater cost compared to the rest of crystalloids. Our study did not assess the option of colloidal solutions (neither synthetics nor albumin-based) as part of extracorporeal priming. This will require future studies where this type of solutions is included together with other additives.

The analysis of the availability and routine use of devices, equipment, and disposable material by Latin American perfusionists revealed that most of them do not use them because they're not available to them and because of the the cost factor, which would be the 2 greatest obstacles for their implementation. Similarly, it was observed that they have other technologies available like, for example line gas monitoring (40.74%) and built-in arterial filters (62.50%), which represents a growing trend in Latin America. Values that we hope will keep growing for all patients to have equal opportunities regarding healthcare.

3-Techniques

A- Occlusiveness –Calibration

Currently, the association between both methods is not well established and perfusion guidelines do not issue any recommendations regarding calibration methods. The importance of a proper degree of occlusion of the arterial roller lies in that excessive occlusiveness would traumatize blood elements even causing circuit tubing spallation and in the worst case scenario, severe hemolysis.[1,12] On the other hand, an occlusion defect would be responsible for not guaranteeing the precise delivery of arterial flow to the patient in ECC and/or the presence of retrograde flow from the patient to the extracorporeal circuit.[12] Based on the results obtained, 59.72% of perfusionists use one method only to verify the optimal occlusion of arterial roller of whom 38.89% tend to use the static calibration method and 20.83% the dynamic one. However, this survey revealed that 40.28% of perfusionists use both methods (dynamic and static) to confirm the optimal occlusiveness of arterial roller. Although the methods are well known, the procedure to achieve the objective of calibration varies considerably between one method and the other.

B- Partial Oxygen Pressure (PaO_2)

Recent studies among the adult population have associated hyperoxia during perfusion with greater risk of developing acute kidney injury[13] (AKI) and greater oxidative stress to the myocardium.[14] Management of oxygen pressures during perfusion is another technique that still lacks enough evidence. The current clinical guidelines do not issue very large recommendations on this technique other than a rather solid recommendation regarding lung protection: "use of leukocyte filtration or hyperoxia is ill-advised to protect the lungs during ECC". (Class III Level A).

It was evident that there was a significant similarity among perfusionists regarding PaO_2 management during perfusion performed between 34ºC and 37°C. A total of 75% of perfusionists surveyed manage PaO_2 in ECC between 120 – 250 mmHg, which are results suggestive of a significant trend toward the normoxemic strategy (Table 7). Theoretically speaking, it has been reported that high oxygen concentrations can cause oxidative stress when reactive oxygen species exceed the body antioxidant systems, which exacerbates the injury due to ischemia of reperfusion after ECC, which basically damages myocardial, pulmonary and neurological functions.[15]

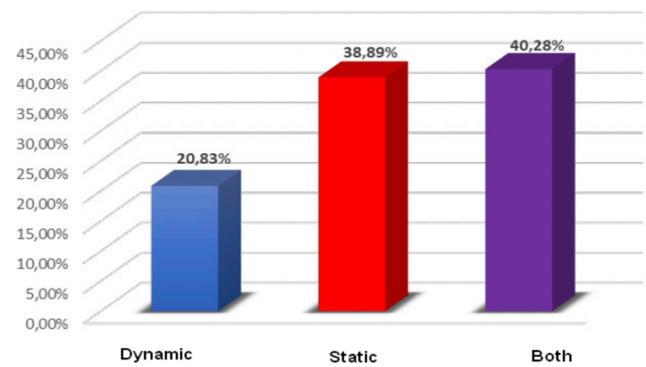

Figure 3

C- Techniques to reduce hemodilution (HD)

The current perfusion guidelines in adult cardiac surgery seem to agree on issuing strong recommendations, with levels of evidence between good and moderate regarding techniques to reduce HD. Limiting HD and priming volume as a strategy to preserve blood is a Class I Level B recommendation. Retrograde autologous priming (RAP) of the ECC circuit was reported in the 2019 EACTS/EACTA/EBCP guidelines with a Class I Level A recommendation, and 2021 STS/SCA/ AmSECT/SABM guidelines as Class I Level B recommendation. Also, in 2017 guidelines published by the EACTS/EACTA on patient blood management for adult cardiac surgery (2017 EACTS/EACTA) issued a Class IIa Level A recommendation. According to the European guidelines on patient blood management for adult cardiac surgery, limitation of HD is advised as part of a strategy of blood preservation to reduce bleeding and transfusions.[16]

A total of 59.26% of Latin American perfusionists use all the techniques aimed at reducing HD, which is indicative that there is very good introduction of these recommendations

Table 7: Ranges of oxygen partial pressure in ECC

		n	%
Ranges of oxygen partial pressure in ECC	80 to 120 mmHg	27	12.50%
	120 to 200 mmHg	82	37.96%
	200 to 250 mmHg	80	37.04%
	> 250 mmHg	27	12.50%

Table 8. Techniques to reduce hemodilution.

		N	%
Techniques to reduce Hemodilution	Retrograde autologous priming	35	16.20%
	Shortens the length of lines and reduces contact surface whenever possible	85	39.35%
	Restricts and controls fluids together with anesthesiology	54	25.00%
	All the above	128	59.26%
	Does not use any additional techniques	1	0.46%
	Other	6	2.78%

within their daily work practice. In addition, these perfusion techniques are the ones most strongly backed by scientific evidence. To a lesser degree, perfusionists indicated that they use some of these techniques individualizedly: 39.35% shorten the length of lines and reduce contact surface, 25% restrict and control fluid administration together with anesthesia and 16.20% perform RAP. (Table 8).

D- Ultrafiltration techniques (CUF, MUF, and Z-BUF)

Ultrafiltration techniques CUF, MUF, and Z-BUF are used in ECC to maintain the patient's fluid balance, especially in cases of kidney disease or cases of excessive HD in which it is necessary to individualize this technique among patients considering their previous hydric status to prevent dehydration due to excessive hemoconcentration. There is no established consensus on the amount of volume that is safe to filter regarding ECC. Nevertheless, a study conducted by Manning et al.[17] associated ultrafiltration >32 mL/Kg with a higher risk of developing AKI post ECC. The utility of hemofiltration as a technique to control total blood volume during cardiopulmonary bypass is widely accepted and known. However, review of different clinical practice perfusion guidelines does not contribute any recommendations on the level of evidence associated with the conventional ultrafiltration technique. However, it is true that, overall, ECC is associated with significant HD.

Conventional Ultrafiltration (CUF)

Upon inquiring among the perfusionists on the criteria used to decide whether to use the CUF technique during perfusion, 76.86% use it for specific reasons: 7.87% when infusing a high volume of cardioplegic solution, 9.72% as a strategy to regulate fluid balance, 10.65% in patients with prior kidney disease, and 48.62% for the 3 reasons given above. A total of 37.50% indicated that they routinely use the CUF technique in all the patients. Regarding the decision on the amount of volume to be ultrafiltrated when the CUF technique is used, it was obvious that most respondents (46.30%) ultrafiltrate based on HTC target followed by 27.78% who filtrate based on the level of blood available in the reservoir, 20.83% filtrate between 10% and 20% of the patient's blood volume, 3.70% filtrate between 20% and 50% of the patient's blood volume while 1.39% of respondents filtrate a fixed volume for all the cases. (Table 9).

Modified ultrafiltration (MUF) in adults

MUF was created by Naik and Elliot bac in the 1990s as a strategy to eliminate excess plasma water and inflammatory markers after ECC among the pediatric population. Due to its proven efficacy reverting the unwanted effects of HD, the consumption of blood derivatives is reduced while the patient's hemodynamics and myocardial function are improved. Afterwards, it was used in adult patients.[18]

This study revealed that 59.26% of perfusionists do not apply MUF to adult patients followed by 27.78% who do so in specific cases while only 12.96% do it routinely. The 2017 EACTS/EACTA, 2019 EACTS/EACTA/EBCP, and 2021 STS/SCA/AmSECT/SABM guidelines provide three Class IIb Level B recommendations on this technique, suggesting that it can be considered to improve postoperative respiratory function,[19] as part of a blood preservation strategy to minimize HD,[16] and to reduce postoperative blood loss in adult cardiac surgeries with ECC.[5] Probably, the uncommon use of this technique—revealed among Latin American perfusionists—is due to lack of more solid scientific evidence in the adult population.

Table 9. Use of ultrafiltration and goals.

		n	%
Use of Ultrafiltration	In patients with prior kidney disease	23	10.65%
	To regulate fluid balance	21	9.72%
	When I use a high volume of cardioplegic solution	17	7.87%
	All the above	105	48.61%
	Used in all patients per protocol	81	37.50%
Ultrafiltration goal	Filtrate between 10% and 20% of patient's blood volume	45	20.83
	Filtrate between 20% and 50% of patient's blood volume	8	3.70%
	Filtrate based on hematocrit target levels	100	46.30%
	Filtrate a fixed volume in all cases	3	1.39%
	Filtrate based on the level of blood available in venous reservoir.	60	27.78%

Table 10. Use of the Z-BUF technique

		n	%
Use of Z-BUF	Yes	48	22.22%
	No	168	77.78%
Objective of Z-BUF	Improve hematocrit figures	13	6.02%
	Improve electrolytic balance	25	11.57%
	Reduce inflammatory response	26	12.04%
	Clear up lactate figures	19	8.80%
	All the above based on the case (a, b, c, d)	131	60.65%
	Other	31	14.35%

Zero-balance ultrafiltration (Z-BUF)

Z-BUF was described, for the first time, by Journois et al.,[20]. It consists of administering a replacement solution while performing perfusion and ultrafiltration on a 1:1 ratio to reduce the concentration of any solutes in plasma by replacing a fluid for another solute-free fluid. Its application occurs mainly during the reheating stage, and is indicated for treating hypercalcemia and systemic inflammatory response thanks to its capacity to eliminate electrolytes, cytokines, and anaphylotixins.[21] Most respondents (77.78%) did not use this routine technique in their procedures (Table 10). These results suggest that in Latin America this technique is rarely used, which could be similar worldwide since the current clinical practice perfusion guidelines do not issue recommendations regarding this technique.

E- Type of cardioplegia and infusion techniques

The cardioplegic solution most often used today in adult patients, representing 59.26%, is the Del Nido cardioplegia followed by cell preservation solutions Custodiol HTK or Plegisol (27.78%), cold blood or normothermic cardioplegia (14.82%), and the Saint Thomas solution (9.72%). The present results differ greatly from those reported in 2018 by Ali et al.[22] in a survey of South American cardiovascular anesthesiologists, 56.6% oh whom used the Saint Thomas solution and 26.4% the Bretschneider solution at that time when both these cardioplegic solutions were the most widely used ones; surprisingly enough, 0% answers were given for the Del Nido cardioplegia (Figure 5). These results suggest that preference for a type of cardioplegic solution has changed over time or that it is highly heterogeneous among Latin-American countries. Although it is true that the popularity of the Del Nido cardioplegia has grown worldwide like publications in Latin-American countries regarding its clinical results;[23] currently, there is no solid evidence demonstrating the superiority of one type of cardioplegic solution over the other regarding heart protection. However, the 2019 EACTS/EACTA/EBCP guidelines contribute recommendations that can guide the selection of myocardial protection strategy based on the patient. They recommend using patient-based myocardial protection strategies based on clinical conditions and the complexity of the procedure instead of using fixed institutional cardioplegic solutions (Class I Level C, table 1). Also, blood cardioplegia should be considered in selected patients to reduce HD, bleeding complications, and transfusion requirements (Class IIa Level B, table 1).

The most common cardioplegia administration system among respondents is the roller pump technique represented (69.91%) followed by infusers/pressurizers, manual cardioplegia (by pressing with their hands), infusing pumps, and gravity in

19.91%, 12.96%, 8.33% and 6.94%, respectively. Although this survey did not inquire on the use of disposable cardioplegia administration systems, usually when administered using the roller pump technique it is accompanied by a system to monitor pressure, temperature, dosage, speed and infusion time.

To conclude, upon verifying the different techniques used to perform perfusion among Latin-American perfusionists, we saw that most comply with what has been indicated in the current guidelines. The parameters where we found the most variability are those on which no recommendations or concepts are defined in other study areas, and there is controversy like in the case of CUF and Z-BUF, and their recommendation for adult surgery. We should mention that the practice of double calibration of arterial rollers is probably due to lack of maintenance of ECC machines and safety systems at regional centers.

Lastly, the use of cardioplegia shows superiority in the Del Nido solution, although there is great heterogeneity in the use of other solutions for myocardial protection and administration systems, with a preference towards rollers (69.91%).

4. Parameters

A- Arterial line pressure

The survey revealed a predominance of perfusionists whose arterial line pressure range goes from 100 to 200 mmHg. These cut-off values go from 100 to 150 mmHg in 39.35%, 150 to 200 mmHg in 42.13%, that is, 81.48% confirmed using values < 200 mmHg. In an article entitled Safety Protocol AEP reports that 230 mmHg is the cut-off value for alarm while 250 mmHg is the cut-off value for stopping arterial pump, which is indicative of arterial cannulation pressure. Higher pressures could be suggestive of cannulas that are too small, bend, are inadequately placed, increased vascular resistance or viscosity. Currently, guidelines do not specify any recommendations regarding what arterial line pressure values should be used.

B- Mean arterial pressure (MAP)

Enough MAP should be used in ECC to keep adequate perfusion pressure in all the organs mainly the brain, kidney and the GI tract. In adults it is advised that MAP values whould be kept between 50 and 80 mmHg. (Table 1). If necessary, with the use of vasodilators or vasopressors, as appropriate, after confirming

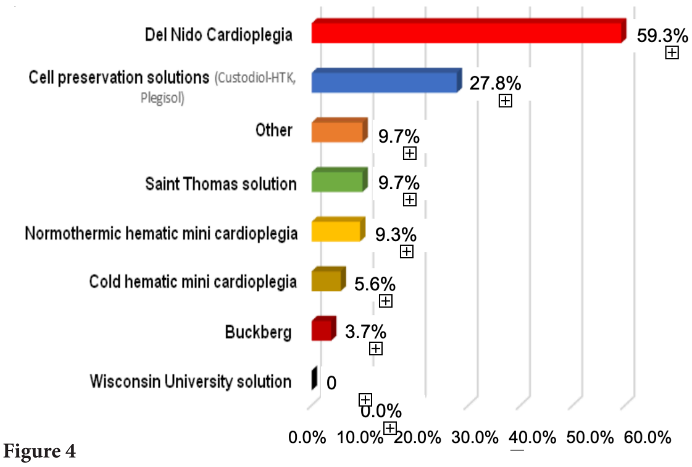

Figure 4

anesthetic depth and adequate perfusion flows (Class I Level A, table 1).

The data revealed by the survey showed that most respondents (72.22%) agree with the recommendations established by the 2019 EACTS/EACTA/EBCP guidelines that keep MAP somewhere between 60 and 80 mmHg, 27.31% of perfusionists consider it adequate to keep MAP between 40 and 60 mmHg, and 0.46% prefer MAP values > 80 mmHg.

C- Estimation and measurement of DO_2, and App use

In periods considered "stable" during the application of techniques like hypothermia and periods considered "unstable" where it is necessary to implement blood flow rate variations, increasing body temperature or knowing the behavior of gas transference of the devices used in gas exchange, determining oxygen delivery (DO_2), oxygen consumption (VO_2) and keeping strict control of the parameters indicated above has an impact on both the quality of the procedure and the patient's postoperative result. The suitability of pump flow volume during ECC should be checked based on metabolic oxygenation parameters (SvO_2, O_2ER, NIRS, VCO_2, and lactates). Similarly, pump blood volume flow should be adjusted based on the content of arterial oxygen to maintain a minimal threshold of DO_2 in moderate hypothermia, both with the same recommendation (Level IIa Class B, table 13). A total of 27.78% of the perfusionists surveyed indicated that they do calculations/measurements of DO_2 during ECC continuously while 45.83% do so intermittently (using apps or manual calculations). The remaining perfusionists surveyed (26.39%), do not estimate it during ECC (Table 13).

The percentage of answers indicative that measurement of DO_2

Table 11. Range of perfusion pressure in the arterial line

		N	%
Range of Perfusion Pressure in Arterial line	< 100 mmHg	15	6.94%
	From 100 to 150 mmHg	85	39.35%
	From 150 to 200 mmHg	91	42.13%
	From 200 to 250 mmHg	24	11.11%
	> 250 mmHg	1	0.46%

is performed intermittently (45.83%) can be due to the fact that users may not have the technology required or use older or limited technologies regarding certain parameters or else it can be due to the unavailability of certain elements (cells, connectors, calibration solutions, etc.) required to get monitors running properly with support from external, manual, digital resources or laboratory analyses to obtain more complete information while performing perfusion.

Table 12. Range of MAP in ECC.

		n	%
MAP Ranges in ECC	From 40 to 60 mmHg	59	27.31%
	From 60 to 80 mmHg	156	72.22%
	> 80 mmHg	1	0.46%

Table 13. Calculation of DO_2 during ECC.

		N	%
DO_2 estimate during extracorporeal circulation	Yes, continuously	60	27.78%
	Yes, intermittently (App/manual)	99	45.83%
	Did not estimate it during CEC	57	26.39%

D- Hematocrit limit to transfuse red blood cells during ECC

Packed red blood cells (PRBC) can be transfused when Hb values drop below a threshold considered critical for adequate DO_2. When HTC values are between 18% and 24%, PRBC are transfused based on tissue oxygenation. In his study of coronary surgery on acute kidney injury (AKI) Dr. Ranucci claims that HD during ECC is a high-risk factor for AKI, and its detrimental effects can be reduced by increasing pump flow and oxygen supply.[24]

PRBC should be transfused during ECC with Hb values < 6.0 g/dL. According to the 2021 STS/SCA/ AMSECT/SABM Update on Clinical Practice Guidelines for patient blood management, it is unlikely that allogenic red blood cell transfusion will improve oxygen supply with Hb levels > 10 g/dL. Class III Level B is ill-advised. Risks outweigh the benefits. In Latin America, most respondents (55.56%) agree with the recommendations of transfusing with a HTC cut-off value between 20% and 24% while 20.83% transfuse PRBC with a HTC cut-off value between 25% and 29%, and 19.44% consider that the HTC cut-off value to transfuse is < 20%. Only 4.17% of perfusionists have different criteria regarding the HTC cut-off value in ECC. (Table 15).

E. Reheating rate

Current literature refers to the different temperature gradients between the oxygenator arterial outlet and venous entry in the cardiotomy reservoir during ECC cooling and reheating mentioning that delta should not exceed 10 ºC to prevent degasification when blood is perfused to the patient (Class I Level C).[25] Although, before mention was made to the gradient between the heat exchanger and nasopharyngeal temperature, we have found Spanish evidence from 2015 that "the temperature gradient between the patient's water and venous temperature should be observed and not exceed 10 C."26 Although 97.22% of the perfusionists surveyed confirmed that their behavior regarding the reheating phase in adult perfusion follows these guidelines, only 2.78% maintain a difference > 10ºC.

Regarding the temperature/time rate in the reheating phase: the 2015 guidelines for management of temperature25 (2015 STS/SCA/AmSECT) present two different scenarios: when arterial outlet blood temperature is > 30 ºC a reheating rate of ≤ 0.5ºC/min or a 4ºC gradient should be observed (Class IIa Level B,) between arterial and venous temperature and when temperature is < 30ºC, the temperature delta between the venous and arterial phase can be 10 ºC (Class IIa Level C). This is due to the increased gas solubility at low temperatures. It is obvious that there is a prevailing preference for a slower heating among respondents. Although they were not specifically asked of the temperature at the beginning of reheating—whether it

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Table 15. Limit for red cell transfusion during ECC.

		N%	%
Limit allowd for transfusion during ECC	> 20%	42	19.44%
	From 20% to 24 %	120	55.56%
	From 25% to 29%	45	20.83%
	Other	9	4.17%

Table 16. Reheating rate·

		n	%
Temperature gradient of heat exchanger /patient	From 51°C to 10°C	168	77.78%
	10°C	42	19.44%
	➢ 10°C	6	2.78%
Reheating rate (Temp/time)	1°C every 5 min	119	55.09%
	1°C every 10 min	26	12.04%
	1°C every 3 min	60	27.78%
	2 °C every 5 min	11	5.09%

was > or < 30ºC—55.09%, 12.04%, and 27.78% reheat at 1ºC/5 min, 1ºC/10 min, and 1ºC/3 min, respectively. The minority (5.09%) consider 2ºC/5 min as appropriate. (Table 16).

Hypothermia techniques during use of ECC depend on the complexity of the anatomy and physiopathology of surgical correction. Overall, valvular surgery, myocardial revascularization, and some non-complex congenital conditions are performed in normothermia or moderate hypothermia. However, deep hypothermia is spared for high-risk cardiovascular surgery like valvular procedure, aortic aneurysms, significant bleeding during trans- and postoperative periods, and technical accidents during the surgical act requiring application to guarantee the patient's myocardial and cerebral protection.

Hypothermia is defined as the condition in which body temperature is lowered below normal limits in a homoeothermic organism (capacity of human beings to maintain a temperature level of approximately 36.5ºC to 37 °C), which is known as autonomic thermoregulation of body and conducted by activating metabolic processes.[27,28,29]

To perform hypothermal perfusion, different temperature degrees are described. Temperature measurement can be nasopharyngeal, rectal, and tympanic, in the urinary bladder, esophageal and/or on the skin. The European Board of Cardiovascular Perfusion proposes the description of hypothermia degrees shown on figure 6.

In the survey, the question what is the temperature at which you usually manage PP except for cases of severe aortic conditions? 27.31%, 57.41%, and 14.81% perform ECC in conditions of normothermia (36.5ºC-37ºC), mild hypothermia (36ºC-32ºC), and moderate hypothermia (32ºC-28ºC). Finally, 0.46% said that they perform deep hypothermia at temperatures < 18ºC.

When asked what is the temperature at which you manage surgeries that require moderate hypothermia? 68.06% consider temperatures between 32ºC and 30°C; 25.46% that moderate hypothermia is achieved at 29ºC down to 27°C; 5.56% claim that moderate hypothermia can be established between 26ºC and 25°C and a minority of just 0.93% say that moderate hypothermia can be achieved between 25ºC and 23°C. This reveals that there is no consensus on the temperature cut-off values that define moderate hypothermia uniformly when performing perfusion in Latin America.

F- Site of ECC circuit to measure line pressure

According to the 2019 EACTS/EACTA/EBCP guidelines, control devices of arterial line pressure should be used (Class I Level C, table 1). However, these guidelines do not specify what part of the circuit is better for them to be used at.

Regarding the part of the ECC circuit used by perfusionists to measure arterial line pressure, we found that a significant percentage of them (47.72%) do so after the membrane, across different points of the line, from the membrane outlet port or at some point of the circuit arterial line while 22.41% measure it after the membrane, but specifically at its outlet port; 18.67% measure it directly in the AF (in this case the percentage represent a group of perfusionists that use external AF).

In conclusion, when locating perfusion management parameters regarding pressure, tissue perfusion, and temperature considered within the cut-off values, Latin American perfusionists often adapt to the indications in the clinical guidelines. The techniques that are the least common of all are those without recommendations or with weak scientific evidence. Also,

Hypothermia	Temperature in ºC
Mild	36-32
Moderate	32-28
Severe	28-18
Deep	< 18

the use of older technologies or limited resources trigger manual or App-based measurements of parameters like DO_2. Guidelines do not recommend specific sites to place arterial line pressure measurement devices, which is why there is great heterogeneity regarding placement. Regarding temperature, although recommendations are observed here, there are certain differences in terms of management of the ranges associated with the need for definitions of the field of perfusion per se like moderate hypothermia. That shows the need for perfusionists to produce theoretical material to achieve greater consensus in clinical practice and greater scientific evidence to make this profession move forward.

5.SAFETY

A- Safety devices

As indicated by the 2019 EACTS/EACTA/EBCP guidelines, monitoring the performance parameters of ECC is the pillar of patient care for perfusionists. (Class I Level C).

By conducting this survey, we found that 11.57% of respondents do not use or have any safety devices. This tells us that taking for granted the presence or use of different devices during ECC can be a big mistake that is often made. Also, although the 2019 EACTS/EACTA/EBCP guidelines tag it as "obvious or common sense" the presence of basic devices to monitor blood pressure, blood gas tests, flow monitors, among others, are not always available due to lack of knowledge or resources.

We also found a representative figure of 42.59% of respondents who use all safety devices mentioned in the survey like bubble, pressure, flow, level, and temperature sensors. In addition, it was evident by the answers given that the sensors most frequently used by perfusionists are also the most widely available ones (pressure and temperature sensors with rates of 43.52% and 41.20% respectively).

B- Disassembly:

In a different safety context when Latin American perfusionists disassemble the ECC circuit after surgery, we found that 33.80% do so when the thorax is closed with steel/wire sutures while 31.48% do so when the patient's thorax and skin are closed and once the wound has been healed.

When analyzing these data, we compared them to the recommendations set forth in the 2019 EACTS/EACTA/EBCP guidelines identifying that most perfusionists who answered the survey (65.28%) agree with the recommendations, suggestive that after the patient has been weaned from from ECC, the circuit should remain functional until the his thorax has been closed (Class I Level C).

In conclusion, the identification of safety devices used by perfusionists revealed that most comply with the recommendations indicated in the guidelines. The percentage of those who don't use safety systems can be due to lack of resources. Still, we think that lack of information should be analyzed in future studies.

6. Concepts

A- Acute normovolemic hemodilution (ANH)

Regarding ANH, the survey asked whether this technique was routinely used; 71% of respondents said they use it in all their cases as opposed to 29%. Based on the 2021 STS/SCA/AmSECT/SABM guidelines, ANH is a method rarely used in cardiac surgery probably because it buys time to perform the technique or perhaps due to the perception of possible risks while being performed. Currently there are very few protocols on this.[5]

ANH is a technique used in the intraoperative period of cardiac surgery defined as patient's blood draw during the early stages of surgery with the simultaneous replacement of a crystalloid/colloid solution to maintain normovolemia. Technique is based on drawing 1 to 3 units of autologous blood through an arterial or venous pathway into collector blood bags and the simultaneous replacement of the circulating volume with colloids and crystalloids. If replacement solution is a crystalloid or a colloid it will be replaced in a 3:1 and 1:1 ratio, respectively. During ECC, HTC is kept at around 25% to 30% instead of the normal 45% to 50%. This technique improves rheology of formed elements that make it up, tissue microcirculation, and decreases inflammatory response. After it was introduced 3 decades ago, ANH is still not the standard of care. However, it has a place within blood preservation programs to increase red blood cell mass in patients during the preoperative period.[30]

The 2017 EACTS/EACTA guidelines introduce the concept of ANH as the procedure through which the patient donates blood right before surgery and it is replaced with the same amount of volume to keep normovolemia. This blood will be transfused back into the patient after ECC (Class IIb Level B).

Recently an update of the guidelines (2019) reclassified this recommendation as a Class IIa Level B recommendation (table 1) referring to ANH as a technique that should be performed prior to the ECC: "ECC is responsible for multiple negative effects of circulating blood and its components. ANH is a method that limits these effects in a portion of the patient's blood." This is a reasonable method that reduces bleeding and transfusions. (Class IIa Level A). The blood drawn with this technique should be stored and preserved in a bag with preservatives like citrate-phosphate-dextrose-adenine (CPDA-1) so it can later be reinfused during ECC, if necessary, or after the administration of protamine.[31]

Analyzing the results, it call our attention that 71% of respondents perform this technique routinely when it is an uncommon technique that requires the patient to have certain conditions like adequate blood pressure, optical HTC values, lack of severe aortic regurgitation, and coronary artery disease. By consensus, the authors believe that this can be due to misinterpretations made by respondents of the term "normovolemic hemodilution" as an interpretation of the term "moderate hemodilution" that, in routine clincal practice, adapts to ECC priming and consists of diluting blood up to hematocrit values of 20% to 25%. When HTC drops down to values around 10% it is referred to as extreme dilution.[32]

CONCLUSIONS

When studying what PP is like today in the adult cardiac surgery population in Spanish-speaking Latin American, several aspects associated with the lack of theoretical production regarding this field were revealed, starting with the concept that appears in the title of this study and the absence of the term PP replaced by Performance of Cardiopulmonary Bypass as it became apparent in the bibliographic search stage and construction of the theoretical framework. Reviews have confirmed that only a very small percentage of publications are supported by solid scientific evidence in our region.

This study revealed that the Andes region was the region where most answers came from while Colombia showed a whopping 20.37%. When determining the demographic characteristics of Latin American perfusionists, we saw that they join the public and private sectors equally. A very significant contribution of this study is that the personnel distribution rule and the number of certified perfusionists "n+1" per surgical center was not followed since most perfusionists work alone in the OR, which is not compliant to the recommendation indicated by the guidelines. Nevertheless, we were surprised that 46.7% follow this rule, which, we concluded, is a growing trend in Latin America.

Under 50% have technological resources and devices available like NIRS, cell saver, and line gas monitors. Although the guidelines widely recommend the use of these technological devices to improve the quality of performance of perfusion. On the other hand, over 50% of perfusionists have oxygenators with built-in arterial filters, hemoconcentrators, and anesthetic vaporizers available for use. We can also consider the lack of resources and limited and old technologies are also factors that impact the implementation of all recommendations set forth by the guideliness in this region. However, the overall trend is to respect them even with manual resources like tablets or perfusion Apps.

Techniques to perform perfusion are most widely used by Latin American perfusionists are double calibration of rollers (dynamic – static), arterial line pressure monitorization after the membrane, normoxemic strategies for perfusion between 34ºC and 37°C, a set of techniques to reduce hemodilution, Del Nido cardioplegia for myocardial protection and its administration through the roller. CUF is used mainly in specific cases to obtain a certain hematocrit cut-off value while MUF and Z-BUF are rarely used. Observation of safety reinforcement techniques like double checking arterial roller occlusiveness confirms the use old pumps or without the mandatory maintenance service or lack of other safety measures, which should be studied in the future trials as this is beyond the scope of this study.

Regarding the management of parameters to perform perfusion, the trend observed was arterial line pressure between 100 and 200 mmHg, MAP between 60 and 80 mmhg, manual and intermittent DO_2 measurement, and transfusion to maintain HTC levels between 20% and 24%. A total of 97.22% of perfusionists keep temperature gradients between nasopharyngeal temperature and heat exchanger 5ºC-10°C during the reheating phase, with a preferred time/temperature ratio of 1°C every 5 min. However, there is no clear evidence in the guidelines regarding this practice. Our study also showed no consensus regarding the temperature values that define uniformly the concept of moderate hypothermia when performing perfusion in Latin America.

Most perfusionists comply with the safety protocols recommended since 42.59% have all the safety devices where those associated with pressure and temperature stand out as the most commonly used ones. In spite of this, 11.59% do not have any safety devices yet, which is a potential risk for accidents to happen. Another safe practice based on the recommendation set forth by the guidelines is that perfusionists often disassemble the circuit once the patient's thorax has been closed.

The study also revealed that terminology such as NHD, moderate hypothermia, and others represent linguistic variability or are absent from the guidelines on performance of cardiopulmonary bypass. Therefore, it is necessary to standardize what we understand colloquially with what is expressed in evidence-based academic documents as part of the evolution of our profession towards clinical practice and more certified perfusionists regarding research and production of scientific evidence. We believe that stabilizing the terminological variables in the field of perfusion will be a challenge for perfusionists all over world in the years to come since the terms used today come from the field of cardiac surgery or anesthesiology, but very few—if any—come from the field of perfusion.

On the other hand, we saw that many Spanish-speaking Latin-American perfusionists comply with the recommendations set forh by the guidelines and follow the current PP trends. Those who don't is because such recommendation is not there. It is no strange that these conceptual absences or silences fall within the realm of perfusion only, which reinforces our conclusion. We often associate these divergences with a lack of consensus when what we're talking about here is bibliographic absence.

In conclusion, this study revealed that Latin American perfusionists' knowledge, experience, and clinical observations help them make decisions consistent with today's scientific evidence available from international guidelines on PP. Also, that technique implementation shows a growing trend toward unifying criteria with the resources available in each region, which will become more stable as scientific research in this field grows even further.

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LIMITATIONS

The limitations we came across while conducting this study were open questions and confusion among readers regarding option selection to questions, extremely large or poorly defined ranges due to not being conceptualized in international guidelines on the management of PP or coming from other fields of study. Also, confusion in the conceptualization of some terms such as ANH and honesty while answering the questions: the survey referred to current performance of perfusion. However, it can be interpreted as practice assessment and having been conducted digitally, but we are not sure respondents took this into account.

1. Kaplan JA, Reich DL, Lake CL, Konstadt SN. Kaplan's Cardiac Anesthesia. 5taed. Philadelphia: Saunders Elsevier; 2006.

2. Mata MT, Pomar JL. Fisiopatología y Técnicas De Circulación Extracorpórea. 2da ed. Madrid: Ergon; 2012.

3. Hessel EA, Groom RC. Guidelines for Conduct of Cardiopulmonary Bypass. J Cardiothorac Vasc Anesth [Internet]. 2021 Jan 1 [cited 2022

Mar 11];35(1):1–17. Available from: http://www.jcvaonline.com/article/ S1053077020304171/fulltext

4. AmSECT: Standards and Guidelines for Perfusion Practice [Internet].2017 [cited 2022 Mar 28]. Available from: https://www.amsect.org/p/cm/ld/fid=1617

5. Tibi P, McClure RS, Huang J, Baker RA, Fitzgerald D, Mazer CD, et al.STS/SCA/AmSECT/SABM Update to the Clinical Practice Guidelines on Patient Blood Management. J Cardiothorac Vasc Anesth [Internet]. 2021 Sep 1 [cited 2022 Mar 23];35(9):2569–91. Available from: http://www.ncbi.nlm.nih.gov/pubmed/34217578

6. Curle I, Gibson F, Hyde J, Shipolini A, Smith D, Van Besouw JP, et al.Recommendations for Standards of Monitoring and Safety during Cardiopulmonary Bypass (CPB). Society of Clinical Perfusion Scientists of Great Britain & Ireland/ Association for Cardiothoracic Anaesthesia and Critical Care/ Society for Cardiothoracic Surgery in Great Britain

& Ireland. 2017 [cited 2022 Apr 12]; Available from: https://www.actacc.org/sites/default/files/2019-06/Standards-of-Monitoring-duringCPB-168235-08-08-2017.pdf

7. Ottens J, Tuble SC, Sanderson AJ, Knight JL, Baker RA. Improving Cardiopulmonary Bypass: Does Continuous Blood Gas Monitoring Have a Role to Play? J Extra Corpor Technol [Internet]. 2010 Sep [cited 2022 Apr 12];42(3):191. Available from: /pmc/articles/PMC4679958/

8. Bevan PJW. Should Cerebral Near-infrared Spectroscopy be Standard of Care in Adult Cardiac Surgery? Hear Lung Circ [Internet]. 2015 Jun 1 [cited 2022 Mar 28];24(6):544–50. Available from: http:/www. heartlungcirc.org/article/S1443950615000499/fulltet

9. Stanzel RDP, Henderson M. Clinical evaluation of contemporaryoxygenators. Perfus (United Kingdom) [Internet]. 2016 Jan 1 [cited 2022 Mar 28];31(1):15–25. Available from: https://journals.sagepub.com/doi/10.1177/0267659115604709?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed

10. Zorrilla-Vaca A, Núñez-Patiño RA, Torres V, Salazar-Gomez Y. The Impact of Volatile Anesthetic Choice on Postoperative Outcomes of Cardiac Surgery: A Meta-Analysis. Biomed Res Int. 2017 [cited 2022 Mar 8]; 2017(7073301):. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5603325/

11. Protsyk V, Rasmussen BS, Guarracino F, Erb J, Turton E, Ender J. Fluid Management in Cardiac Surgery: Results of a Survey in European Cardiac Anesthesia Departments. J Cardiothorac Vasc Anesth [Internet]. 2017 Oct 1 [cited 2022 Mar 28];31(5):1624–9. Available from: http://www.jcvaonline.com/article/S1053077017304068/fulltext

12. Alarcón BV, Nicolás MG. Protocolo de seguridad en el circuito de CEC. Rev Española de Perfusión [Internet]. 2015 [cited 2022 Mar 28]; 59 (2):31-35. Available from: https://www.aep.es/revista-articulo/48/59_5.pdf

13. Bae J, Kim J, Lee S, Ju JW, Cho YJ, Kim TK, et al. Association Between Intraoperative Hyperoxia and Acute Kidney Injury After Cardiac Surgery: A Retrospective Observational Study. J Cardiothorac Vasc Anesth [Internet]. 2021 Aug 1 [cited 2022 Mar 25];35(8):2405–14. Available from: http://www.jcvaonline.com/article/S1053077020312891/fulltext

14. Topcu AC, Bolukcu A, Ozeren K, Kavasoglu T, Kayacioglu I. Normoxic management of cardiopulmonary bypass reduces myocardial oxidative stress in adult patients undergoing coronary artery bypass graft surgery. Perfus (United Kingdom) [Internet]. 2021 Apr 1 [cited 2022 Mar 25];36(3):261–8. Available from: https://journals.sagepub.com/doi/10.1177/0267659120946733?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed

15. Roberts SM, Cios TJ. Con: Hyperoxia Should Not Be Used Routinely in the Management of Cardiopulmonary Bypass. J Cardiothorac Vasc Anesth [Internet]. 2019 Jul 1 [cited 2022 Mar 25];33(7):2075–8. Available from: http://www.jcvaonline.com/article/S1053077019301764/fulltext

16. Pagano D, Milojevic M, Meesters MI, Benedetto U, Bolliger D, Heymann Cvon, et al. 2017 EACTS/EACTA Guidelines on patient blood management

for adult cardiac surgery. Eur J Cardio-Thoracic Surg [Internet]. 2018 Jan1 [cited 2022 Mar 23];53(1):79–111. Available from: https://academic.oup.com/ejcts/article/53/1/79/4316171

17. Manning MW, Li YJ, Linder D, Haney JC, Wu YH, Podgoreanu M V., et al. Conventional Ultrafiltration During Elective Cardiac Surgery and Postoperative Acute Kidney Injury. J Cardiothorac Vasc Anesth [Internet]. 2021 May 1 [cited 2022 Mar 25];35(5):1310–8. Available from: http://www.jcvaonline.com/article/S1053077020312714/fulltext

18. Santos Fonseca PL, Pereira A, Franco P, Figueira I, Furtado D, Cláudio V, et al. Estrategias de ultrafiltración en CEC y su impacto en la morbilidad postoperatoria. Rev AEP[Internet]. 2017 Oct [cited 2022 Mar 23];63(2):37–48. Available from: https://www.aep.es/revistaarticulo/20/63_5.pdf

19. Puis L, Milojevic M, Boer C, De Somer FMJJ, Gudbjartsson T, van den Goor J, et al. 2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery. Interact Cardiovasc Thorac Surg [Internet]. 2020 Feb 1 [cited 2021 Sep 2];30(2):161–202. Available from: https://academic.oup.com/icvts/article/30/2/161/5579824

20. Journois D, Israel-Biet D, Pouard P, Rolland B, Silvester W, Vouhé P, et al. High-volume, Zero-balanced Hemofiltration to Reduce Delayed Inflammatory Response to Cardiopulmonary Bypass in Children. Anesthesiology [Internet]. 1996 Nov 1 [cited 2022 Apr 12];85(5):965–76. Available from: https://pubs.asahq.org/anesthesiology/ article/85/5/965/35873/High-volume-Zero-balanced-Hemofiltration-toReduce

21. Wang S, Palanzo D, Ündar A. Current ultrafiltration techniques before, during and after pediatric cardiopulmonary bypass procedures. Perfus (United Kingdom) [Internet]. 2012 Sep 1 [cited 2022 Apr 12];27(5):438–46. Available from: https://journals.sagepub.com/doi/10.1177/0267659112450061?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed

22. Ali JM, Miles LF, Abu-Omar Y, Galhardo C, Falter F. Global Cardioplegia Practices: Results from the Global Cardiopulmonary Bypass Survey. J Extra Corpor Technol [Internet]. 2018 [cited 2022 Mar 25];50(2):83. Available from: /pmc/articles/PMC6002645/

23. Barbosa FM, Moyano C, Colichelli DA, Otero AE, Castro F, Morelli D, et al. Primera experiencia argentina de cardioplegía de Del Nido en adultos. Trabajo comparativo con cardioplegía de Buckberg. Rev Argent Cardiol [Internet]. 2019 Oct [cited 2022 Mar 5];87(5):378–82. Available from: http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1850-37482019000500378&lng=es&nrm=iso&tlng=es

24. Ranucci M, Romitti F, Isgrò G, Cotza M, Brozzi S, Boncilli A, et al. Oxygen Delivery During Cardiopulmonary Bypass and Acute Renal Failure After Coronary Operations. Ann Thorac Surg [Internet]. 2005 Dec 1 [cited 2022 Apr 12];80(6):2213–20. Available from: http://www. annalsthoracicsurgery.org/article/S0003497505009653/fulltext

25. Engelman R, Baker RA, Likosky DS, Grigore A, Dickinson TA, Shore-Lesserson L, et al. The Society of Thoracic Surgeons, The Society of Cardiovascular Anesthesiologists, and The American Society of ExtraCorporeal Technology: Clinical Practice Guidelines for Cardiopulmonary Bypass—Temperature Management During Cardiopulmonary Bypass. Ann Thorac Surg. 2015 Aug 1;100(2):748–57.

26. Barry AE, Chaney MA, London MJ. Anesthetic Management during Cardiopulmonary Bypass: A Systematic Review. Anesth Analg [Internet]. 2015 Apr 25 [cited 2022 Mar 28];120(4):749–69. Available from: https:// journals.lww.com/anesthesia-analgesia/Fulltext/2015/04000/Anesthetic_ Management_During_Cardiopulmonary.13.aspx

27. Rudolf J., Tschaut; Dreher, Molly; Walczak, Ashley; Rosenthal. Extracorporeal Circulation in Theory and Practice. Alemania: Dustri;2020.

28. Echevarría JL, Echevarría JRL. Técnicas de Hipotermia aplicadas en la cirugía cardiovascular con circulación extracorpórea. Rev Cuba Cardiol y Cirugía Cardiovasc [Internet]. 2016 Jul 30 [cited 2022 Apr 12];22(2):102–7. Available from: http://www.revcardiologia.sld.cu/index.php/revcardiologia/article/view/642

29. Ho KM, Tan JA. Benefits and Risks of Maintaining Normothermia during Cardiopulmonary Bypass in Adult Cardiac Surgery: A Systematic Review. Cardiovasc Ther [Internet]. 2011 Aug 1 [cited 2022 Apr 12];29(4):260–79. Available from: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1755-5922.2009.00114.x

30. Chamorro Gálvez YA, Restrepo Restrepo EL. Tendencia en los niveles de hemoglobina y hematocrito y requerimiento transfusional de los pacientes en el intraoperatorio de cirugía cardiaca bajo circulación extracorpórea con hemodilución normovolémica aguda en la Clínica del Rosario. Medellín 2013-2017. REDICES: Repositorio Digital Institucional [Internet]. 2018 [cited 2022 Mar 28]. Available from: https://repository.es.edu.co/handle/10946/3843

31. Kay P, Munsch CM. Techniques in Extracorporeal Circulation. 4 Ed. Londres: Taylor & Francis Group; 2012.

32. Olivares Valbuena UE. Hemodilucion Normovolemica en Cirugia Cardiaca Centro Médico ISSEMYM-Tesis. Universidad Autónoma del Estado de México. 2013. Available from: https://docplayer.es/80357065-Hemodilucion-normovolemica-en-cirugia-cardiaca-centro-medicoissemym-tesis.htm

APPENDIX:

Regarding the survey, the questions that were asked to conduct our study were:

1. The center you work at.

2. The number of perfusionists/surgical case at your center.

3. To achieve optimal occlusiveness of arterial roller, do you use calibration?

4. Say which of the following safety systems do you use during ECC? What arterial line perfusion pressure ranges do you use during ECC?

5. What mean arterial pressure range do you use during ECC?

6. At what circuit site do you measure line pressure?

7. Are oxygenators with built-in arterial filters into the membrane used at your center?

8. If membrane filters available to you too, do you use line arterial filters built into your extracorporeal circuit?

9. What range of oxygen arterial partial pressure do you have as your target during normothermia (34ºC to 37 ºC)?

10. Do you routinely use hemoconcentrators in ECC?

11. When do you use the ultrafiltration technique?

12. Do you use MUF in adult surgery?

13. When you perform CUF, what's your target regarding the volume that should be ultrafiltrated?

14. Do you routinely use Z-BUF in your surgeries?

15. What is your target when using the Z-BUF technique?

16. What hematocrit limit do you use for transfusion during ECC?

17. Do you perform normovolemic Hemodilution in your practice?

18. To prime your circuit you use: plasmalyte, normosol, multylitos R, Ringer Lactate, Ringer without lactate, 0.9% sodium chloride.

19. What technique do you use to reduce hemodilution?

20. Do you use blood cell saver or autotransfusion (CELL-SAVER) in your routine clinical practice?

21. Do you use gas line monitors in all your surgeries?

22. Do you estimate/measure oxygen delivery (DO_2) during extracorporeal circulation?

23. Do you use a vaporizer (anesthetic gases) interspersed with gas system administered to your oxygenator?

24 .During cardiac surgery do you monitor brain oximetry (NIRS)?

25. In your myocardial protection protocol, what cardioplegia do you use most often?

26. You perform cardioplegia infusion through rollers, infusion pump, infuser/pressurizers, gravity, manual (pressure by hand)

27. What temperature is often used to perform perfusion? Except for cases of severe aortic valve disease.

28. What temperature do you often use in surgeries that require deep hypothermia?

29. In the reheating phase, what rate (temp/time) is used at your center?

30.What temperature gradient between the heat exchanger and the patient's temperature (nasopharyngeal, rectal or tympanic) do you use during the reheating phase?

31.At the end of the surgery when do you disassemble the extracorporeal circuit?