



CONSENSUS STATEMENT

Summary of the consensus document: “Clinical practice guide for the management of low cardiac output syndrome in the postoperative period of heart surgery”^{☆,☆☆}

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Received 3 November 2011; accepted 7 January 2012

Available online 4 July 2012

KEYWORDS

Low cardiac output syndrome;
Ventricular failure;
Cardiac surgery;
GRADE methodology

Abstract Low cardiac output syndrome (LCOS) is a potential complication in cardiac surgery patients and is associated with increased morbidity and mortality. This guide provides recommendations for the management of these patients, immediately after surgery and following admission to the Intensive Care Unit (ICU). The recommendations are grouped into different sections, addressing from the most basic concepts such as definition of the disorder to the different sections of basic and advanced monitoring, and culminating with the complex management of this syndrome. We propose an algorithm for initial management, as well as two others for ventricular failure (predominantly left or right). Most of the recommendations are based on expert consensus, due to the lack of randomized trials of adequate design and sample size in patients of this kind. The quality of evidence and strength of the recommendations were based on the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology. The guide is presented as a list of recommendations (with the level of evidence for each recommendation) for each question on the selected topic. For each question, justification of the recommendations is then provided.

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[☆] Please cite this article as: Pérez Vela E, et al. Resumen del documento de consenso «Guías de práctica clínica para el manejo del síndrome de bajo gasto cardíaco en el postoperatorio de cirugía cardíaca». *Med Intensiva*. 2012;36:277–87.

^{☆☆} The full version of this consensus document is published in *Medicina Intensiva* 2012. doi:10.1016/j.medin.2012.02.007.

Available from: www.elsevier.es/medicina-intensiva.

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PALABRAS CLAVE

Síndrome de bajo gasto cardiaco;
Fracaso ventricular;
Cirugía cardiaca;
Metodología GRADE

Resumen del documento de consenso «Guías de práctica clínica para el manejo del síndrome de bajo gasto cardiaco en el postoperatorio de cirugía cardiaca»

Resumen El síndrome de bajo gasto cardiaco es una potencial complicación de los pacientes intervenidos de cirugía cardiaca y asocia un aumento de la morbilidad. La presente guía pretende proporcionar recomendaciones para el manejo de estos pacientes, en el postoperatorio inmediato, ingresados en UCI. Las recomendaciones se han agrupado en diferentes apartados, tratando de dar respuesta desde los conceptos más básicos como es la definición a los diferentes apartados de monitorización básica y avanzada, y terminando con el complejo manejo de este síndrome. Se propone un algoritmo de manejo inicial, así como otros de fracaso ventricular predominantemente izquierdo o derecho. La mayor parte de las recomendaciones están basadas en el consenso de expertos, debido a la falta de estudios clínicos aleatorizados, de adecuado diseño y tamaño muestral en este grupo de pacientes. La calidad de la evidencia y la fuerza de las recomendaciones se realizó siguiendo la metodología GRADE. La guía se presenta como una lista de recomendaciones (y nivel de evidencia de cada recomendación) para cada pregunta del tema seleccionado. A continuación, en cada pregunta, se procede a la justificación de las recomendaciones.

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Glossary of abbreviations and terms

ACC/AHA	American College of Cardiology/American Heart Association
IABP	intraaortic counterpulsation balloon pump
PAC	pulmonary artery catheter
HS	heart surgery
ECC	extracorporeal circulation
EG	echocardiogram
ESC	European Society of Cardiology
TEE	transesophageal echocardiogram
TTE	transthoracic echocardiogram
LVEF	left ventricle ejection fraction
CO	cardiac output
GRADE	Grading of Recommendations Assessment, Development and Evaluation (working group)
PHT	pulmonary hypertension
CI	cardiac index
AHF	acute heart failure
PCI	percutaneous coronary intervention
CVP	central venous pressure
RIFLE/AKIN	Risk, Injury, Failure, Loss of kidney function, and End-stage renal failure/Acute Kidney Injury Network
LCOS	postoperative low cardiac output syndrome (in heart surgery)
CS	cardiogenic shock
SEMICYUC	<i>Sociedad Española de Medicina Intensiva, Crítica y Unidades Coronarias</i>
ALS	advanced life support
ScvO ₂	central venous oxygen saturation
SvO ₂	venous oxygen saturation
BP	blood pressure
MBP	mean blood pressure
SBP	systolic blood pressure
LCT	left common trunk
ICU	Intensive Care Unit

Concept

Low cardiac output syndrome (LCOS) in the postoperative period of heart surgery (PHS) is a potential complication in heart surgery (HS) patients. Its reported incidence varies between 3 and 45%, depending on the literature source, and the syndrome is associated to an increase in morbidity–mortality, a prolongation of stay in the Intensive Care Unit (ICU), and an increase in resource utilization.^{1–3} LCOS is a broad concept, and the literature also offers other terms or designations such as postoperative myocardial dysfunction, postoperative cardiocirculatory dysfunction, acute cardiovascular dysfunction, postsurgery heart failure, heart failure or postcardiotomy shock. The origin and form of presentation of LCOS differ from those of medical acute heart failure (AHF). Consequently, the AHF classifications of the European Society of Cardiology (ESC) and of the American College of Cardiology (ACC) are not directly applicable to the postoperative PHS.⁴

Morbidity–mortality in the postoperative phase of HS has evolved favorably in recent years. This is probably a result of improvements at all implicated healthcare levels, including surgery (surgical technique, myocardial protection, etc.), anesthesia, monitorization, and postoperative management and treatment. The sum of these improvements has encouraged surgeons to operate upon increasingly older patients and with greater comorbidity, i.e., individuals more likely to develop complications, including hemodynamic problems.

Objectives of the guide

The present guide aims to offer recommendations for the management of adult patients with LCOS in the immediate postoperative period of HS, admitted to the ICU. The recommendations are based on consensus among experts in Intensive Care Medicine with special dedication to PHS, as well as an intensivist with expertise in methodological issues. The guide is transparent in reference to the literature

supporting the recommendations and the level of evidence, as well as regards the methodology used to develop the guide. This makes it reproducible and applicable in the different ICUs.

Scope of the guide

The recommendations have been grouped into different sections, attempting to address aspects ranging from the more basic concepts such as definitions (where homogeneity is lacking in the literature) to the different basic and advanced monitorization areas in these patients, and the complex management of LCOS. Management in turn ranges from drug treatments available in any center to the most complex procedures such as mechanical circulatory assist techniques and heart transplantation. Lastly, the guide offers a series of simple algorithms applicable to the initial patient management and to the treatment of predominantly left or right ventricle failure.

Limitations of the guide

Most of the recommendations are based on expert consensus, due to the lack of randomized clinical studies of adequate design and sample size in patients of this kind. On the other hand, the guide does not address the pediatric population.

Users

This guide has been developed for consultation and use by physicians involved in the perioperative management of HS or, in reference to the more general aspects, by physicians implicated in cardiac critical care. It can also prove useful for teaching activities targeted to intensivists or residents in training.

Methodology for development of the guide

Conformation of the group

Under the auspices of the Cardiological Intensive Care Working Group of the Sociedad Española de Medicina Intensiva, Crítica y Unidades Coronarias (SEMICYUC), a group of experts gathered with especial dedication to PHS and working in different Autonomous Communities all over Spain. In addition, an intensivist with expertise in methodological issues also participated in the project from the start—providing orientation and support in the literature searches, and contributing to the methodology and development of the guide.

The members of the Working Group established the issues of particular interest to be addressed in the context of LCOS. In this sense, systematic literature searches were made, and after due analysis of the data, a series of initial recommendations were discussed and established among the different members of the group. The text and initial recommendations in turn were submitted to a group of intensivists with special experience and dedication to patients in the context of PHS (Appendix 1 can be consulted

in the full version, doi:10.1016/j.medin.2012.02.007. Based on the contributions of these intensivists and on common consensus, established on occasion of the meeting of the Cardiological Intensive Care Working Group of the SEMICYUC at the National Congress of the SEMICYUC 2011, the final conclusions to the document were drawn.

Biomedical literature search and development of the guide

Development of the guidelines was based on a MEDLINE search of publications up until December 2010. Since the biomedical literature can cite LCOS in different terms, randomized clinical trials were sought, together with reviews, cohort studies, case-control studies, descriptive observational studies and case series using the following keywords: *post/perioperative low cardiac output syndrome, postcardiotomy heart/cardiac failure, postcardiotomy cardiogenic shock (CS), post/perioperative cardiac/heart failure, transient ventricular dysfunction or myocardial stunning, and low post-cardiac surgery cardiac output (CO)*. These terms in turn were crossed in each of the sections addressed in this guide: monitorization, inotropic drugs, etc. As a starting point, use was made of the only guides available to date on the hemodynamic management and treatment of HS patients, based on the literature review and experts opinion survey recently published by the Association of the Scientific Medical Societies in Germany.⁵ In addition, secondary literature references were used (identified from the analyzed studies found in the literature search), together with general recommendations and guidelines referred to heart failure, arrhythmias and monitorization.

The quality of the evidence and the strength of the recommendations were defined following the methodology of the GRADE (Grading of Recommendation Assessment, Development and Evaluation) Working Group.^{6,7} This system is based on the sequential assessment of the quality of the evidence (taking into account the design and quality of the study, consistency, and the direct-indirect evidence) and the possible recommendations. Thus, the quality of the evidence is classified as high (grade A), moderate (grade B), low (grade C) or very low (grade D) (Table 1 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007), and the recommendations are defined as strong (grade 1) or weak (grade 2). Grading of the recommendations as either strong or weak is conditioned more by clinical importance than by the quality of the evidence. A strong recommendation in favor of a given intervention indicates that the desirable effects obtained on applying the recommendation clearly outweigh the undesirable effects, and means "we recommend". In contrast, a weak recommendation in favor of an intervention indicates that the undesirable effects will probably outweigh the desirable effects, and means "we suggest" (Table 1 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

The guide is presented as a list of recommendations (with the level of evidence of each recommendation) for each issue or question in the selected topic. Then, in each concrete question, justification of the

recommendations is provided. Given the large dimensions of the full guide, the present text offers an abridged version addressing only the recommendations. The full text, which includes the justifications of the recommendations and the total 483 literature references, can be accessed at: doi:10.1016/j.medin.2012.02.007.

Updating of the guide

Updating of the guide every four years from the date of publication is proposed, in order to adapt the recommendations to the results and findings of the new clinical studies.

Exoneration

The guide is a useful tool for improving medical decisions, but in any case, the recommendations of such documents are not meant to replace the decision making capacity of the clinician in a concrete situation or circumstance and involving specific clinical variables. Application of the recommendations also depends on the availability of means and resources in each center or institution. On the other hand, new clinical research findings may produce new evidence requiring a change in routine clinical practice even before this guide is updated.

How could we define low cardiac output syndrome in the postoperative period of heart surgery?

Recommendation

The following definitions are recommended:

1. *Postoperative LCOS*: Measured cardiac index (CI) $< 2.2 \text{ l/min/m}^2$, without associated relative hypovolemia. It may be due to left and/or right ventricle failure and can be accompanied or not by pulmonary congestion. Blood pressure may be normal or low.
2. *Clinical condition consistent with LCOS*: This would apply to patients in which CO is not monitored, and is not known, but in whom the clinical manifestations are consistent with low CO, i.e., oliguria (diuresis $< 0.5 \text{ ml/kg/h}$), central venous saturation $< 60\%$ (with normal arterial saturation) and/or lactate $> 3 \text{ mmol/l}$, without relative hypovolemia. This group should also include those patients coming from the operating room with inotropic medication and/or an intraaortic counterpulsation balloon pump (IABP), and in which these measures must be maintained to secure adequate hemodynamic conditions.
3. *CS*: This is the most serious situation in the context of LCOS, and is defined as CI $< 2.0 \text{ l/min/m}^2$, with SBP $< 90 \text{ mmHg}$, without relative hypovolemia, and with oliguria.

Is low cardiac output syndrome acute heart failure?

Recommendation

LCOS could be regarded as AHF with differences referred to its etiology, physiopathology and course versus the forms of clinical AHF contemplated in the classifications proposed by the ESC and ACC/AHA.

Can we identify risk factors for the development of low cardiac output syndrome?

Recommendation

No known individual risk factor is able to predict the development of LCOS in the PHS (2D).

What are the basic monitorization needs in the postoperative period of heart surgery?

Recommendations

1. Monitorization in the PHS should be adapted to the clinical situation of the patient (1C).
2. The recommended basic monitorization measures for clinically stable patients comprise continuous electrocardiographic monitoring, systemic arterial oxygen saturation, invasive arterial pressure recording, fluid balance (diuresis, drains), and the measurement of central venous pressure (CVP) (1D).
3. In low risk patients, monitorization with CVP is considered sufficient, with no need for pulmonary artery catheterization (PAC) or other systems for the measurement of CO or venous oxygen saturation (SvO₂) on a continuous basis (1B).
4. The use of other devices or techniques will depend on the surgical complexity, the clinical situation and the postoperative course with patient instability (1D).

In which patients should advanced hemodynamic monitorization be considered?

Recommendation

Advanced hemodynamic monitorization is advised in postoperative patients showing hemodynamic instability or suspected LCOS, and who fail to respond to the initial management measures (1C) (Fig. 1 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

How can we estimate preload?

Recommendations

1. The evaluation of preload must be made with integration of the clinical data, the information obtained from the different monitorization techniques, and the dynamic

response to the adopted treatment measures. A dynamic response on the part of preload as determined after volume expansion is considered fundamental (1D).

2. It is not advisable to adopt preload modifying measures on the basis of isolated data obtained by a given technique or procedure (1D).
3. The extreme values of CVP offer us information on the situation of preload, though as occurs with the data obtained by other methods, this information must be integrated with the clinical situation of the patient and the data drawn from other explorations (1D).
4. In situations of suspected LCOS, it is advisable to assess the information provided by other methods, which moreover afford additional hemodynamic information—particularly echocardiography (EG) and CO measurement systems (1D).

In which patients should we know cardiac output in the postoperative period of heart surgery?

Recommendations

1. Routine CO monitoring is not advised in patients with an uncomplicated PHS (1C).
2. Ventricle function should be assessed in the PHS in situations of clinical instability and/or suspected LCOS (1C).
3. There are no recommendations for the choice of a specific method. The decision should depend on the conditions of the patient, availability, and the experience of the attending medical team (1D).
4. In patients with prior moderate to severe pulmonary hypertension (PHT), the recommendation is to use PAC (1D).

What role does the echocardiogram play in the postoperative period of heart surgery?

Recommendations

EG offers relevant information in postoperative patients with clinical stability, and in cases of suspected LCOS. Therefore:

1. EG is recommended in the PHS in patients with persistent hypotension or hypoxemia who fail to respond to the initial therapeutic measures, and in which no apparent cause is identified (1C) (Fig. 1 can be consulted in the full version, doi:10.1016/j.medic.2012.02.007).
2. Echocardiography is recommended in patients with suspected LCOS (1C).
3. TEE is advised when the information cannot be obtained by TTE or other means (1C).
4. It is advisable to have TEE available in the PHS in all centers where heart surgery is carried out (2D).
5. Continuous transesophageal Doppler is not advised for monitorization in the PHS (2C).

Should venous oxygen saturation be determined?

Recommendation

1. Its routine use cannot be recommended, though the measurement of venous oxygen saturation (SvO₂ or central venous oxygen saturation [ScvO₂]) is useful for the identification and management of patients with suspected or established LCOS (2C).
2. The serial determination of SvO₂ or ScvO₂ may be useful for assessing the efficacy of the adopted measures, though it has limitations (2D).

Should we determine lactate in the postoperative period of heart surgery?

Recommendations

1. Initial lactate measurement in the PHS is advised (2C).
2. In the same way as in other critical patients, lactate clearance in the PHS informs us of a favorable/unfavorable trend in the clinical course, and as such may be useful for assessing the patient condition (2C).

What are the general hemodynamic objectives in the management of a patient with low cardiac output syndrome?

Recommendation

1. Table 3 describes the general hemodynamic objectives in LCOS (1D) (Table 3 can be consulted in the full version, doi:10.1016/j.medic.2012.02.007).
2. Fig. 1 shows the recommended algorithm for the initial management of LCOS (1D) (Fig. 1 can be consulted in the full version, doi:10.1016/j.medic.2012.02.007).

Is it important to control heart rate and cardiac rhythm? How should arrhythmias be dealt with?

Recommendation

1. In bradyarrhythmias with hemodynamic repercussions, epicardial pacing is to be maintained in order to secure adequate hemodynamic conditions (1D).
2. Tachyarrhythmias with hemodynamic repercussions require urgent treatment (1B).
3. Synchronized electric cardioversion is advised in atrial fibrillation/flutter, in order to restore sinus node rhythm in patients with severe hemodynamic alterations or myocardial ischemia (1B).
4. In patients with atrial fibrillation/flutter and less serious hemodynamic alterations, the recommendation is to administer intravenous amiodarone (1B). When the arrhythmia is not accompanied by hemodynamic instability, ventricle frequency should be controlled (1B).

Fig. 2 shows a simplified form of the arrhythmia management algorithm (Fig. 2 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

From what hemoglobin levels do these patients require transfusion?

Recommendation

There is no defined hemoglobin concentration threshold below which transfusion is indicated in patients without hemorrhagic shock or without acute bleeding, in the presence of hemodynamic instability. Transfusion is reasonable in most patients in the PHS when hemoglobin <7 g/dl (1D).

What inotropic drugs and vasopressors may be useful in the management of low cardiac output syndrome? Is there any "best" option?

Recommendations

1. It is not advisable to administer inotropic drugs based only on the measurement of CO as an isolated parameter. Such medication is recommended in the presence of some accompanying clinical manifestation of LCOS (1D).
2. It is not advisable to attempt to normalize or optimize a single hemodynamic parameter with inotropic drugs or vasopressors without taking the global clinical context into account. The previously mentioned hemodynamic objectives must be kept in mind (1D) (Table 3 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).
3. Inotropic drugs and vasopressors are recommended in the circumstances contemplated in the algorithms (1C) (Figs. 3 and 4 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).
4. Inotropic drugs and vasopressors are recommended to increase CO and vascular tone, both of which are altered in LCOS during the PHS, until the patient has clinically recovered from the syndrome (2D).
5. No specific inotropic drug or vasopressor can be recommended. It is advisable to use the management algorithms in Figs. 3 and 4 as a general reference, and also to consider the clinical experience and drug availabilities in each particular center (1D) (Figs. 3 and 4 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

The clinical indications for the intravenous administration of inotropic drugs in heart surgery patients comprise supportive treatment in weaning from extracorporeal circulation (ECC), LCOS in the PHS, and CS. However, it has not been clearly defined when the patient requires medication or of what kind (purely vasopressors or inotropic agents), or which drug is best - since there are no adequately designed randomized clinical trials offering sufficiently solid evidence, despite the large number of patients subjected to heart surgery. Appendixes 2 and 3 (can be consulted in the full version, doi:10.1016/j.medin.2012.02.007) summarize the most important clinical studies with inotropic drugs in

adult patients subjected to heart surgery, and in patients with low CO-CS.⁸⁻⁸⁰

At general level, the ESC guides 2005⁸¹ and 2008⁸² on the diagnosis and treatment of AHF advise (strong recommendation, with low level of evidence) the use of inotropic agents in the presence of peripheral hypoperfusion, with or without congestion or lung edema, refractory to diuretics and vasodilators at optimum doses. In turn, the AHA/ACC⁸³ guides (with weak recommendation and low level of evidence) consider that dopamine, dobutamine and milrinone can reduce the congestive symptoms and should be reserved for carefully selected patients with low blood pressure, severe systolic dysfunction and evidence of lowered CO, with a view to maintaining systemic perfusion.

Algorithm for the management of predominant left ventricle failure

Recommendation

Fig. 3 shows the algorithm for the recommended management of predominant left ventricle failure in LCOS during the PHS (1D) (Fig. 3 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

Algorithm for the management of predominant right ventricle failure

Recommendation

Fig. 4 shows the algorithm for the recommended management of predominant right ventricle failure in LCOS during the PHS (1D) (Fig. 4 can be consulted in the full version, doi:10.1016/j.medin.2012.02.007).

In what high-risk surgical patients should we consider the preoperative use of an intraaortic counterpulsation balloon pump?

Recommendation

An IABP is advised in the preoperative phase of HS when the patient presents the following clinical and/or anatomical criteria (2C).

When meeting at least two of the following criteria

- Left ventricle ejection fraction (LVEF) < 0.40–0.35
- Lesion of the left common trunk (LCT) > 70%
- Unstable angina
- Coronary reintervention

Other criteria to be considered

- High risk patients (EUROSCORE \geq 6)
- Hemodynamic instability
- Emergent surgery after failed percutaneous coronary intervention (PCI) (<6 h)

- Myocardial revascularization in the presence of ventricular aneurysms or combined with ventricular reconstruction surgery (aneurysmectomy, aneurysmoplasty)

When is an intraaortic counterpulsation balloon pump indicated in the intra- or postoperative phase?

Recommendation

An IABP is recommended in patients who cannot be weaned from ECC after one or several attempts, or in the patients who develop LCOS or CS in the immediate PHS, refractory to adequate conventional management (1C).

There are many circumstances in which an adequate level of recommendation cannot be established due to a lack of evidence. However, it may be interesting from the practical perspective to evaluate some recommendations made by experts:

In the case of predominant right ventricle failure: Is an intraaortic counterpulsation balloon pump indicated?

The indication in this case is subject to important controversy,^{84,85} though there are experiences that report an increase in CI and mean blood pressure (MBP) within one hour after insertion, and with a high disconnection (75%) and hospital survival rate (69%). This benefit has been related to the diastolic increase in blood flow to the right coronary artery, which may improve ventricle function, and to the reduction in systemic vascular resistance which can indirectly increase the contractile capacity of the right ventricle.⁸⁶

When should we switch to another type of ventricular assist device? or When should we no longer continue with the therapeutic effort?

There are a series of useful prognostic scales or clinical and biochemical markers allowing us to predict the success or failure of IABP on an early basis. In this sense, Boeken et al.⁸⁴ described different factors indicative of a poor course, while according to the prognostic scale developed by Haussmann,⁸⁷ patients with higher scores should be regarded as candidates for early ventricular assist measures.

When is an intraaortic counterpulsation balloon pump contraindicated in the heart surgery patient?

Recommendation

The following are regarded as absolute contraindications (1D):

- Moderate to severe aortic valve insufficiency
- Aortic dissection
- Bilateral femoropopliteal or iliofemoral bypass (percutaneous IABP)

Its use and potential benefits should be carefully evaluated in patients at risk of suffering complications:

- Abdominal aortic aneurysm
- Severe aortoiliac or femoral disease
- Previous aortofemoral bypass
- Severe coagulation disorders
- Absence of definitive treatment for underlying diseases
- Multiorgan failure associated to CS and/or sepsis.⁸⁸

Which patients could be candidates for mechanical circulatory assist measures in the postoperative period of heart surgery?

Recommendation

Mechanical circulatory assist devices are recommended in heart surgery patients in which:

- In the operating room: weaning from ECC is not possible, despite adequate surgical correction.
- In the PHS: the patient develops criteria of CS in the immediate postoperative period.

In any of the situations: patients refractory to maximum pharmacological circulatory support (with at least 2 vasoactive drugs) and/or IABP, and who present no contraindications to implantation (1C).

Which patients with postcardiotomy shock should not receive circulatory assist devices?

Recommendation

A circulatory assist device should not be implanted in the absence or lack of indication criteria. In many cases the contraindication is not absolute; as a result, evaluation is required of the possible general and relative contraindications in each concrete case—with individualized assessment of the possible benefits as weighed against the potential complications (1D).

Which patients could be candidates for heart transplantation in LCOS in the postoperative period of heart surgery?

Recommendation

Possible candidates for heart transplantation are patients who after heart surgery:

- Suffer CS refractory to treatment, including mechanical support (IABP and/or ventricular assist), or have confirmed dependency upon intravenous inotropic support in order to maintain adequate organ perfusion.
- Present irreversible hemodynamic conditions.
- Present no contraindication, with non-reversible multiple organ involvement (2D).

In which patients are renal replacement therapy recommended, and which modality should be used in postcardiotomy low cardiac output syndrome?

Recommendation

- In patients who develop acute renal failure according to the Risk, Injury, Failure, Loss of kidney function, and End-stage renal failure/Acute Kidney Injury Network (RIFLE/AKIN) criteria, with due clinical evaluation of the patient (1C).
- These techniques are advised in patients with fluid overload and for correcting hyponatremia, in patients refractory to diuretics (1C).

What is the correct moment for starting such therapy in patients with low cardiac output syndrome?

Recommendation

No universal recommendation can be made regarding the promptness of use in LCOS during the PHS. The decision depends on clinical and logistic criteria (2D).

Conflicts of interest

The authors declare no conflicts of interest.

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