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Perfusion Quality Score (P.Q.S), in Material Selection before of Cardiopulmonary Bypass

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Abstract There is a large number of systems and technique patterns that deal with the extracorporeal circulation technique to reduce the biologic impact of the system. Nevertheless, there is no such thing as an evaluation quality score of the pathophysiology of the CPB cardiopulmonary bypass, as our world consists of a wide range of variants of the extracorporeal circulation, which are not provided with a quality yardstick.This work seeks to create a quality score, aiming at measuring the extra-corporeal circulation technique and its impact, linked to an inspection of the scientific literature in particular, to achieve goal directed perfusion.The studies concerning the optimisation of extracorporeal circulation techniques have been analysed to reduce the pathophysiological consequences of conventional systems. Also analysed were studies on patients with low- and high-risk candidates, candidates for cardiac surgery, who used special extracorporeal circulation techniques aimed at containing the pathophysiological response, cohort studies, prospective studies, retrospective studies and meta-analysis. This paper is meant to create a quality score of the components of the cardiopulmonary bypass, stimulating the qualitative selection of the materials of the techniques and methods.

Keywords: *cardiopulmonary bypass, quality, materials selection, goal directed perfusion*

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1. Introduction

This work aims to create a quality evaluation scale based on the Items of preparation and management of CPB, encouraging the team to limit the invasiveness in terms of SIRS, Systemic inflammatory response syndrome, Fluid-dynamic management, Metabolic management, and Myocardial protection management during the extracorporeal circulation. The discipline of Pathophysiology analyses the changes in the organic functions during any pathologic condition (Figure 1); the cardiocirculatory pathophysiology and cardiovascular perfusion study the issues and changes of the organic functions pertinent to the extracorporeal circulation methodology for individuating the cause of alteration of the issue and not just its final consequences. The biologic invasiveness, which is a subject of study of pathophysiology, is a condition, part of a therapeutic process that involves the temporary alteration of the organic homeostasis determined by process, mechanisms, and surgery-medical techniques that are external to the human body for fixing functional anatomic diseases of organs, tissues and apparatuses. A series of research have been carried out from 1980 on high-biocompatible devices and extracorporeal circulation methodologies to contain the pathophysiology of the cardiopulmonary bypass (CPB). However, all the samples have always been restrained with big procedure boundaries and complexity to the extent of not having strong statistically significant evidence, although empirically, the main biological invasiveness ITEMS are being restrained within the extracorporeal technique. A quality evaluation score might yet simplify and render more immediate a quantification of preparation and management based on a procedural approach. The authors seeks to analyse the literature in every pathophysiologic aspect to individuate elements of optimisation that can contain the hurdles of the cardiopulmonary bypass (CPB). This work seeks to schematise and individuate an indicator of the quality of the extracorporeal circulation within the flow charts of the process, penalising the variables that involve an alteration of the hemodilution, hemolisis and fluid dynamic alteration namely the pathophysiological response of the human body during CPB, and enhancing the accurate methodologies that, in the literature, reduce the biological impact of the extracorporeal circulation. The variables were given scores according to the scientific evidence and the relationship between the patient’s variable and outcome. Procedure algorithms were associated.

ECC Models	Value Perfusion quality	Biological impact of Cpb
Conventional ECC	7.5	High - Intermediate
Compact ECC	14.3	Intermediate- Low
Closed ECC	16.6	Intermediate- Low
M.i.E.C.C	20.6	Low - Very Low

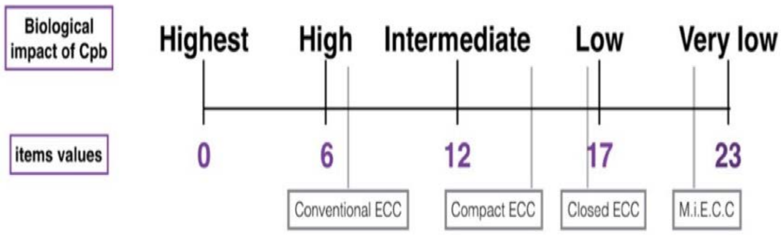

Figure 1. Perfusion quality score, quantification of quality

2. Models and Techniques of Extracorporeal Circulation

2.1. Conventional Extracorporeal Circulation (E.C.C.)

The conventional extracorporeal circulation (E.C.C.) is appreciated for its versatility and safety in the monitoring systems (pressures, alert statuses, bubble detector subjugation). It nevertheless contains in its methodology each of the elements of SIRS, including the generation and transport of GME gaseous micro-emboli [1-48]. All over the world, it avails itself of an essentially horizontal or vertical managing console placed to the right or left of the patient along the body, from the patient's suprasternal to their groin. The polyvinylchloride PVC circuits have principally a venous and arteriosus line of variable diameters (1/4-3/8-1/2 inches); the aspirator uses a sub pump in either PVC or silicon of various diameters (1/4-3/8-1/2 inches), which may not be treated or may be treated by passive coating (phosphorylcholine) or active coating (links of the circuit to heparin). The venous reservoir is used with or without the inclusion of vacuum-assisted venous drainage (VAVD), a roller pump or centrifugal type of impeller of various models (single-disc) and an oxygenator module selected according to the patient's body surface area (BSA), presence or absence of an arteriosus filter, integrated or external to the oxygenator module. The aspirators used are principally roller warheads, which are either directly injected into the venous reservoir or indirectly into specific cardiotomes to select the active blood, filter it with lipid-lowering and leucocyte filters, or treat it with cell-saver. The circuit for the myocardial protection, which is structured according to the technique and the protocol, involves a broad use of either crystalloid solutions (Custodiol, Del Nido, Buckeberg, Saint Thomas and more) or haematic with reduced levels of crystalloids (Calafiore, Saint Thomas and more).

2.2. Extracorporeal Circulation, Closed System

The closed system extracorporeal circulation aims to limit and minimise the air-blood contact [3] Item of the main SIRS, eliminating depth filters in the reservoir, making use of a volumetric collapsible bag as a venous reservoir, which takes advantage of the gravitational drainage even though many use a centrifugal kinetic pump kinetic-assisted venous drainage in sequence to the venous line to improve the venous return, and reducing the calibre and length of the circuit. The management of the intracavitary suction is gravitational in series to the venous return and exploits the venturi effect reducing the generation and transport of GME gaseous micro-emboli [4], this is often a limit to the management of the valvular heart surgery. The extra-cavitary aspirator is managed into a container equipped with a filter separated from the volumetric bag, with a possibility of processing it or injecting it into circulation. Nevertheless, the restriction of this technique is the high contact surface, which is associated, in hypovolemic patients, with an excessive haemodilution, both ITEMS of SIRS, with a procedural limitation of the haematic intracavitary evacuation on the valvular surgery in patients who have developed collateral pulmonary circles. The features of the safety systems and the oxygenator module in the coating and cardioplegia circuit are specular to the ECC conventional model.

2.3. Compact Extra-corporeal Circulation c E.C.C.

It constitutes an evolution in selecting and maximising the materials in the extracorporeal circulation, which was developed in the first decade of the 21st century in Belgium (U. Borrelli), and particularly in the coating biocompatibility, reduction of the contact surface and haemodilution. It is a circulation that uses the venous reservoir and the oxygenator module at the patient's shoulder height; the venous drainage is ensured from 3/8 inches in the line through a low negative pressure (-25 mmHg) with VAVD vacuum-assisted venous drainage; the roller modules are very close to the reservoir, just as the roller pump module is to the oxygenator, in order to minimise the length of the tube, reduce the filling volumes, eased by RAP retro priming autologous manoeuvres. This modular console type evokes next-generation console models in its design. This circulation significantly reduces two of the SIRS items, haemodilution and contact surface, improving the metabolic management set-up during the direction of CPB cardiopulmonary bypass. Nevertheless, there is still air-blood contact, which is typical of the conventional ECC, in addition to the use of a single reservoir for the intra/extra cavitary aspirators through the use of roller pumps, which shall lead to a stress from cut and breakup of the red cell [48], as well as a generation of GME [4]. It is an extremely versatile technique that may be applied to all kinds of heart surgery. Evidence from studies shows significant improvement of the patient's outcome in terms of intensive care stay, reduction of the mechanic ventilation, reduction in bleedings of the lactate dehydrogenase levels, and reduction in administering of blood products [5].

2.4. Minimal Invasive extra-corporeal Circulation (M.i.E.C.C)

It is an extracorporeal circulation technique with a MiECTIS (Minimal invasive Extra-Corporeal Technologies international Society) position paper based on the potential advantages in terms of biological invasiveness reduction [6-51]. Type 3 circuit, the most flexible in terms of volume management, consists of a venous line and of intracavitary aspirators linked to a venous bubble trap, a centrifugal pump and an oxygenator, with a line dedicated to cardioplegia and an arteriosus line. The volume is managed actively inside a post-oxygenator volumetric bag and then instilled into the venous line. This methodology works on each of the items of SIRS, reduces the contact surface, eliminates the air-blood contact, reduces haemodilution, and do not use roller pumps for the aspirators. The intracavitary blood is strictly selected and processed [7]; this implies improved metabolic management and a more physiologic perfusion quality during (CPB) cardiopulmonary bypass [8]. MiECC reduces the generation and transport of gaseous micro-emboli (GME) relating to conventional extracorporeal circulation (ECC), especially in the cerebrovascular system [9]. This involves considerable benefits in terms of the patient's outcome and cognitive dysfunctions [9] of acute kidney damage (AKI), atrial fibrillation (FA) incidence, reduction of bleeding, mechanic ventilation, ICU stay, and an improvement of the post-surgical life quality after coronary aortic bypass [10], especially in patients at high-risk [11], who have been described in studies carried out especially on coronary surgery and aortic valvular surgery. However, it remains inflexible in other heart surgery kinds due to air and bleeding management.

3. Perfusion Quality Score, Biologic Impact of the CPB, Review

3.1. Explanation

We tried to express a quality score of the extra-corporeal circulation technique relating to the scientific evidence, improvement of every single component, integration of the latter, and the technique that comes from the materials selection, numerically proving that the final sum of the variables chosen is a quality expression for the integration of every single component, namely an indirect score benchmark according to the SIRS reduction literature, and of the improvement in the intraoperative management and patient's outcome (Table 2).

3.2. Preparation of Cardiopulmonary by-pass, Qualitative Selection of Components

The main items individuated from the review of the literature (Table 1), which impacts the S.I.R.S., are the coagulation disturbs, the intra-operatory metabolic management (Goal-directed Perfusion), acute kidney insufficiency incidence (A.K.I.), and post-operatory cognitive disturbs (P.O.C.D.). The use of blood products, drug, and ultrafilters is attributable to:

Table 1. Quality items of Cardiopulmonary bypass (CPB)

Quality Items of CPB	Coating	Surface and Volume	Fluid Dynamics 1	Fluid Dynamics 2	Myocardial protection
	circuit coating	surface contact	aspirators	venous reservoir fluid dynamics	circuit for Blood Cardioplegia
	oxygenator	retrograde Autologus Priming	venous reservoir and aspirators	arterial filters	priming Circuit Cardioplegia
	venous reservoir coating	hemodilution static priming	master pump	venous reservoirs and aspirators	cristalloid solution Cardioplegia

Table 2. Calculation of values, perfusion quality score

ITEMS					value
circuit coating	no 0	biopassive 1	active 1.5		
surface contact	>2 m2 0	2 m2 0.5	<2m2 1.5		
aspirator	roller 0	vacuum 1.0	no roller 2.0		
master	roller 0.5	centrifugal 0.8			
hemodilution static priming	>1000 0	500-1000 1	<500 1.5		
retrograde autologus priming	no 0	<300 ml 0.5	300-500 ml 0.8	>500 ml 1.2	
venous reservoir fluid dynamics	splashing 0	anti splashing 1			
venous reservoir coating	no 0	biopassive 1	active 1.5		
venous reservoir and aspirators	with extra-cavitary aspirators 0	with outextra-cavitary aspirators 1.5	soft shell reservoir 3.0	no reservoir 5.0	
oxygenator coating	no 0	biopassive 0.5	bioactive 1.0		
arterial filter	no 0	external 0.5	integrated 1.0		
circuit blood cardioplegia	open 0	closed 2.0			
priming circuit cardioplegia	>300 0	300 0.5	<300 1.5		
cristalloide solution cardioplegia	infused 0	not infused 1.5	no cristalloide 2		
Final Score					

3.2.1. Circuit Coating

The first item is the Circuit Coating. In the literature, the neuter proteins used for the internal surface coating increase the biocompatibility of the circuit with blood, reducing the activation of coagulation and inflammation [1-16]. The score 0 was attributed to the absence of coating treatment, score 1 to the biopassive coating (phosphorylcholine) [17-47], and score 1.5 to the bioactive coating containing heparin molecules linked to the circuit. The attributed scores are quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.2. Contact Surface

The second item is the length of the contact surface. In the literature, any increase in the surface is directly related to the exposure period of the blood to the artificial surface [5]; the reduction in the surface implies a reduction in the quantity of liquids that are required for the filling. The score 0 was attributed to a surface >2 m^2, the score 0.5 to a surface=2 m^2, the score 1.5 to a surface < 2.0. The attributed scores are quality measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.3. Aspirators

The third item is the type of suction technique for the aspirators. The use of the roller pumps represents a high traumatisation level for the corpuscular blood components [49], according to the literature, for the haemolysis and the creation of GME [2]. Score 0 was attributed to the use of the roller pump, score 1 for the use of Vacuum, score 2 for the suction with venturi effect in the venous draining line. The scores attributed are quality measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.4. Pumps

The fourth item is correlated to the main pump type (Master). There is no statistically significant superiority evidence in terms of reduction of the inflammatory response or oxidative stress between roller and centrifuge [15], nonetheless the centrifuge is described as a pump, reducing the haemolysis in the long extracorporeal circulations [14] and decreasing the GME transport and the endothelial traumatization of the arteriosus vessels [2]. The score 0.5 was attributed to the use of a roller pump as the main pump, and the score 0.8 to the use of a centrifugal pump as the main pump. The attributed scores are the quality measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.5. Haemodilution

The fifth item is the static priming haemodilution, namely the quantity of liquids required to fill a circuit without a stream. This is an indirect expression of the contact surface, of the reduction in the corpuscular average volume, of the reduction in the haemoglobin [18], hence of the transport of oxygen [19], of the alteration of the coagulation planning, and of the extravasation into the third place of the secondary SIRS liquid. The score 0 was attributed to prime scores >1000ml, the score 1 to prime scores ranging from 500 to 1000ml, the score 1.5 to prime scores <500ml. The attributed scores are quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.6. Retrograde Autologous Priming

The sixth item consists in a removal technique of the filling liquid (priming) within the extra-corporeal circulation, which is essential to eliminate micro- and macro-bubbles during the preparation phase. This is carried out by substituting the liquid with the blood taken up from the arteriosus and venous cannulation sites once the heart-lungs machine has been linked before the installation of the cardiopulmonary bypass. This technique has enabled the reduction of the issues of haemodilution [20], haemoglobin content and transport of oxygen during CPB, use of blood products during and after surgery, viscosity associated with hypotension, plasmatic electrolytes, and interstitial extravasation secondary to SIRS [21,22]. Score 0 was attributed to 0ml priming removal, score 0.5 to priming removal <300ml, score 0.8 to priming removal ranging from 300 to 500ml, and the score 1.2 to priming scores >500ml. The attributed scores are quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.7. Venous Reservoir Fluid Dynamics

The seventh item found in the literature deals with the selection of the venous reservoir model, particularly aiming at a project of reducing the splashing effect, which implies the creation of GME gaseous micro-emboli [2], for low venous return levels during cardiopulmonary bypass (CPB) conduction with or without the use of VAVD [23,24], the selection of the model, structure and design of the reservoir. If we are to get a higher quality impact, we must take these variables into account. Score 0 was attributed to the reservoir models that create elevated turbulence and creation of micro-emboli to low levels of venous return; score 1 was given to the reservoir models that create low turbulence and low creation of micro-emboli to a low level of venous return. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.8. Venous Reservoir Coating

The eighth item deals with reservoir treatment. According to the literature, using the bio-passive or bioactive coating reduces the activation of the inflammation and of the coagulation [1-16]. The score 0 was attributed to the absence of coating treatment, the score 0.5 to the bio-passive coating (phosphorylcholine) [17], the score 1.0 to the bioactive coating containing heparin molecules linked to the reservoir. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.9. Venous Reservoir and Aspirators

The ninth item deals with the management technique of the extra-cavitary aspiration; in the studies present in the literature, the blood that had been wasted during the surgery process in the mediastinum is a highly active one, rich with pro-inflammatory factors, lipids, mixed to surgery irrigation solution, trans celomatic liquids, and exposed to the air. Its selection and direct separation from the venous reservoir and the treatment with auto-trans have reduced, on a randomised controlled trial, the TNF factors to alpha tissue necrosis factors, and low reactive C protein (CRT) levels to the perioperative inflammation [25]. Just like in other trials, here we wanted to highlight the utility of the separation and of the treatment in appropriate anti-lipid and leucocyte filters, reducing the potential systemic embolism [5,26,27], which contributed to increase the incidence of POCD (post-operatory cognitive disorders) [2], and the potential leucocyte activation during CPB [28]. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.10. Oxygenator

The tenth item deals with the selection of the oxygenator module design. This one, besides its characteristics and the patient's surface, was chosen for its technical characteristics, structure and surface of the fibre, gas exchange thermic coefficients (O_2 CO_2 transfer) IT exchanger efficiency, fluid dynamics and barometric qualities [29,30,31]. The fibre used by all the construction houses for the oxygenator modules of the extracorporeal circulation is propylene, while the oxygenator module ECMO uses polymethylpentene. Polypropylene is a hydrophilic material; it thus needs a coating to become hydrophobic, in contact with the blood during its usage. There are two kinds of coating (treatment): passive and active. The passive coating is characterised by a coating of the oxygenator fibre with phosphocholine; the active coating is characterised by a coating of the oxygenator fibre with phosphocholine, with heparin ligaments to the surface. The score 0 was attributed to the absence of treatment, the score 1 to the biopassive coating (phosphocholine) [17], and the score 1.5 to the bioactive coating containing heparin molecules linked to the oxygenator module. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.11. Arterial Filter

The eleventh item is the arteriosus wire, a biomedical device that in the literature has proved the reduction of the macro-micro gaseous and solid embolic activities created and transported during CPB cardiopulmonary bypass not retained by the filters of the venous reservoir [32]. There are different filters, structured for the adult and kid extracorporeal circulation, each one having different fluid dynamic characteristics and design with a filtration screen membrane or in the absence of a micrometric screen membrane. The arteriosus filter may either be integrated with the model of the oxygenator module or be externally placed in the arteriosus line [33]. Nevertheless, not all the oxygenator modules provide for the integration of the arteriosus module; the differences in the literature, prevalently about the arteriosus filter, both integrated and external to the oxygenator module, are relative to the haemodilution and to the quantity of the filling volume of the circuit. A single blind prospective randomised study proved that the external filter causes a higher administering of concentrated erythrocytes and reduced erythrocytes, compared to the oxygenator module with integrated arteriosus filter [34-50]. The score 0 was attributed to the absence of utilisation of the arteriosus filter, the score 1 to the utilisation of the arteriosus filter external to the oxygenator module, and the score 1.5 to the utilisation of the arteriosus filter integrated to the oxygenator module. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility, as compared to the absence of processing.

3.2.12. Circuit for Blood Cardioplegia

The twelfth item is the haematic cardioplegia circuit. There are different methods for myocardial coating in the world, based on various formulas of intra- or extracellular protection, with haematic, crystalloid or mixed vectors, multidose, single-dose, at different temperatures and infusion volumes [35]. The utilisation, by cardioplegia infusion, of an open circuit increases the air-blood contact, contributing to a persistence of the pro-inflammatory phenomenon [3], as against a closed circuit where a reduction of the exposition of the air to the blood occurs. Score 0 was attributed to the open-air circuit and score 2 to the air-closed circuit. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.13. Priming Circuit for Cardioplegia

The thirteenth item deals with the filling volume of the cardioplegia circuit, indirect benchmark of the contact surface and of the haemodilution degree [1-19,22,36,37,38]. The score 0 was attributed to prime values >500ml, the score 0.5 to primes ranging around =500ml, and the score 1.5 to prime values >500ml. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility as compared to the absence of processing.

3.2.14. Crystalloid Solution Cardioplegia

The fourteenth item deals with the management of the infusions in the low-sodium or mixed Crystalloid Cardioplegias, which have a prevalence of different indexed volumes per kg, and different intra- and extracellular coating mechanisms (external to the membrane) [35]. However, these often involve an increase of the administering of liquids, followed by various techniques for the elimination, such as ultrafiltration. Nevertheless, the period of the technique process exposes the patients to an excessive haemodilution degree and electrolytic imbalance; for this reason, it has not been placed as a way to maximise the management [1-19,22,36,37,38]. The non-elimination and excessive recast of liquids contributes to increase the waste of blood products and the extravasation into the third space [21]. The score 0 was attributed to the crystalloid solution recast into circulation, the score 1.5 to the aspiration of the crystalloid solution contextual to the administering, and the score 2.0 to the absence of crystalloid solution. The attributed scores are the quality-measuring scales of an additional score that works on the component of extracorporeal circulation, which has proved, in the literature, an increase in biocompatibility, as compared to the absence of processing.

4. Goal-directed Perfusion and CPB Typologies

The benchmark of the main literature of management during the extracorporeal circulation is the detection of the known oxygen delivery DO2 ml/min/m2; it is a benchmark calculated from the equation [39];

DO2(mL⁄minute⁄m2) = 10 × pump flow (L⁄minute⁄m2) × arterial O2content (mL⁄100 mL);

Arterial O2 content (mL/100 mL) = Hb (mg/dL) × 1.34 × Hb saturation (%) + 0.003 × O2 tension (mmHg)

The benchmark resulted from several studies on the predictive factor of AKI at the first stage with high impact and is a score lower than 280 ml/min/m2 of DO2 (Marco Ranucci et al).

Different ways are practicable to achieve this benchmark during the management of the cardiopulmonary bypass. Within this work we believe that maximising the technique and selecting the materials will help to reduce any correcting factor towards the achievement of this target, which, in the literature, encourages co-morbidities of the extracorporeal circulation, S.I.R.S. (systemic inflammatory response syndrome), P.O.C.D. (Post-operative cognitive disorders), coagulation disorders, T.R.A.L.I (transfusion-related acute lung injury), A.K.I. (acute kidney injury) and distributive alteration of tissue perfusion [40,41,42,43].

To increase DO2 delivery O2/VCO2 (oxygen availability) during CPB, it is necessary to achieve such Hb gr/dl values, which will depend on the patient's characteristics, particularly on volemia, base haemoglobin, hydration and co-morbidity (renal, respiratory, haematopoiesis system diseases); from the type of extra-corporeal circulation technique, contact surface, filling volume of the circuit and liquid type, haemolysis, and retro-priming air-blood contact [44]. From the adjustments during Cardiopulmonary bypass: ultrafiltration, use of a diuretic or vasoconstrictors (Norepinephrine, Dopamine) [45], administering of concentrated red cells.

Besides being responsible for the transport oxygen and formation of bicarbonate ions, the Hb gr/dl score is an indirect expression of the blood viscosity (Figure 2). It thus contributes to maintaining the vascular resistance during CPB [40].

5. Perfusion Quality Score, Quantification of Quality and Examples

The score, which is the expression of the values chosen from the 14 items, is attributed to an evaluation scale for the involved biological invasiveness scores (Table 1):

-Extremely high-high (0-6)
-High-Intermediate (6-12)
-Intermediate-Low (12-17)
-Low-Extremely Low (17-23)

The biological invasiveness scores ranging from 0 to 23 are associated with haemodilution, contact surface and exposition of blood to the air, with adjustments to the goal-directed perfusion during CPB (filtration, administering of blood products) and with the pathophysiologic consequences previously described and highlighted in the literature.

A few CPB samples have been analysed on perfusion quality score (Figure 1)

- Conventional extracorporeal circulation technique with PQS score 7.5. High-Intermediate biological invasiveness
- Compact extracorporeal circulation technique with PQS score 14.3. Intermediate-Low biological invasiveness
- Closed extracorporeal circulation technique with PQS score 16.6 Intermediate-Low biological invasiveness
- MiECC extracorporeal circulation technique with PQS score 20.6 Low-Extremely low biological invasiveness

The PQS scores may be compared, in terms of technology and methodology, to the advantages relating to inflammation, administering of blood products, coagulation alteration and metabolic management described in the literature.

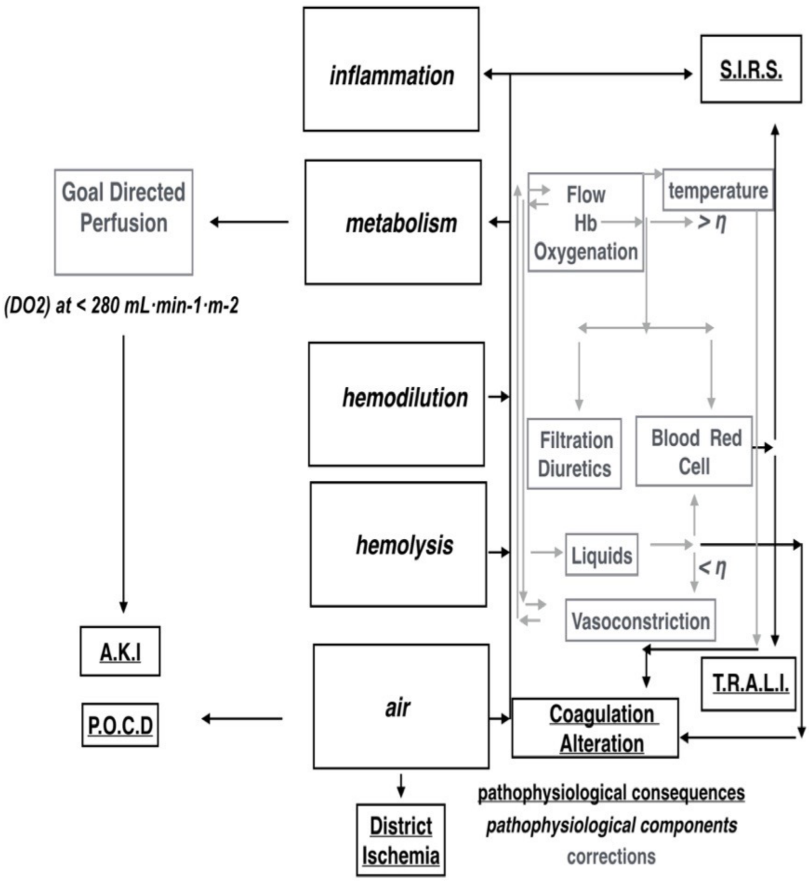

Figure 2. Algorithm, the pathophysiology of cardiopulmonary bypass, elements correlation and corrective actions

6. Discussion

In a few CPB models and techniques, which have been described in the literature, the maximisation of the assemblage and quality selection of some components of the cardiopulmonary bypass have determined an improvement or deterioration in the pathophysiologic impact. We wanted to test the perfusion quality score, a quantitative integration measurement unit meter. The models are as follows: the conventional extra-corporeal circulation, the compact extra-corporeal circulation, the closed extra-corporeal circulation and the M.i.E.C.C. (minimally invasive extra-corporeal circulation). Nonetheless, different centres using the heart-lung machine in heart surgery employ extra-corporeal circulations different in the technique and selection of their components [46]. However, to the current status, it is hard to state the belonging to a CPB macro-area, in terms of technical features. The use of a perfusion quality score structured based on the scientific evidence and of the analysis of the literature may be an all-embracing yardstick for the evaluation of all methodologies and techniques of work and further encouragement for the maximisation of the extracorporeal circulation circuits.

7. Conclusions

The perfusion quality score, which is a result of review from literature that converted the models described in the literature in quality terms into numbers and quantitative variables, can be exported and converted into clinical practice, in different cardiopulmonary bypass typologies and techniques, tested in future studies and linked to the ITEMS.

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Perfusion quality score

ITEMS					Value
circuit coating	no 0	biopassive 1	active 1.5		
surface contact	>2 m2 0	2 m2 0.5	<2 m2 1.5		
aspirators	roller 0	vacuum 1.0	no roller 2.0		
master	roller 0.5	centrifugal 0.8			
hemodilution static priming	>1000 0	500-1000 1	<500 1.5		
retrograde autologus priming	no 0	<300 ml 0.5	300 -500ml 0.8	>500 ml 1.2	
venous reservoir flui dynamic	splashing 0	anti splashing 1			
venous reservoir coating	no 0	biopassive 1	active 1.5		
venous reservoir and aspirators	with extra-cavitary aspirators 0	with outextra-cavitary aspirators 1.5	soft shell reservoir 3.0	no reservoir 5.0	
oxygenator coating	no 0	biopassive 0.5	bioactive 1.0		
arterial filter	no 0	external 0.5	integrated 1.0		
circuit blood cardioplegia	open 0	closed 2.0			
priming circuit cardioplegia	> 300 0	300 0.5	<300 1.5		
cristalloide solution cardioplegia	infused 0	not infused 1.5	no cristalloide 2		
Final score					