Current aspects of extracorporeal membrane oxygenation in a tertiary referral centre: determinants of survival at follow-up†

Erwan Fléchera, Amedeo Anselmi*, Hervé Corbineaua, Thierry Langanay, Jean-Philippe Verhoyea, Christian Félix, Guillaume Leurent, Yves Le Tulzo, Yannick Malledant and Alain Leguerrier

* Department of Vascular and Cardio-Thoracic Surgery, Rennes University Hospital, Rennes, France
† Department of Cardiology, Rennes University Hospital, Rennes, France
‡ Department of Medical, Intensive Care Unit, Rennes University Hospital, Rennes, France
§ Department of Anesthesiology, Surgical Critical Care and Emergencies, Rennes University Hospital, Rennes, France

†† Corresponding author. Department of Vascular and Cardio-Thoracic Surgery, Rennes University Hospital, 2 rue Henri Le Guilloux, 35 033 Rennes Cedex 9, France. Tel: +33-2-99282497; fax: +33-2-99282496; e-mail: amedeo.anselmi@alice.it; amedeo.anselmi@aliceposta.it (A. Anselmi).

Received 20 October 2013; received in revised form 17 December 2013; accepted 30 December 2013

Abstract

OBJECTIVES: To describe the clinical results (both early and at follow-up) of patients currently receiving extracorporeal membrane oxygenation (ECMO) therapy for cardiac and/or pulmonary failure. To assess the effect of indications, clinical presentations and ECMO modalities on early/late clinical outcomes. To identify baseline factors associated with worse survival at follow-up.

METHODS: We reviewed the prospectively collected data of 325 patients receiving ECMO therapy at a tertiary referral centre during the 2005–2013 period. Follow-up was prospectively conducted by dedicated personnel (average: 84 ± 86 days, 100% complete). Survival was analysed by stratified Kaplan–Meier curves.

RESULTS: Veno-arterial (VA) ECMO was employed in 80% of cases (due to early graft failure (EGF) in 13% of cases, post-cardiotomy in 29%, primary cardiogenic shock in 42% for miscellaneous aetiologies, other indications in 15.4%) and veno-venous (VV) ECMO in the remainders (adult respiratory distress syndrome). In the VA and VV groups, weaning rates were 59 and 53%, survival at 30th postimplantation day was 44 and 45% and survival at the end of the follow-up was 41 and 45%, respectively. Implantation under advanced life support (ALS) occurred in 15% of cases (26% survival at 30 days). VA patients had a higher rate of thrombotic/haemorrhagic complications and of transfusion of blood products and shorter ventilation time. Worse early and follow-up survival were observed among patients aged ≥65 years, having pH ≤7, lactates >12 mmol/l, creatinine >200 µmol/l at implantation or receiving ECMO under ALS. No difference in survival was noted among VA vs VV patients. Patients receiving ECMO for EGF displayed better early and late survival (64% at 30 days and 53% at 6 months) than post-cardiotomy (36 and 34%, respectively), post-acute myocardial infarction (48 and 40%) and the remaining patients (46 and 45%).

CONCLUSIONS: Despite most critical baseline conditions, ECMO therapy is confirmed useful for the treatment of patients with acute cardiopulmonary failure refractory to conventional treatments. The ECMO modality (VA vs VV), as well as indications to support, identifies different patient profiles and dissimilar outcomes. Preimplantation markers of gravity and end-organ damage are useful in the stratification of expected survival. These may facilitate clinical decision-making and appropriate allocation of hospital resources.

Keywords: Extracorporeal membrane oxygenation • Survival • Determinants • Follow-up

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) is an accepted and reliable technique to provide temporary circulatory and/or respiratory support in patients affected by severe myocardial and/or pulmonary failure [1]. Miniaturization and technical innovations have led to its rapid diffusion worldwide during the last 10 years, both in the field of cardiac surgery and of intensive care medicine. Patients receiving veno-arterial (VA) and veno-venous (VV) ECMO can be reasonably discriminated as two major categories on the basis of indication to treatment, clinical course and outcomes [2, 3]. Nonetheless, there are few previous data allowing a formal comparison of clinical features and early results among these opposed categories. In addition, the candidates to ECMO therapy represent an extremely extensive and heterogeneous population, on the basis of the aetiologies of organ failure and modalities of presentation. Therefore, direct comparison within patient subgroups is required to facilitate evidence-based decision-making in these complex clinical scenarios.

Commendable early results have been reported among these severely ill patients, in terms of survival to major circulatory and/or respiratory failure. Nonetheless and quite surprisingly, the published data concerning the follow-up outcomes of the patients

© The Author 2014. Published by Oxford University Press on behalf of the European Association for Cardio-Thoracic Surgery. All rights reserved.
surviving acute illness thanks to ECMO support are scarce [4]. Such data would better clarify the clinical suitability of ECMO therapy in various patient subgroups and the appropriateness of the allocation of health care resources.

Herein, we describe the development of the overall ECMO programme in our institution. The first study purpose was to address the major characteristics of a large and current population of patients receiving ECMO therapy and to assess the impact of changing trends, indications, organizational issues on the early clinical results. Secondly, we aimed at providing the average 6-month clinical follow-up among different patient subgroups and at identifying the factors associated with worse survival.

MATERIALS AND METHODS

Patients and collection of data

Since the beginning of the ECMO programme at our institution in 2005, all data pertaining to patients receiving either VA or VV support for cardiorespiratory failure have been prospectively entered in an electronic database registry by dedicated research nurses. This database is regularly checked for completeness and consistency. In September 2013, we performed a retrospective analysis of patients included in the registry (n = 325) over the January 2005 to July 2013 period. The indication to ECMO therapy was established in compliance with the current recommendation [1] by a multidisciplinary team including two physicians and a surgeon in all cases. The indication was posed when the chances of success were believed to outweigh the risks and the use of hospital resources. Patients had to present a projected good quality of life and either potential for recovery or possible candidacy to transplantation/long-term mechanical support. When ECMO was judged to prolong the course of illness without a realistic chance of survival or acceptable quality of life in case of recovery, ECMO support was not instituted. VA ECMO was implanted for refractory circulatory failure with isolated one-organ insufficiency or before massive multiorgan failure developed. VV ECMO was considered in case of persisting severe respiratory failure (PaO$_2$/FiO$_2$ ratio < 150) despite optimal invasive ventilation, which could not be controlled by conventional methods (including high-frequency oscillatory ventilation, inhaled vasodilators, patient mobilization, etc.). Patients were evaluated using the Simplified Acute Physiology Score (SAPS) version 2 immediately before ECMO implantation [5], using the calculator available online at www.sfar.org (website of the French Society of Anesthesia and Intensive Care). All patients receiving ECMO at our institution were included in the present study.

Surgical technique

The implantation of ECMO was performed under general anaesthesia and mechanical ventilation in 99% of cases and under sedation and local analgesia in the remaining. The implanting team included two surgeons (senior and resident), a scrub-nurse and a perfusionist. All required material was available on a dedicated trailer, allowing full autonomy for prompt displacement of the team within-hospital facilities wherever ECMO implantation was needed, including operating theatre, intensive care units (ICUs) and catheterization room.

Veno-arterial extracorporeal membrane oxygenation.

Peripheral implantation through the femoral access was most commonly employed (92%). The anterior surface of the right common femoral artery and vein was exposed through groin incision and cannulated using the Seldinger technique (16–20 Fr for the inflow cannula and 18–32 Fr for the drainage cannula, according to the patient’s body surface area, vessels quality and surgeon’s preference) (Edwards Lifesciences, Inc., Irvine, CA, USA). In all peripheral VA cases, a reperfusion catheter was introduced in the superficial femoral artery to prevent limb ischaemia (5–10 Fr). The left groin was accessed in case of unsuitable vascular access on the right side. VA ECMO implantation was performed within the cardiac surgery operating theatre if the patient could be safely transported (60%). In case of unstable haemodynamics or cardiac arrest, implantation was done bedside (40%). Removal of the VA ECMO cannulae was performed in the operating theatre (except in case of death under support) to allow optimal vessel repair. Few post-cardiomyopathy patients (n = 20, 8%) received central ECMO with a left atrial vent through median sternotomy.

Veno-venous extracorporeal membrane oxygenation. In 89% of cases, this was established through cannulation of the right femoral (drainage) and jugular (reinjection) veins (Edwards Lifesciences, Inc.). The remaining patients (11%) received one double-lumen cannula (AVALON® device, Avalon Lab, Rancho Dominguez, CA, USA) [6] through the right internal jugular vein. Percutaneous implantation using the Seldinger technique was used in all cases. Correct placement of the cannulae was checked by chest X-ray and transthoracic/transoesophageal echocardiography, and their removal was done bedside within an ICU (followed by compression of the venous entry sites).

A bolus of unfractioned heparin (5000 IU) was administered immediately before cannulation. After ECMO insertion, heparin was given through a central venous line in order to maintain an activated clotting time between 150 and 180 s; in the presence of haemorrhagic complications or in trauma/post-cardiomyopathy patients, the dose of heparin was adjusted or the administration temporarily withheld. Pump speed was adjusted in order to keep the cardiac index within the 2.2–2.8 l/min/m$^2$ range and obtain adequate cardiac decompression (transthoracic and/or transoesophageal echocardiography). Magnetic centrifugal pumps (Maquet Rotaflo® or Cardiohelp® devices) with heparin-coated circuit and Quadrox® oxygenator (Maquet, Inc., Hirrlingen, Germany) were adopted. The flow provided by the pump was continuous, laminar and non-pulsatile, directly related to perfusion pressure. External driving units are of a size small enough to facilitate transportation and to avoid space conflict. Patients were evaluated on a daily basis by a multidisciplinary team including surgeons, cardiologists and anaesthesiologists. In case of inadequate left ventricular (LV) unloading and/or pulmonary oedema, inotropic drugs were adjusted and/or intra-aortic balloon pump therapy considered. Weaning from mechanical ventilation while under ECMO support was practised at the discretion of the medical team. Normothermic ECMO support was conducted in all patients with the exception of those with suspected brain damage. Performance of a weaning trial was considered when partial or complete recovery of myocardial/pulmonary function was disclosed on echocardiography, haemodynamic assessment and chest X-rays.

Follow-up

Patients who were discharged alive from the hospital were periodically contacted by nurse personnel experienced in the management of mechanical circulatory support. An inquiry over vital
status, functional conditions and occurrence of complications was performed. In case of impossibility to get in touch with the patients, the referring general practitioners or cardiologists were contacted. Data were prospectively entered in the Rennes ECMO Registry database.

Statistical analysis

Statistical analysis was performed with the SAS ver. 9.33 software for Windows (SAS Institute, Inc., Cary, NC, USA). Continuous variables are presented as mean ± standard deviation and categorical variables as frequencies and percentages. For inter-group comparison, Student’s t test (continuous data and normal distribution), the Mann–Whitney U-test (continuous data and non-normal distribution) and the χ2 test (categorical data) were employed. Survival analysis was performed according to the Kaplan–Meier estimates, and corresponding survival curves were built. Opposed curves were compared with the log-rank statistic. The alpha level was 0.05.

RESULTS

Since 2005, a total of 325 patients received ECMO treatment at our institution; about 50 implantations/year were performed since 2008. The study flowsheet for VA patients is depicted in Fig. 1A and B for VV patients. The majority of patients were male (70%), and the mean age at implantation was 53 ± 15 years; VA ECMO was employed in 80% of cases (n = 259) and VV ECMO in the remainder (n = 64). In the overall population, average SAPS II score was 47 ± 22 (range: 6–106). Interestingly, the patients who were implanted within the operative theatre or in the post-cardiac surgery ICU presented lower average SAPS II score (43 ± 20 and 41 ± 23) than patients who were implanted within other sites (56 ± 25 for medical ICU and 53 ± 18 for general post-surgical ICU) (P = 0.004). This probably reflects different aetiologies of cardiopulmonary failure among these patient subgroups. At the time of ECMO implantation, average serum creatinine was 169 ± 102 μmol/l, pH was 7.3 ± 0.2 (7% of patients having pH < 7) and serum lactate level was 6.6 ± 5.1 mmol/l (33% of patients having lactate >8 mmol/l); 37% were receiving dobutamine >10 μg/kg/min, 22% had adrenaline >5 μg/h and 10% had noradrenalin >5 μg/h. As many as 15% of ECMOs were instituted during advanced life support (ALS) and cardiac massage; among these, only 5 patients (10%) received out-of-hospital implantation of ECMO. The above features underline the severely compromised baseline conditions of these patients. The average diameters of the inflow and of the outflow cannulae were 19 ± 2 Fr and 21 ± 3 Fr, respectively. Difficult implantation was reported in 4% of cases (including need to contralateral groin exploration). Table 1 summarizes the indications to VA and VV support; VV ECMO was primarily employed in case of isolated adult respiratory distress syndrome (ARDS), while VA ECMO was preferred in cases where significant cardiac dysfunction coexisted or was predominant. In the cardiogenic shock subgroup, most frequent aetiologies were ischaemic heart disease (66%), dilated cardiomyopathy (17%) and myocarditis (12%). Table 2 compares the main baseline characteristics of VA vs VV ECMO patients. Overall, VA ECMO patients presented significantly older age, lower body temperature, larger use of catecholamines and higher lactates level. This may be interpreted as a result of their clinical background, dominated by cardiac failure. Nonetheless, overall clinical gravity was comparable among groups, as underlined by the absence of meaningful differences in terms of SAPS score and pH.

One hundred and eighty-nine patients (58%) could be weaned from ECMO support (59% in the VA group vs 53% in the VV group). Overall, 146 patients (45%) were alive at the 30th post-implantation day (44% in the VA group vs 45% in the VV group). The majority of early deaths occurred during ECMO support, mainly due to multorgan failure. VA ECMO implanted under cardiac arrest and ALS (n = 49) allowed a 26% survival rate at 30 days. Table 3 depicts the rates of major in-hospital morbidity among opposite subgroups. Ischaemic complications of the lower limb in

Table 1: Indications to ECMO support (VA vs VV)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>VA ECMO (n = 259) (%)</th>
<th>VV ECMO (n = 64) (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-cardiotomy</td>
<td>75 (29)</td>
<td>3 (5%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Post-heart transplantation</td>
<td>35 (13)</td>
<td>1 (2%)</td>
<td></td>
</tr>
<tr>
<td>Cardiogenic shock</td>
<td>109 (42)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Septic shock</td>
<td>1 (0.4)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>ARDS</td>
<td>8 (3)</td>
<td>53 (83%)</td>
<td></td>
</tr>
<tr>
<td>Trauma, others</td>
<td>32 (12)</td>
<td>6 (9%)</td>
<td></td>
</tr>
</tbody>
</table>

ARDS: adult respiratory distress syndrome.

Figure 1: Study workflow for VA ECMO (A) and for VV ECMO (B).
Similarly, 7 (3.7% of survivors at explantation) received a long-term implantable LV assist device for failure to recover adequate cardiac function. All these individuals had received VA ECMO, and heart transplantation was always performed on an urgent priority.

### Follow-up results

In the overall population, average follow-up was 85 ± 86 days (27 481 patient-days available for analysis) and was 100% complete. The major decrease in survival was observed within 30 postimplantation days (46% ± 3). After this timepoint, survival remained globally stable: 44% ± 3 at 3 months and 42% ± 3 at 6 months. Stratified analysis according to ECMO type (Fig. 2A) evidenced no difference in follow-up survival among patients receiving VA vs VV ECMO (P = 0.6). Conversely, patients who are older, who were implanted under ALS or having pH < 7 had a significantly worse follow-up survival (P < 0.001 all, Fig. 2B-D). Similar results were observed for patients having lactates >12 mmol/l or serum creatinine >200 μmol/l at the time of implantation (Fig. 2E and F). Finally, we stratified patients into four major classes of indications to ECMO: post-heart transplantation (n = 36) vs post-cardiomyopathy (n = 80) vs post-acute myocardial infarction (AMI), (n = 60) vs all other indications (n = 149). The better follow-up survival was observed in the post-heart transplantation subgroup (53% ± 8 at 6 months), and the worse survival among the post-cardiomyopathy patients (34% ± 5); the post-AMI patients and the remainders presented an intermediate behaviour (40% ± 6 and 45% ± 4, respectively) (Fig. 3). Although statistical significance was not attained (probably due to insufficient sample size), we believe that this finding presents clinical significance on the basis of well-delineated differences in clinical behaviour among major patient subgroups.

### DISCUSSION

Temporary cardiopulmonary support has gained a pivotal role in the advanced treatment of patients affected by acute cardiac and/or lung failure [1]. Although expensive and highly demanding [7], ECMO therapy is greatly versatile, being adaptable to different strategies of cannulation and of support. Miniaturization allows portability of devices and implantation outside of the cardiac surgery theatre. A large body of literature is currently available over the early clinical results obtained with this approach within distinctive patient populations. The purpose of the present investigation was to provide a comprehensive picture of the current (2005-2013) ECMO activity in a tertiary referral centre and to decline the impact on the clinical outcomes of different modalities and indications to cardiopulmonary support. Specifically, a comparison of follow-up outcomes is expected to offer useful information for decision-making in critically ill patients and appropriate allocation of hospital resources.

In our global experience, about 4 over 10 patients receiving ECMO therapy will be alive at 6 months postimplantation. Such a result is considerable given the severe conditions of these individuals and the presence in our series of particularly complex cases at remarkable rates (implantation during ALS in 15% of cases, treatment of post-cardiomyopathy heart failure in 34% of cases). One major finding of the present study is that patients who survive the 30th postimplantation day display a globally steady survival over the later follow-up, irrespective of the indication to ECMO and to the modality of support (VA vs VV). Nonetheless, early outcome is greatly influenced by the indication to ECMO. Survival to hospital

---

**Table 2:** Comparison of baseline characteristics in VA vs VV ECMO patients

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>VA ECMO (n = 259)</th>
<th>VV ECMO (n = 64)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender: male</td>
<td>179 (69%)</td>
<td>47 (73%)</td>
<td>0.5</td>
</tr>
<tr>
<td>Age (years)</td>
<td>54 ± 15</td>
<td>49 ± 16</td>
<td>0.02</td>
</tr>
<tr>
<td>SAPS score</td>
<td>47 ± 23</td>
<td>47 ± 17</td>
<td>0.8</td>
</tr>
<tr>
<td>Body temperature</td>
<td>36 ± 2</td>
<td>37 ± 1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>implantation (°C)</td>
<td>2 ± 0.3</td>
<td>0.8 ± 0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Catecholamines (number ongoing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum creatinine (μmol/l)</td>
<td>171 ± 99</td>
<td>158 ± 115</td>
<td>0.38</td>
</tr>
<tr>
<td>Serum lactates (mmol/l)</td>
<td>7 ± 5</td>
<td>4 ± 3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>pH</td>
<td>7.32 ± 0.18</td>
<td>7.28 ± 0.15</td>
<td>0.11</td>
</tr>
</tbody>
</table>

**Table 3:** Comparison of in-hospital morbidity among VA vs VV ECMO patients

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>VA ECMO (n = 259)</th>
<th>VV ECMO (n = 64)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical ventilation time (h)</td>
<td>11 ± 13</td>
<td>20 ± 23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Duration of ECMO support (days)</td>
<td>7 ± 6</td>
<td>8 ± 8</td>
<td>0.1</td>
</tr>
<tr>
<td>(weaned patients only)</td>
<td>8 ± 7</td>
<td>9 ± 9</td>
<td>0.4</td>
</tr>
<tr>
<td>Thrombotic/haemorrhagic complications</td>
<td>162 (63%)</td>
<td>20 (32%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Packed RBC transfusion</td>
<td>220 (86%)</td>
<td>48 (86%)</td>
<td>0.9</td>
</tr>
<tr>
<td>Platelets transfusion</td>
<td>164 (65%)</td>
<td>20 (36%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FFP transfusion</td>
<td>163 (64%)</td>
<td>22 (40%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Infectious complications</td>
<td>91 (35%)</td>
<td>21 (33%)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Infectious complications included local and generalized infections, and sepsis. Haemorrhagic complications on ECMO were defined as the need to perform at least one surgical revision for bleeding and/or to transfuse at least 4 units of packed RBC to treat anaemia resulting from bleeding.

VA ECMO were observed in 15 patients (6%) only. Administration of blood products in VA ECMO was very frequent; while the rate of red blood cell transfusion was not different compared to VV patients, VA ECMO individuals presented significantly higher rates of transfusion of platelets and plasma units. This can be ascribed to the greater prevalence of early post-cardiomyopulmonary surgery and post-heart transplantation patients in the VA group. More prolonged mechanical ventilation time in VA patients essentially reflects the distribution of the underlying pathology (predominantly pulmonary in the VV group). We report longer duration of VA ECMO therapy than VA ECMO, both in the overall groups and among weaned patients only (Table 3). Although such difference did not reach statistical significance, it may reflect the tendency towards earlier removal of VA ECMO due to its expected heavier impact on patient morbidity (risk of limb ischaemia, of thromboembolic complications etc.).

In the global population, 15 patients (8% of survivors at ECMO explantation) were successfully bridged to heart transplantation. Similarly, 7 (3.7% of survivors at explantation) received a long-term implantable LV assist device for failure to recover adequate cardiac function. All these individuals had received VA ECMO, and heart transplantation was always performed on an urgent priority.
discharge may range between 27% in the most severe refractory cardiac arrest cases [8] and 43% after early graft failure (EGF) [9] or 56% in the setting of VV ECMO implantation for acute lung failure [10]. Despite remarkably different baseline profiles between VA and VV ECMO patients, in the present series we observed similar early and follow-up survival among these subgroups. Selection bias may exist due to the relatively limited number of VV patients ($n = 64$); continued follow-up and expanding experience may clarify this issue. In-hospital survival after VV ECMO for ARDS was lower in our series than in previous randomized trials supporting the efficacy of this strategy compared with conventional treatments [2]. This could be explained on the basis of severely compromised baseline patient conditions in our experience (PaO$_2$/FiO$_2$ ratio < 150). Worse results are reasonably expected without ECMO under these circumstances; novel randomized studies focused on this topic are currently ongoing.

We confirm previous data on worse results among patients receiving ECMO for post-cardiotomy myocardial failure. Our 36% survival at the 30th day compares well with the 38% survival rate observed in the Cleveland Clinic experience [11] and with the 24% rate of discharge observed in the Leipzig series [4]. Tendency towards improved results in more recent time can be observed [12]. One major study (enrolment period: 1996–2008) evidenced a remarkable difference among the rate of weaning from ECMO (63%) and the rate of hospital discharge (25%) of post-cardiotomy patients [3]. Such divergence was less evident in our experience (58.2% weaning-rate and 36% survival), which may be attributed to advances of care during ECMO support in more recent years. Patients receiving ECMO support for EGF display the best survival rates both at the 30th postimplantation day and at follow-up. Although EGF remains a severe and life-threatening condition, the employment of ECMO allowed to save about 64% of patients in

Figure 2: Kaplan–Meier survival curves. (A) Stratified according to the ECMO modality (AV vs VV). (B) Stratified according to age (cut-off: 65 years). (C) Stratified according to implantation under ALS. (D) Stratified according to pH (cut-off: 7). (E) Stratified according to serum lactates (cut-off: 10 mmol/l). (F) Stratified according to serum creatinine (cut-off: 200 μmol/l). *Log-rank P.
highly demanding under both the medical and economic perspectives; a broad spectrum of patient profiles is possible (as underlined by varying SAPS score among different sites of ECMO implantation). Therefore, integration of competences (surgery, intensive care, cardiology, perfusion and blood bank), teamwork and continuing training are pivotal. The rate of distinct ECMO-related morbidities (such as peripheral vascular complications) has dramatically decreased over the years due to a centre-volume and learning-curve effect. Standardization of decision-making then appears as a major objective to pursue in order to improve results. Ideally, the analysis of multi-institutional databases may allow the development of dedicated scores to predict the chances of survival after ECMO therapy in individual patients.

The present study is limited by its retrospective nature and by the heterogeneity of the patient cohort. No stratified analysis was possible for peripheral vs central cardiopulmonary support due to limited sample. Nevertheless, we illustrate a direct outcome comparison among different patient subgroups issued from a multidisciplinary collaboration in a large-volume tertiary centre. To the best of our knowledge, this is the first investigation providing such a comparison with respect to follow-up survival. These findings may be helpful for evidence-based decision-making and allocation of hospital resources. Additionally, these data may provide the conceptual basis for the potential of development of a dedicated ECMO risk model and score, to assist the clinician’s judgment in these difficult cases. Inclusion of a heterogeneous patient population in the present analysis is justified given the latter purpose.

CONCLUSIONS

ECMO is now a standard-of-care and allows saving critical patients with acute cardiopulmonary failure. Analysis of stratified late survival and of determinants of outcomes is pivotal in facilitating a complex decision-making in this field. Motivated and trained teams are mandatory to develop such a programme.

ACKNOWLEDGEMENTS

The authors are grateful to Pascale Rouault and Veronique Desriac for the collection of data and to Anne Ingels for her invaluable help in data analysis.

Conflict of interest: none declared.

REFERENCES

APPENDIX. CONFERENCE DISCUSSION

Dr R. Lorusso (Brescia, Italy): Yours is an impressive experience, and I think it’s a very good piece of work. But I have a few short questions.

I didn’t understand why you considered 60 patients as refractory cardiac arrest cases, but you actually had 47 patients under external cardiac massage. Was there any difference in definition? Because this, as you showed, is also a predictive factor for mortality.

Dr Fletcher: That was the primary indication. For example, if we were called for cardiac arrest, the indication was cardiac arrest. But sometimes we were called for cardiogenic shock, for I don’t know, acute MI, but when we arrived, or during the ECMO implantation, the patient had a cardiac arrest. But the indication was cardiogenic shock. That’s how we decided to fill the database.

Dr Lorusso: I see. Secondly, I noted that you always implanted a limb perfusion when you performed peripheral ECMO, but still you had 15 patients suffering from limb ischaemia despite the distal perfusion. Could you comment on that? Do you think that in some patients this is not sufficient?

Dr Fletcher: No, I think there is a learning curve. You’re right, we do implant a catheter for perfusion of the leg in all our patients. However, in the beginning I think we were using catheters which were too small for perfusion. Now we are implanting 7, 8, 9, 10 French. Recon perfusion catheters more frequently, that is the first point. Secondly, in the beginning, the catheter was fixed outside at skin level. Now we implant this perfusion catheter inside the wound, completely inside, so there is no kinking of the catheter. I think that’s all.

Dr Lorusso: Another question concerns the use of the intra-aortic balloon pump, because I saw that 15% of your patients had a balloon pump before ECMO. What is your management and your strategy when you implant a VA ECMO? Do you always implant an intra-aortic balloon pump, or not?

Dr Fletcher: Well, I don’t know. What is certain is that if a patient already has an intra-aortic balloon pump implanted, we will keep it rather than remove it. And should we remove it after ECMO implantation and when? I’m not sure and I don’t know when. Should we systematically add an intra-aortic balloon pump to all patients on ECMO? That’s a question I have no answer for yet. Maybe. I know some surgeons used to add the intra-aortic balloon pump. I don’t know. If the balloon is already there, I keep it, but I don’t add it.

Dr A. Lofarte (Bologna, Italy): We know that one of the limitations of the femoro-femoral ECMO support is low oxygenation of the upper part of the body. Why didn’t you ever use a subclavian vessel as a return? And a second question: I’m surprised that you have a really high rate of peripheral VA ECMO. But what do you do if you have insufficient loading of the veins or insufficient circulation due to the small diameter of the cannulas? You never switched to central ECMO?

Dr Fletcher: Yes, we did, but very rarely. First, I think you can have good flow even in femoral vessels, but you need a big venous cannula to have good drainage. But what do you do if you have insufficient unloading of the ventricles or insufficient unloading of the ventricles or insufficient breathing. We had more bleeding. But maybe it’s because we didn’t do it enough. Maybe if we had, I don’t know. But we were able to manage the patient with peripheral ECMO not so badly, so we keep it as a reference in our centre.

And we did few, very few, subclavian artery ECMO. But in real life it’s not so easy. Because in real life it’s always two in the morning, during the night, and the patient is not well at all, you don’t have everybody available, so it’s much quicker in intensive care to perform a femoro-femoral ECMO. A subclavian artery ECMO is more difficult to do. You have to place a graft. So in real life it’s why we did mostly femoro-femoral ECMO, but we did very small number of subclavian artery ECMO.

Dr F. Beyersdorf (Freiburg, Germany): I also would like to comment upon this because cerebral hypoxia is a very severe complication on ECLS, and therefore the question is: Did you always measure the oxygen content in the right radial artery? Because that’s a diagnostic tool. And if it’s lower, then you have to do something, otherwise you will have cerebral problems afterwards.

Dr Fletcher: Yes, we do. And the ones we switched were either for central ECMO and a few for subclavian artery ECMO.

Dr D. Saeed (Dusseldorf, Germany): I have a similar kind of question. Do you see any outcome difference between peripheral and central ECMO in your cohort?

Dr Fletcher: I’m not sure we checked, because we’ve got only 20 central ECMO, and I didn’t have a look in that. I don’t know. What is sure is if we go for central ECMO, we will add a vent; but we also had thrombosis in the vents in the 20 ECMO. I think like half of the patients have a thrombosis of the left ventricular vent during the central ECMO, maybe because the vent was not big enough. So we had some issues with the central ECMO and we had much more bleeding, much more blood transfusions, but I didn’t check if there was a significant difference between both groups.