Use of Minimal invasive Extracorporeal Circulation in Cardiac Surgery: Principles, Definitions and Potential Benefits - A position paper from the Minimal invasive Extra-Corporeal Technologies international Society (MiECTiS) -

Running title: MiECC consensus document

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Abstract

Minimal invasive extracorporeal circulation (MiECC) systems have initiated important efforts within science and technology to further improve the biocompatibility of cardiopulmonary bypass components to minimize the adverse effects and improve end-organ protection. The Minimal invasive Extra-Corporeal Technologies international Society (MiECTiS) was founded to create an international forum for the exchange of ideas on clinical application and research of Minimal invasive Extra-Corporeal Circulation technology. The present work is a consensus document developed to standardize the terminology and the definition of minimal invasive extracorporeal circulation technology as well as to provide recommendations for the clinical practice. The goal of this manuscript is to promote the use of MiECC systems into clinical practice as a multidisciplinary strategy involving cardiac surgeons, anaesthesiologists and perfusionists.

Keywords: extracorporeal circulation, minimal invasive extracorporeal circulation, cardiopulmonary bypass, modular systems, systemic inflammation reaction syndrome, complications

Introduction

Substantial experience has been accumulated with cardiac procedures performed using extracorporeal circulation (ECC) over the last decades. Several technological improvements have been realized, thus making cardiopulmonary bypass (CPB) the gold standard equipment for the majority of cardiac surgical procedures. This has contributed to improved perioperative and long-term results, despite an increasing prevalence of elderly and high-risk patients [1]. For the most frequent procedure, coronary artery bypass grafting (CABG), CPB provides optimal conditions (bloodless field and arrested heart) to allow the most complete myocardial revascularization and additionally offers for the possibility to perform other procedures such as valve repair or replacement, aortic surgery [2].

Major drawbacks of CPB are the adverse systemic effects triggered by a systemic inflammatory response syndrome (SIRS), which is mainly caused by the contact of blood with air and foreign surfaces [3,4]. Trials have shown that the inflammatory response to CPB adversely influences clinical outcome [5,6] although CPB cannot be considered as the main cause of postoperative morbidity.

Since the begin of extracorporeal perfusion, the main inputs have been focused on one objective – to reduce the adverse effects of CPB. Perfusionists and bioengineers have developed optimized 'CPB systems' that combined the best features derived from perfusion science. The idea was to create a system that integrates all modifications into one combined set-up, known as the minimal invasive extracorporeal circulation (MiECC) system [7]. This concept has further initiated important new efforts to improve the biocompatibility of CPB components and minimize the side-effects.

Despite clinical advantages that have been reported in several papers [8], penetration of MiECC technology into clinical practice remains extremely low. There is also significant heterogeneity between the various systems. Low implementation of MiECC may be due to the inability to precise which aspects of MiECC are beneficial, because several elements may act both interactively and/or independently, e.g. coated surfaces, closed systems, anticoagulation strategies, shed blood separation and reduced priming volumes.

The Minimal invasive Extra-Corporeal Technologies international Society (MiECTiS) was founded to create an international forum to exchange ideas on clinical practice and research in the field of Minimal invasive Extra-Corporeal Circulation technology (*www.miectis.org*). The Society brings together, under a scientific interdisciplinary association, cardiac surgeons, anaesthesiologists, perfusionists and basic researchers.

The present work is a consensus document developed to standardize the terminology around minimal invasive extracorporeal circulation technology and to provide recommendations for clinical practice. The authors have graded the levels of evidence and classified the findings listed below using the criteria recommended by the American Heart Association and the American College of Cardiology Task Force on Practice Guidelines (Table 1). The authors represent a multidisciplinary group to promote evidence-based perfusion practice to improve clinical outcomes.

Methods

The initiative to analyze the current practice was based on a questionnaire which was written by the Steering Committee of MiECTiS (KA, TC, AB, JM, MR, EG, JS). During an Expert Consensus Meeting, the statements were discussed and subsequently this consensus paper was developed. For each statement, the best available published evidence derived from meta-analyses of peer-reviewed literature, randomized controlled trials (RCTs) and data coming from large cohort studies were considered. Relevant studies were searched in PubMed (1975 - present), Embase (January 1980 - present) and Cochrane review of aggregate data for reports written in any language. The full PubMed search strategy is available in Table 2 (appendix). Moreover, hand or computerized search involving the recent (1999-2014) conference proceedings from the Society of Thoracic Surgeons, European Association for Cardiothoracic Surgery and European Society for Cardiovascular Surgery and the American Association for Thoracic Surgery annual meetings was performed; ClinicalTrials.gov was explored in order to identify any ongoing or unpublished trials (Table 3).

Recommendations and evidence-based practice guidelines

Expert Committee statements are presented in Table 4. Evidence-based clinical practice guidelines are presented in Table 5.

Terminology

Minimal invasive extracorporeal circulation (MiECC) refers to a combined strategy of surgical approach, anaesthesiological and perfusion management and is not be limited to the CPB circuit alone.

Several terms have been used to describe a minimal invasive extracorporeal circulation circuit: miniaturized extracorporeal circulation (MECC), mini extracorporeal circulation (mECC), minimized extracorporeal circulation, mini cardiopulmonary bypass (mCPB, mini-CPB), minimal invasive cardiopulmonary bypass (MICPB), miniaturized cardiopulmonary bypass (MCPB), veno-arterial extracorporeal membrane oxygenation, minimized perfusion circuit, minimized extracorporeal life support system, minimized cardiopulmonary bypass, minimal invasive extracorporeal circulation. This divergent terminology creates confusion and disagreement between centres. But the major problem is the fact that the focus is made only on the priming volume of the circuit and not on the reduction of the adverse effects of ECC.

The Steering Committee of MiECTiS considers the term ‘minimal invasive’ as a procedure which involves not only the CPB circuit, but the global approach to the procedure. This concept strives to render the procedure minimally invasive as opposed to the widely employed misnomer ‘minimal invasive’ when a limited surgical access is performed. The term ‘minimal invasive’ is misleading since the patient is often a longer period on CPB, cross-clamping and duration of the anaesthesia are prolonged. In this sense, the term minimal invasive relates only to the size of the scar [9]. Hence, we believe that the term ‘minimal invasive extracorporeal circulation’ corresponds better to the above mentioned concept and should be used to describe this technology with the abbreviation: **MiECC**.

Components of MiECC system

In order to be characterized as MiECC, the main components of the system must include: a closed CPB circuit; biologically inert blood contact surfaces; reduced priming volume; a centrifugal pump; a membrane oxygenator; a heat exchanger; a cardioplegia system; a venous bubble trap/venous air removing device and a shed blood management system.

Because different groups have utilized either commercially available or customized CPB circuits with a variety of components, the Consensus Meeting defined the main components of the CPB circuit when it should correspond to a MiECC system. The Steering Committee of MiECTiS emphasizes that a MiECC system should comprise all necessary elements to obtain a maximal benefit.

Originally, MiECC system was an Extracorporeal Life Support (ECLS) circuit with the possibility to administrate cardioplegia (type I) and used mainly to perform CABG procedures [10]. However, safety concerns regarding air entrapment / air lock into the venous line prompted the integration of venous bubble trap/venous air removing devices into the system (type II). This design increased safety for CABG procedures and enabled aortic valve surgery [11]. The need for blood volume management during valvular procedures required the addition of a soft-bag / soft-shell reservoir integrated into the system (type III). This enabled safe performance of aortic valve surgery and other intracardiac procedures. Initiation of modular MiECC (hybrid) systems that integrate a second open circuit with a venous reservoir and cardiotomy suction as a stand-by component (type IV) enabled performance of complex procedures that pertain a high possibility of unexpected perfusion scenario [12,13]. Classification of MiECC types is illustrated in Figure 1. The Consensus Meeting defined as a prerequisite for a system to be considered as MiECC to have at least type II circuit characteristics.

Additional components to be integrated into a MiECC system are: 1) pulmonary artery vent, 2) aortic root vent, 3) pulmonary vein vent, 4) soft bag / soft-shell reservoir, 5) hard-shell reservoir (modular systems), 6) regulated smart suction device, 7) arterial line filtration.

Modular systems

The major reticence to limit expansion of MiECC is due to thoughts about safety in case of massive air entrance into the system or significant blood loss. Although CABG and valve surgery are feasible with the standard type II MiECC circuit, a modular configuration is welcome to expand MiECC for the majority of cardiac procedures and to create a ‘safety net’ for unexpected intraoperative scenarios. Recently published results from a single-centre indicate that a modular circuit design offers 100% technical success rate in high-risk patients, even in those undergoing complex procedures including reoperations, valve and aortic surgery as well as emergency cases [12].

Anticoagulation management

During perfusion with MiECC, less thrombin generation may allow reduced heparin dose targeted by shorter ACT (Class of Recommendation IIB, Level of Evidence B). In this case, individual heparin dosage should be determined using heparin dose-response monitoring systems.

A number of factors including better biocompatible surfaces, elimination of blood-air interaction and exclusion of unprocessed shed-blood re-infusion favourably influence thrombin generation under MiECC system compared to the standard CPB [14]. A patient-adjusted and/or a procedure-adjusted coagulation management based on unfractionated heparin (UFH) can be adopted [15,16,17]. Thus, a low-dose anticoagulation protocol for CABG with a targeted activated clotting time (ACT) of 300-350 sec, and 400-450 sec for valve surgery and complex cardiac procedures is safe [18]. Serial assessment of ACT during CPB is mandatory. Point-of-care (POC) coagulation monitoring (for instance the Hepcon system) to optimize heparin and protamine dosage during CPB) is recommended if a low-dose heparin protocol is adopted. Appropriate protamine reversal should be used post-CPB to normalize ACT. Continuous infusion of UFH may result in less consumptive coagulopathy and transfusion requirements [19,20].

Anaesthesia for surgery on MiECC

Use of short-acting opioids in combination with propofol or volatile anaesthetics, and monitoring of the depth of anaesthesia by processed EEG, is recommended for all patients undergoing cardiac surgery with MiECC. (Class of Recommendation IIB, Level of Evidence C). TEE findings pertinent to institutional management of MiECC should be communicated during the preoperative surgical safety time out (Class of Recommendation IIB, Level of Evidence C).

Anaesthetic management of patients undergoing cardiac surgery with the aid of a MiECC system follows the international recommendations, especially regarding the use of transesophageal echocardiography (TEE) [21,22]. Following anaesthesia induction, TEE may provide additional information that may influence the site and/or the type of cannulation or perfusion strategy (eg. patent foramen ovale, significant mitral or aortic valve pathology or severe aortic atheromatosis). This information is important when type I or II MiECC systems are used, whereas any modifications can be accommodated when type III or modular type IV configuration are available.

Specifically, the absence of venous reservoir in MiECC systems renders the patient´s own venous capacitance compartment critical for haemodynamic as well as for optimal volume management. Positioning of the patient (Trendelenburg or anti-Trendelenburg) and low-dose vasoactive agents are useful to control intraoperative haemodynamics. Excessive fluid administration should be avoided to reduce haemodilution and avoid transfusion [16].

Beneficial effects of MiECC include attenuation of inflammatory response, higher haematocrit, less coagulation disorders and improved end-organ function (brain, kidneys, lungs). It facilitates implementation of fast track protocols [23]. Hence, perioperative use of short-acting intravenous and/or volatile anaesthetic agents is recommended. Moreover, titration of anaesthetic agents using processed electroencephalogram (EEG) ensures adequate anaesthesia depth [24]. Microporous capillary membrane oxygenators enable volatile anaesthetics to be used for anaesthesia maintenance, which is not feasible with diffusion membrane oxygenators [25]. To date randomized controlled trials comparing different anaesthetic protocols for MiECC-based surgery are still missing.

Haemodilution – Haematocrit – Transfusion

MiECC systems reduce haemodilution, better preserve haematocrit and reduce postoperative bleeding and the need for RBC transfusion (Class of Recommendation I, Level of Evidence A).

There is compelling evidence that MiECC – mainly because of the significantly reduced priming volume of the circuit - reduces haemodilution and results in a higher haematocrit at the end of the perfusion period [26,27]. This significantly reduces need for red blood cells (RBC) transfusion and improves oxygen delivery during perfusion [13,18, 26,28,29]. Coagulation disorders are reduced [26] and platelet count and function are better preserved following perfusion with MiECC systems [30]. Postoperative bleeding and incidence of re-exploration are significantly lower in patients operated with MiECC [18]. As it reduces haemodilution, MiECC fulfil, Class I, Level of Evidence A indication for blood conservation according to the STS guidelines, especially in patients at high-risk for adverse effects of haemodilution (paediatric patients and small-sized adults) [8]. Patients refusing transfusion of allogeneic blood products, e.g. Jehovah's Witnesses, are optimal candidates for this strategy [31].

Attenuation of the inflammatory response

Inflammatory response is attenuated with use of MiECC (Class of Recommendation IIA, Level of Evidence B)

Several studies have investigated the inflammatory response triggered conventional CPB and compared it with MiECC systems. MiECC components are designed to limit the severity of SIRS. Coating and reduction of the size of the circuit reduce the amount of foreign surfaces, which is the main trigger of SIRS, but multicenter studies still have to confirm this observation [32]. Assessment of the inflammatory response is complex and clinical presentation is highly variable [33]. Nevertheless, some studies provide evidence of the beneficial effects of MiECC. Moreover, Fromes described a less pronounced intraoperative decrease of monocytes as well as during the first 24 hours in patients with MiECC than in those with conventional CPB [34]. Others demonstrated significantly lower peak levels of IL-6 under MiECC [34-36]. Finally several studies demonstrated that perfusion with MiECC resulted in significantly lower levels of neutrophil elastase – a specific marker of neutrophile activation – than with conventional CPB [34,37,38].

Neurologic function

MiECC systems reduce cerebral gaseous microembolism and better preserves neurocognitive function (Class of Recommendation IIA, Level of Evidence B).

Several prospective studies and meta-analyses have reported reduced incidence of stroke following MiECC when compared to conventional CPB [28,39,40]. A recent meta-analysis found a trend to reduction of neurologic damage in favour of MiECC [18]. Of course, stroke is multifactorial and the perfusion system is only one of the issues beside aortic manipulations and other patient's specific factors [41]. A possible explanation for the neuroprotective effect of MiECC is the significant reduction of gaseous microemboli [42-46]. MiECC also offers improved cerebral perfusion during CPB, as indicated by the lower reduction in near infrared spectroscopy (NIRS) -derived regional cerebral oxygen saturation ($rScO_2$) values and cerebral desaturation episodes [42,45,47,48]. Reduced incidence of cerebral desaturation episodes favourably affects neurocognitive outcome [49-51].

Atrial fibrillation

MiECC reduces the incidence of postoperative atrial fibrillation (Class of Recommendation I, Level of Evidence A).

Several randomized studies have demonstrated that postoperative atrial fibrillation (AF) is significantly reduced following MiECC when compared to conventional CPB [13,23,36,52]. Moreover, there is strong evidence of a lower incidence of AF in all meta-analyses regarding MiECC systems [18,28,40]. Attenuated inflammatory reaction and less volume shifts associated with MiECC may be an explanation for this beneficial effect [53].

Renal function

MiECC preserves renal function (Class of Recommendation I, Level of Evidence A).

Several studies have shown that the use of MiECC systems was associated with better preservation of renal function [54-56]. This was confirmed by a meta-analysis of 24 RCTs but this meta-analysis and other studies failed to demonstrate a reduced incidence of postoperative renal failure [18,54,57]. More stable haemodynamic together with higher perfusion pressure and a reduced need for vasopressors during MiECC perfusion may explain this observation [10,58]. A significant independent association was found between the lowest haematocrit value during bypass and acute renal injury, with significant benefits on renal function seen after reduction of the priming volume. This may be due to a higher DO_2 associated with a higher haematocrit on CPB [29]. In addition, different markers to evaluate renal function (i.e. glomerular filtration rate, levels of neutrophil gelatinase-associated lipocalin), confirm better renal protection under MiECC. Larger studies are required to investigate if this protective effect is sufficient to prevent development of acute renal failure.

Myocardial protection

MiECC is associated with improved myocardial protection (Class of Recommendation I, Level of Evidence A).

Several studies have demonstrated a beneficial effect of MiECC on intraoperative myocardial protection [10,18,59,60]. Reduced cardioplegia volumes with less crystalloids and attenuation of SIRS may explain this beneficial effect [34]. Studies with MiECC and intermittent cross-clamping show a similar effect on myocardial protection [61]. However, myocardial protection is not related only to the duration of ischemia, but also to the reperfusion phase. Increased arterial pressure during CPB as well as the volume-constant perfusion with a closed system may also contribute to improved myocardial protection [54,58].

End-organ protection

MiECC has a subclinical protective effect on end-organ function (lung, liver, intestine) caused by improved microvascular organ perfusion (Class of Recommendation IIA, Level of Evidence B).

MiECC is a closed system that allows a better peripheral perfusion with higher arterial pressure and systemic vascular resistance close to normal values [54]. This is associated with reduced requirement for vasoactive support [10,58]. Data from randomized studies suggest improved lung protection [62], attenuated liver and intestinal dysfunction [55,62,63]. These studies evaluated only surrogate markers of end-organ dysfunction that may beneficiate from MiECC, while the effects remain subclinical. However, it may become clinically perceptible in high-risk patients and in those with longer procedures since MiECC would lead to fewer alterations of microperfusion [64].

Mortality

MiECC appears to offer survival benefit in terms of lower 30-day mortality after CABG procedures (Class of Recommendation IIB, Level of Evidence B).

A number of studies have demonstrated a trend towards reduced mortality in CABG performed on MiECC. A recent meta-analysis of 24 studies involving 2770 patients showed that MiECC was associated with a significant decrease in mortality, compared to conventional CPB (0.5% vs. 1.7%; p=0.02) [18]. This finding has also confirmed by other studies [65,66,67]. A trend towards decreased mortality in favour of MiECC has also been found in meta-analyses [28,40] and in a propensity score analysis [68]. This survival benefit may be the result of the cumulative beneficial effects of MiECC on end-organ protection but it calls for a multicentre randomized controlled trial sufficiently powered to prospectively investigate this survival benefit.

Cost-effectiveness

Data from a cost-analysis study indicate a cost-effectiveness of MiECC systems that offer economic advantages in various healthcare settings [69]. Nevertheless, these results have to be considered in the context of the local conditions. A more detailed analysis together with an analysis from payers' perspective is necessary. Better standardization should be achieved to allow comparison of costs and economical benefits.

Discussion

MiECC systems have been developed to integrate all advances in CPB technology in one closed circuit: the goal is to improve biocompatibility and minimize side-effects of CPB. MiECC is associated with more stable hemodynamic during and early after perfusion and better end-organ protection. This concept provides comparable or better outcomes in terms of morbidity and mortality in CABG and valve procedures, as shown in prospective randomized studies and meta-analyses. However, despite several clinical advantages, implementation of MiECC technology remains weak probably there are still some concerns regarding air handling as well as blood and volume management during perfusion [12]. This Consensus paper primarily serves to summarize the available information about this technology and to clarify some of the open issues. We have made substantial efforts to provide the best available actual evidence and strongly encourage to consider the technology as a multidisciplinary strategy.

There is still debate about the optimal handling of air during the perfusion, as well as volume and blood management when a MiECC system is used. Mean arterial pressure (MAP) is usually higher during MiECC: this raises the question of optimal pump flow rate during MiECC perfusion [10,58]. A reference blood flow based on body surface area is not a guarantee of adequate body perfusion during CPB. Modern protocols adjust pump flow to achieve adequate DO_2. In this area, it is still unclear if the use of MiECC may allow lower than traditional cardiac index without end-organ damage as has been suggested by recent studies [70,71]. The use of NIRS and other parameters to monitor cerebral blood flow may lead to greater individualization of perfusion index for adequate end-organ perfusion [48,72]. Lower heparin requirement and reduced haemodilution offered by MiECC facilitate the management of postoperative bleeding. Prophylactic use of low-dose antifibrinolytics [73] and POC coagulation management based on thromboelastometry and aggregometry is generally advised [74]. In patients with higher perioperative risk [68], those with low ejection fraction and emergencies [67,68,75], MiECC has proven to be safe.

In general, MiECC can be considered as the 'circuit-of-choice' to replace conventional CPB at least for CABG surgery. Novel modular systems (type IV MiECC) may be utilized for all cardiac procedures. We believe that the terms 'circuit' which refers to the CPB, the 'MiECC system' which integrates certain components to a CPB circuit, and the 'MiECC strategy' that represents the multidisciplinary approach to MiECC should be differentiated. The **Minimal invasive Extra-Corporeal Technologies international Society** (MiECTiS) advocates this strategy to obtain the maximal benefits for the patients. The authors believe that MiECC should be understood as an additional tool in the chapter of minimal invasiveness. The latter should not be restricted to 'minimal-access' surgery, but should also incorporate a strategy towards a 'more physiologic CPB'. Use of MiECC should be integrated within fast-track algorithms, POC management of coagulation disorders together with any initiative that improve aortic assessment (epiaortic ultrasound), novel anti-inflammatory strategies, low shear-stress cannula design and implementation of contemporary biofiltration techniques.

Lack of high volume data requires the creation of a registry to further evaluate this technology. Moreover, the variation in extent of miniaturisation / complexity of MiECC systems should be analyzed. Additional RCTs, focusing on valve and other cardiac procedures, as well as large cohorts of patients will provide more evidence regarding clinical effectiveness. Adequately powered multicentre studies are required in order to prove superiority of the MiECC over the conventional CPB.

Concerns in the literature have been raised regarding loss of safety net, ventricular dilatation during perfusion using the standard circuit, loss of a bloodless field and the risk of air embolism [76,77]; however, these reports are anecdotal and are not supported by large-scale studies. Loss of safety during perfusion with a modern MiECC circuit is easily addressed with integration of a venous bubble trap/air removing device into the circuit. Moreover, significant air entrainment that blocks the circuit could be resolved immediately by a skilled perfusionist. Ventricular dilatation, attributed to poor off-loading of the heart, is anticipated with the use of aortic root and/or pulmonary artery/vein venting from type II MiECC onwards. The same applies to creation of a full bloodless field. Special patient populations, such as patients with a higher body surface area requiring higher circulatory flows, are easily managed with kinetic-assisted venous drainage and increased flow through the centrifugal pump. Regarding air embolism, contemporary evidence suggests that there is significantly reduced amount of gaseous microemboli in the arterial line of MiECC systems compared with conventional CPB [78].

Nevertheless, it should be emphasized that MiECC is a demanding system which should be implemented in cardiac surgery as a strategy and not as a simple circuit. A real teamwork from all disciplines of the surgical team, meticulous surgery, a skilful perfusionist and optimal anaesthetic management are mandatory towards a more physiologic perfusion that could lead to improved clinical outcomes. MiECTiS supports initiatives that promote research and clinical application of MiECC systems as a strategy through multidisciplinary training programs (dry labs/hands-on simulators, wet labs, peer-to-peer workshops). Integration of specific training programs under the accreditation of MiECTiS will stimulate and improve the collaboration between clinicians while the industry will get important information to further improve the systems. MiECTiS is planning to endorse a comprehensive and structured program that contributes to the advancement of patient care.

In conclusion, the authors consider MiECC as a physiologically-based strategy and not just a CPB circuit or a particular product. For this reason multidisciplinary approach is mandatory. Collaboration between surgeons, anaesthesiologists and perfusionists is of paramount importance to emphasize the key tenets of MiECTiS.

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Figure 1.

Classification of MiECC circuits [12]. [Note that the modular type IV circuit is literally type III with a standing-by component, used only when necessary].
(X:pump; O:oxygenator; C: cardioplegia; T: bubble-trap/air removing device; V: vent (aortic/pulmonary); S: soft-bag/reservoir; H: hard-shell/reservoir).

Tables

Table 1. Methodology and policy from the American College of Cardiology/American Heart Association Task Force on Practice Guidelines.

Classification of recommendations	**Level of Evidence**
Class I: Conditions for which there is evidence, general agreement, or both that a given procedure or treatment is useful and effective	Level A: Data derived from multiple randomized clinical trials or meta analyses
Class II: Procedure-treatment should be performed-administered	Level B: Data derived from a single randomized trial or nonrandomized studies
Class IIA: Additional studies with focused objective needed	
Class IIB: Additional studies with broad objective needed; additional registry data would be helpful	Level C: Consensus opinion of experts
Class III: Procedure-treatment should not be performed-administered because it is not helpful or might be harmful	

ACCF/AHA Task Force on Practice Guidelines. Methodology Manual and Policies From the ACCF/AHA Task Force on Practice Guidelines. American College of Cardiology Foundation and American Heart Association, Inc. cardiosource.org. 2010. Available at: http://assets.cardiosource.com/Methodology_Manual_for_ACC_AHA_Writing_Committees.pdf

Table 2. Criteria for literature search of the studies used during writing of the consensus document.

Search query

Minimized [All Fields] OR minimal [All Fields] OR miniaturized [All Fields] OR minimizing [All Fields] OR mini [All Fields] OR (minimally [All Fields] AND invasive [All Fields]) AND "extracorporeal circulation" [All Fields] OR minimized [All Fields] OR minimal [All Fields] OR miniaturized [All Fields] OR minimizing [All Fields] OR mini [All Fields] OR (minimally [All Fields] AND invasive [All Fields]) AND "cardiopulmonary bypass" [All Fields] OR "resting heart system" [All Fields] OR closed [All Fields] AND ("cardiopulmonary bypass" [MeSH Terms] OR "mecc" [All Fields]).

Table 3. Summary of the studies used for the consensus document.

Author, journal date, (Ref.)	**Study type**	**Type of procedure**	**Patient groups**	**Type of MiECC circuit**	**Key results**	**Comments**
Wiesenack, Artif Organs 2004, [10]	Retrospective analysis	CABG	485 MiECC/ 485 CCPB	type I	- higher MAP and mean pump flow rate during in MiECC. - reduced frequency of vasoactive drug administration in MiECC patients ($p<0.05$). - maximum values of lactate concentration during bypass were significantly higher in CCPB. - minimum values of haemoglobin as an indicator of haemodilution were higher in MiECC patients, ($p<0.05$). - transfusion of packed red blood cells during surgery and during the complete perioperative course was significantly larger in CCPB ($p<0.05$). - 30-day mortality was similar between groups. - incidence of postoperative complications was significantly higher in CCPB ($p<0.05$).	First reported large series showing improved perfusion characteristics and clinical results
Yilmaz, Interact Cardiovasc Thorac Surg 2010, [11]	Prospective cohort study	CABG+AVR	65 MiECC/ 135 CCPB	type III	- reduced preoperative haemoglobin drop and higher haemoglobin at discharge in MiECC ($p=0.03$). - reduced blood products requirements in MiECC ($p=0.004$). - no differences were noted in pulmonary complications, neurological events or mortality.	Feasibility study

Anastasiadis, Perfusion 2015, [12]	Prospective cohort study	various cardiac case-mix	50 consecutive pts	type IV	- technical success 100% - 4% conversion rate from type III to type IV (modular MiECC)	Clinical study on modular type IV MiECC in all types of cardiac surgery (feasibility and safety study)
El-Essawi, Perfusion 2011, [13]	Multicentre RCT (six centres)	CABG and/or AVR	252 MiECC/ 248 CCPB	type IV	- no operative mortality or device-related complications. - cardiotomy suction was necessitated by major bleeding in 10 patients. - integration of a hard-shell reservoir was deemed necessary for air handling in one patient. - transfusion requirement (p=0.001), incidence of atrial fibrillation (p=0.03) and the incidence of major adverse events (p=0.02) were all in favour of the MiECC group.	Focus on modular type IV MIECC in CABG and/or AVR
Fromes, Anaesthesia 2011, [15]	Retrospective analysis	CABG	100 pts 300 IU/kg heparin/ 68 pts 145 IU/kg heparin	type II	- no thromboembolic events in either group - low-dose group had lower 24-hour mean postoperative blood loss (p=0.001) and reduced rate of transfusion of allogeneic blood (p=0.01).	Implementation of low-dose heparin protocol
Nilson, Interact Cardiovasc Thorac Surg 2012, [17]	RCT	CABG	27 low-dose heparin/ 29 regular dose	type II	- four patients in the control group received a total of 10 units of packed red blood cells, and in the low-dose group no transfusions were given (p = 0.046). - no patient was reoperated because of bleeding. - ICU stay was significantly shorter in the low-dose group (p = 0.020),	Feasibility of low-dose heparin

					- patients in low-dose group were less dependent on oxygen on the first postoperative day (p =0.034), better mobilized (p = 0.006) and had less pain (p=0.019).	
Anastasiadis, J Cardiothorac Vasc Anesth 2013, [23]	RCT	CABG	60 MiECC/ 60 CCPB	type II	- incidence of fast-track recovery was significantly higher in patients undergoing MiECC (p=0.006). - MiECC was recognized as a strong independent predictor of early recovery (p=0.011). - duration of mechanical ventilation and cardiac recovery unit stay were significantly lower in patients undergoing MiECC. - need for blood transfusion, duration of inotropic support, need for intra-aortic balloon pump, development of postoperative atrial fibrillation and renal failure were significantly lower in patients undergoing MiECC.	Focus on fast-track protocols.
Anastasiadis, Perfusion 2010, [26]	RCT	CABG	50 MiECC/ 49 CCPB	type I	- less haemodilution (p=0.001), markedly less haemolysis (p<0.001) and better preservation of the coagulation system integrity (p=0.01) favouring MiECC group. - less bank blood requirements were noted and a quicker recovery, as far as mechanical ventilation support and ICU stay are concerned, in MiECC group.	Focus on haematological effects
Haneya, ASAIO J 2013, [27]	Retrospective cohort analysis	CABG	1073 MiECC/ 872 CCPB	type I	- postoperative creatine kinase and lactate levels were significantly lower in the MiECC group (p<0.001). - no difference in postoperative blood loss between the groups. - intraoperative and postoperative transfusion requirements	Focus on patients with preoperative anemia.

					were significantly lower in the MiECC group (p<0.05). - MiECC patients had lower incidences of postoperative acute renal failure, low cardiac output syndrome, shorter intensive care unit lengths of stay and reduced 30-day mortality (p<0.05).	
Zangrillo, J Thorac Cardiovasc Surg 2010, [28]	Meta-analysis (16 RCTs)	CABG or AVR	803 MiECC/ 816 CCPB		- MiECC was associated with significant reductions of neurologic damage (p=0.008), reduction in peak cardiac troponin (p< 0.001), and in the number of transfused patients (p<0.001). - no difference in mortality was noted.	Meta-analysis
Anastasiadis, Int J Cardiol 2013, [18]	Meta-analysis (24 RCTs)	CABG or AVR	1387 MiECC/ 1383 CCPB		- MiECC was associated with a significant decrease in mortality (p=0.02), in the risk of postoperative myocardial infarction (p=0.03) and reduced rate of neurologic events (p=0.08). - MiECC was associated with significantly reduced systemic inflammatory response, haemodilution, need for red blood cell transfusion, reduced levels of peak troponin release, incidence of low cardiac output syndrome, need for inotropic support, peak creatinine level, occurrence of postoperative atrial fibrillation, duration of mechanical ventilation and ICU stay.	The largest meta-analysis
Rahe-Meyer, Artif Organs 2010, [30]	Prospective cohort study	CABG	44 MiECC/ 44 CCPB	type I	- aggregation decreased significantly in both groups as early as 30 min after the institution of CPB (p<0.05) and recovered within the first 24 h postoperatively, without reaching the preoperative level. - intraoperative aggregometry values reflected a significantly	Focus on coagulation

					more severe reduction of platelet function in CCPB group ($p<0.01$).	
El-Essawi, Perfusion 2013, [31]	Cohort study (Jehovah's Witnesses)	various cardiac case-mix	29 pts 22CABG +/- AVR 7 various case-mix	type IV	- mean decrease in hemoglobin was 2.1 ± 1.3 g/dl during cardiopulmonary bypass and 3.4 ±1.4 g/dl at discharge. - lowest postoperative hemoglobin level was 9.3 ±1.8 g/dl.	Feasibility study on Jehovah's Witnesses
Fromes, Eur J Cardiothorac Surg 2002, [34]	RCT	CABG	30 MiECC/ 30 CCPB	type I	- MiECC system allowed a reduced haemodilution ($p<0.05$). - mononuclear phagocytes dropped in a more important manner in CCPB group ($p= 0.002$) - no significant release of IL-1b was observed in either group. - by the end of CPB, IL-6 levels were significantly lower in MiECC group ($p=0.04$), despite a higher monocyte count. - plasma levels of TNF-a increased significantly in CCPB group ($p=0.002$). - neutrophil elastase release was significantly reduced in MiECC group ($p=0.001$). - platelet count remained at higher values with MiECC - β-thromboglobulin levels showed slightly lower platelet activation in the MiECC group ($p =0.10$).	Focus on SIRS
Immer, Ann Thorac Surg 2007, [36]	Comparative cohort study	CABG	1053 MiECC/ 353 CCPB	type I + smart suction	- TnI was significantly lower in the MiECC group ($p < 0.05$). - incidence of AF was significantly reduced	Feasibility/safety study

				device	in MiECC (p < 0.05). - inflammatory markers (IL-6, SC5b-9) were lower in MiECC patients (p<0.05). - propensity score analysis confirmed faster recovery in MiECC patients and lower incidence of AF.	
Abdel-Rahman, Ann Thorac Surg 2005, [37]	RCT	CABG	101 MiECC/ 103 CCPB	type II	- intraoperative blood loss was significantly higher in CCPB group (p < 0.0001) as well as the need of fresh frozen plasma. - postoperative chest drainage did not differ significantly between groups. - one hour after CPB, PMNE as well as TCC were significantly lower in MiECC group (p<0.0001).	Feasibility/safety study
Ohata, J Artif Organs 2007, [38]	RCT	CABG	15 MiECC/ 15 CCPB	type I	- neutrophil elastase levels were lower in MiECC group at POD 1 and 2 (p=0.013) - IL-8 level were reduced in MiECC patients on POD 1 (p=0.016). - intraoperative blood loss and transfusion volumes were significantly lower in MiECC group (p=0.012).	Focus on SIRS
Puehler, Ann Thorac Surg 2009, [39]	Comparative cohort study	CABG	558 MiECC/ 558 CCPB/ 558 OPCAB	type I	- in-hospital mortality for elective and urgent/emergent patients was lower in the MiECC and OPCAB groups (p<0.05). - number of distal anastomoses was lowest in the OPCABG group, but comparable for MiECC and CCPB patients.	Feasibility/safety study

					- postoperative ventilation time, release of creatinine kinase, catecholamine therapy, drainage loss, and transfusion requirements were lower in the MiECC and OPCABG groups, whereas stay in the ICU was shorter only in the latter (p < 0.05).	
Biancari, Heart 2009, [40]	Meta-analysis (13 RCTs)	CABG or AVR	562 MiECC/ 599 CCPB		- MiECC was associated with reduced mortality during the immediate postoperative period, not reaching statistical significance (p=0.25). - postoperative stroke rate was significantly lower in MiECC group (p=0.05). - length of ICU stay was similar in both groups (p=0.87) - MiECC was associated with a significantly lower amount of postoperative blood loss (p=0.0002) along with a higher platelet count 6 h after surgery (p=0.03).	Meta-analysis
Liebold, J Thorac Cardiovasc Surg 2006, [42]	RCT	CABG	20 MiECC/ 20 CCPB	type I	- CCPB group showed a highly significant reduction in both cerebral oxygenated hemoglobin and tissue oxygenation index from the start to the end of cardiopulmonary bypass (p<0.01). - the rate of decrease in cerebral oxygenated hemoglobin after aortic cannulation was faster in the CCPB group (p<0.001). - no significant changes with respect to cerebral oxygenated hemoglobin or tissue oxygenation index occurred MiECC group, except at the beginning of rewarming (p<0 .01). - total embolic count, as well as gaseous embolic count, in the left and right median cerebral arteries was significantly lower	Focus on cerebral protection

					in MiECC group (all p<0.05). - postoperative bleeding was greater (p<0.05) and the transfusion rate was higher (p<0.05) in CCPB group.	
Zanatta, J Cardiothorac Vasc Anesth 2013, [43]	Retrospective cohort	CABG	19 MiECC (CABG)/ 18 CCPB (AVR or MVR)/ 18 port-access MVR	type I	- the number of solid microemboli and gaseous microemboli was significantly reduced in MiECC group (p<0.001).	Focus on cerebral protection
Camboni, ASAIO J 2009, [44]	RCT	CABG	42 MiECC type I 10 MiECC type II 41 CCPB	type I and II	- MiECC resulted in reduced microbubble activity compared to CCPB (p=0.02). – Postoperative neuropsychological dysfunction (p=0.45), renal dysfunction (p= 0.67), days of hospitalization (p=0.27), and 30 day-mortality (p=0.30) did not differ between groups.	Focus on cerebral protection
Anastasiadis, Heart 2011, [45]	RCT	CABG	29 MiECC / 31 CCPB	type I	- MiECC was associated with improved cerebral perfusion during CPB. - Less patients operated on with MiECC experienced at least one episode of cerebral desaturation (p=0.04) with similar duration. - at discharge pts operated on with MiECC showed a significantly improved performance on complex scanning, visual tracking, focused attention and long-term memory. - at 3 months significantly improved performance was also evident on visuospatial perception, executive function, verbal	Focus on neurocognitive outcome

					working memory and short-term memory. - patients operated on with MiECC experienced a significantly lower risk of early cognitive decline both at discharge ($p=0.03$) and at 3-month evaluation ($p<0.01$).	
Reineke, Interact Cardiovasc Thorac Surg 2014, [46]	Cohort study	CABG	31 MiECC	type I + smart suction device	MiECC does not adversely affect cognitive brain function after CABG.	Focus on neurocognitive
Gynaydin, Perfusion 2009, [47]	RCT	CABG	20 MiECC/ 20 CCPB	type IV	- serum IL-6 levels were significantly lower in the MiECC group ($p<0.05$). - C3a levels were significantly less in the Mini- CPB ($p<0.01$). - CK-MB levels in coronary sinus blood demonstrated well preserved myocardium in the MiECC group. - percentage expression of neutrophil CD11b/CD18 levels were significantly lower in the MiECC group ($p<0.05$). - no significant differences in air handling characteristics or free plasma hemoglobin levels in either circuit. - rSO_2 measurements were significantly better in the MiECC group ($p<0.05$). - blood protein adsorption analysis of oxygenator membranes demonstrated a significantly increased amount of	Focus on SIRS and haemodilution

					microalbumin on CCPB fibers (p<0.05).	
Bennett, Perfusion 2014, [48]	Cohort study	CABG and/or AVR	39 MiECC 41 CCPB	type II	- the average indexed bypass pump flow was significantly lower with MiECC with same average oxygen delivery. - pts in the CCPB group had a greater duration and severity of cerebral desaturation., which was significantly associated with low flows during CPB, whereas desaturation with MiECC was associated with low perioperative haemoglobin concentration.	Focus on cerebral protection
Panday, Interact Cardiovasc Thorac Surg 2009, [52]	Prospective cohort study	CABG	220 MiECC 1143 CCPB 109 OPCAB	type II	- operative mortality rates were comparable in all three groups. - the mean number of distal anastomoses was higher in MiECC and CCPB groups than OPCAB group (p=0.01). - arrhythmia occurred in 25% of the MiECC group, in 35.6% of the CCPB group (p=0.05) and in 21.7% of the OPCAB group. - 3% of the MiECC group suffered neurocognitive disorders perioperatively compared to 7% of the CCPB group (p=0.05) and 3% of the OPCAB group. - the median number of blood transfusions per patient was lower in MiECC and OPCAB groups (p<0.0001).	Focus on blood transfusion
Remadi, Am Heart J 2006, [53]	RCT	CABG	200 MiECC/ 200 CCPB	type I + suction device	- operative mortality rate similar between groups. - low-cardiac-output syndrome was reduced in MiECC group (p<0.001.). - inflammatory response was significantly reduced in MiECC. C-reactive protein release postoperatively was significantly	Feasibility/safety study

					higher in CCPB group. - significantly higher decrease of haematocrit and haemoglobin rate in CCPB group. - intraoperative transfusion rate was reduced in MiECC group (p<0001). - patients in the CCPB group had significantly higher levels of postoperative blood creatinine and urea.	
Diez, ASAIO J 2009, [54]	Retrospective observational study	CABG	1685 MiECC / 3046 CCPB	type I	- MiECC exerts beneficial haemodynamic effects but does not prevent AKI. - fewer patients developed a decline in eGFR <60 mL/min/1.73 m^2 in MiECC ($p < 0.001$). - the incidence of eGFR decrease by >50% did not differ (p=0.20). - temporary dialysis was reduced in MiECC group (p<0.001). - MiECC is renoprotective in the early postoperative period but cannot prevent AKI.	Focus on renal function
Huybregts, Ann Thorac Surg 2007, [55]	RCT	CABG	25 MiECC/ 24 CCPB	type II	- MiECC was associated with attenuation of on-pump haemodilution, improved hemostatic status with reduced platelet consumption and platelet activation, decreased postoperative bleeding and minimized transfusion requirements.	Focus on renal and intestinal function

					- MiECC showed reduced leukocytosis and decreased urinary interleukin-6. - levels of urine NGAL were on average threefold lower and urinary intestinal fatty acid binding protein was 40% decreased in patients operated on MiECC.	
Capuano, Interact Cardiovasc Thorac Surg 2009, [56]	Prospective cohort study	CABG	30 MiECC/ 30 CCPB	type II	- CCPB group showed a significant NGAL concentration increase from preoperative during the 1st postoperative day ($p<0.05$). - no patient in MiECC group developed AKI. - renal function is better protected during MiECC as demonstrated by NGAL levels.	Focus on renal injury
Benedetto, Ann Thorac Surg 2009, [57]	Prospective cohort study	CABG	104 MiECC/ 601 CCPB	type II	- overall incidence of AKI for patients undergoing MiECC was reduced ($p=0.03$).	Focus on renal injury
Bauer, J Extra Corpor Technol 2010, [58]	RCT	CABG	18 MiECC/ 22 CCPB	type II	- MAP values were significantly higher in the MiECC group ($p= 0 .002$). - MiECC patients received significantly less norepinephrine ($p =0.045$).	Focus on perfusion characteristics
Skrabal, ASAIO J 2007, [59]	RCT	CABG	30 MiECC/ 30 CCPB	type I	- MiECC patients demonstrated significantly lower levels of TnT at 6, 12, and 24 hours and CK-MB levels at 6 and 12 hours .	Focus on myocardial protection
Van Boven, Eur J	RCT	CABG	10 MiECC	type I	- markers of myocardial oxidative stress or activity were	Focus on myocardial protection

Cardiothorac Surg 2008, [60]			10 CCP 10 OPCAB		significantly lower in MiECC group compared to CCPB and OPCAB (p=0.04 and 0.03 respectively).	
Nguygen, Mol Cell Biochem 2014, [61]	RCT	CABG	13 MiECC/ 13 CCPB (intermittent cross-clamp fibrillation)	type III	- the overall cardiac injury was significantly lower in the MiECC group as measured by TnT (p=0.02).	Focus on myocardial protection
Van Boven, Eur J Anaesthesiol 2013, [62]	RCT	CABG	20 MiECC 20 CCP 20 OPCAB	type I	- MiECC group showed significantly lower median TnT levels compared with CCPB and OPCAB (p<0.003). - HFABP, IFABP and a-GST levels were significantly higher during CCPB compared with OPCAB and MiECC (p<0.009). - there was a trend towards higher median CC16 levels in the CCPB group (p<0.07).	Focus on end-organ protection
Prasser, Perfusion 2007, [63]	RCT	CABG	10 MiECC/ 10 CCPB	type I	- liver function as measured by disappearance rate of indocyanine green was markedly increased after cardiac surgery without significant differences between groups.	Focus on liver function
Donndorf, J Thorac Cardiovasc Surg 2012, [64]	RCT	CABG	20 MiECC/ 20 CCPB	type I	- there is an impairment of microvascular perfusion during CCPB (p=0.034). - changes in functional capillary density indicate a faster recovery of the microvascular perfusion in MiECC during the reperfusion period (p=0.017).	Focus on microvascular perfusion
Haneya, Eur J Cardiothorac Surg	Retrospective cohort study	CABG	105 MiECC /	type I	- CK levels were significantly lower 6 h after surgery in the MiECC group (p < 0.05).	Focus on high-risk patients.

2009, [65]			139 CCPB (high-risk patients)		- need of red blood cell transfusion was significantly lower after MiECC surgery ($p < 0.05$). - 30-day mortality was significantly lower in the MiECC group ($p<0.01$).	
Kolat, J Cardiothorac Surg 2014, [66]	Retrospective cohort analysis	CABG	1137 MiECC / 1137 CCPB	type I	- postoperative requirement of renal replacement therapy ($p=0.01$), respiratory insufficiency ($p=0.004$) and incidence of low cardiac output syndrome ($p= 0.003$) were significantly increased in patients with CCPB.	Focus on clinical outcome.
Ried, J Cardiothorac Surg 2013, [67]	Propensity score analysis	emergency CABG	146 MiECC / 175 CCPB	type I	- 30-day mortality was reduced in patients with MiECC ($p=0.03$). - ICU stay ($p=0.70$), hospital stay ($p=0.40$) and postoperative low cardiac output syndrome ($p=0.83$) did not show significant differences between both groups.	Focus on emergency CABG
Koivisto, Perfusion 2010, [68]	Propensity score analysis	CABG	89 MiECC / 147 CCPB	type II	- stroke rate was significantly higher among CCPB patients ($p=0.026$). - in-hospital mortality, combined adverse end-point rate, postoperative bleeding and need for transfusion were statistically insignificant in the study groups.	Focus on high-risk patients
Anastasiadis, Int J Cardiol 2013, [69]	Cost-analysis	CABG	1026 MiECC/ 1023 CCPB		- in terms of total therapy cost per patient the comparison favored MiECC in all countries. - it was associated with a reduction of €635 in Greece, €297 in Germany, €1590 in the Netherlands and €375 in Switzerland. - in terms of effectiveness, the total life-years gained were	Focus on cost-effectiveness

					slightly higher in favor of MiECC.	
Fernandes, Perfusion 2010, [70]	Retrospective cohort study	CABG	15 MiECC	type II	- using lower than predicted flows, adequate perfusion was provided.	Focus on perfusion characteristics
Puehler, Thorac Cardiovasc Surg 2010, [75]	Retrospective comparative cohort study	CABG	119 MiECC / 119 CCPB	type I	- MiECC patients had a tendency towards a lower 30-day mortality rate, a better postoperative renal function and reduced ventilation times. - CPB time and postoperative high-dose inotropic support were significantly lower in the MiECC group. - ICU and hospital stay were comparable between the two groups.	Focus on high-risk patients

a-GST: a-Glutathione S-Transferase AF: Atrial fibrillation; AKI: Acute Kidney Injury; AVR; Aortic Valve Replacement; CABG: Coronary Artery Bypass Grafting; CCPB: Conventional Cardiopulmonary Bypass; CPB: Cardiopulmonary Bypass; HFABP: Heart type Fatty Acid Binding Protein; ICU: Intensive Care Unit; IFABP: Intestinal type Fatty Acid Binding Protein; IL: Interleukin; MAP: Mean Arterial Pressure; MiECC: Minimal invasive Extracorporeal Circulation; MVR: Mitral Valve Replacement; NGAL: Neutrophil Gelatinase-Associated Lipocalin; OPCAB: Off-Pump Coronary Artery Bypass grafting; pts: patients; POD: Postoperative Day; RCT: Randomized Controlled Trial; SIRS: Systemic Inflammatory Response Syndrome; TNF: Tumor Necrosis Factor; TnT: Troponin-T; TnI: Troponin I

Table 4. Summary of statements endorsed by the Expert Committee

Recommendation
Minimal invasive extracorporeal circulation (MiECC) refers to a combined strategy of surgical approach, anaesthesiological and perfusion management and should not be limited to the CPB circuit alone.
In order to be characterized as MiECC, the main components of the system must include: closed circuit; biologically inert blood contact surfaces; reduced priming volume; centrifugal pump; membrane oxygenator; heat exchanger; cardioplegia system; venous bubble trap/venous air removing device; shed blood management system.
Additional components that can be integrated to a MiECC system are: pulmonary artery vent; pulmonary vein vent; aortic root vent; soft bag / soft-shell reservoir; hard-shell reservoir (modular systems); regulated smart suction device; arterial line filtration.

Table 5. Summary of evidence-based practice guidelines

Recommendation	**Level of Evidence**	**References**
Class I		
MiECC systems reduce haemodilution and better preserve haematocrit as well as reduce postoperative bleeding and the need for RBC transfusion.	A	18,26,28
MiECC systems reduce the incidence of postoperative atrial fibrillation.	A	13,18,23,28
MiECC systems preserve renal function.	A	18,55
MiECC is associated with improved myocardial protection	A	18,59,60,61
Class IIA		
Inflammatory response assessed by specific inflammatory markers is attenuated with use of MiECC.	B	34,36,37,38
MiECC systems can reduce cerebral gaseous microembolism and preserve neurocognitive function.	B	18,42,43,44,45,46
MiECC exerts a subclinical protective effect on end-organ function (lung, liver, intestine) which is related to enhanced recovery of microvascular organ perfusion.	B	55,62,63,64
Class IIB		
Within a MiECC strategy, less thrombin generation may permit reduced heparin dose targeted to shorter ACT times. When such a strategy is followed, individual heparin dose should be determined using heparin dose-response monitoring systems.	B	14,15,17,20
MiECC appears to offer survival benefit in terms of lower 30-day mortality after CABG procedures.	B	18,65,66,67
Use of short-acting opioids in combination with propofol or volatile anaesthetics, and hypnotic effect monitoring by processed EEG, is recommended for induction and maintenance of anaesthesia for MiECC-	C	21,22,23,24,25

based surgery. TEE findings pertinent to institutional management of MiECC should be communicated during the preoperative surgical safety time out.

ACT: Activated Clotting Time; CABG: Coronary Artery Bypass Grafting; EEG: Electroencephalogram; MiECC: Minimal Invasive Extracorporeal Circulation; RBC: Red Blood Cells.