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■ Original Article ■

Inter-Hospital Transportation of Patients on Extracorporeal Life Support: A Single Center Experience

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Background: Extracorporeal life support (ECLS) is an effective life-saving tool for patients in refractory cardiac or respiratory failure. Although transportation of patients on ECLS is challenging, it is necessary in some instances. We report our initial experience of transporting patients on ECLS.
Methods: The study period was between January 2004 and August 2013. We reviewed our ECLS database and identified four patients who were transported to our institution on ECLS. We excluded patients who were not transported by our ECLS team.
Results: There were no clinically significant events during transportation. ECLS indications included acute respiratory distress syndrome in two patients, stress-induced cardiomyopathy induced by pneumonia sepsis in one patient, and cardiac arrest caused by amyloid cardiomyopathy in another patient. One patient was transported by helicopter and three patients were transported in an oversized ambulance. Three patients were successfully weaned off ECLS and discharged without significant complications.
Conclusions: Inter-hospital transport can be safely performed by an experienced ECLS team. Successful transport may improve patient outcome and the ECLS programs of both referring and referral hospitals.

Key Words: extracorporeal circulation; extracorporeal membrane oxygenation; transportation.

INTRODUCTION

Extracorporeal life support (ECLS) is a useful tool for patients in refractory cardiac or respiratory failure. Studies have demonstrated that ECLS is effective as both a bridge to recovery and bridge to transplantation.[1-3] Modern ECLS machines are generally easy to prime and rapidly applicable with percutaneous peripheral cannulation. In Korea, our group reported the first successful use of percutaneous ECLS in 2004.[4] Since 2004, successful ECLS transportation cases have increased, and the total number of cases was approximately 1,494 in 2012 (unpublished data from Korean Health Insurance Review & Assessment Service). Although ECLS in Korea is increasing in popularity, the number of medical centers with sophisticated systems is insufficient. Thus, there is a need for inter-hospital transportation of patients on ECLS, and referral and transport may improve clinical outcomes.[5] Because moving such a critically ill patient is complicated, the process of transportation should be performed in a systematized and cooperative manner (Fig. 1). We reviewed our experiences with inter-hospital ECLS patient transportation.

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METERIALS AND METHODS

This study focused on patients who were transported to our center from other institutions by our ECLS team from January 2004 to August 2013. We excluded patients who were transported by the physicians from other hospitals. We also did not

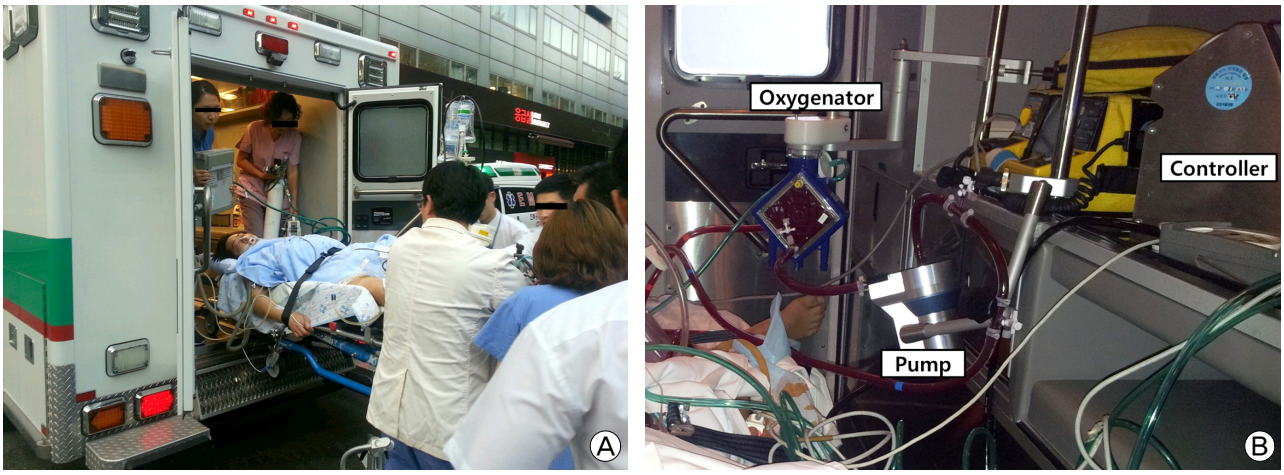

Fig. 1. Photograph of patient no. 2: The pump controller, centrifugal pump, and oxygenator are well placed in the ambulance. The system and patient are continuously monitored (A). Seven people collaborated to move this patient from the ambulance (B).

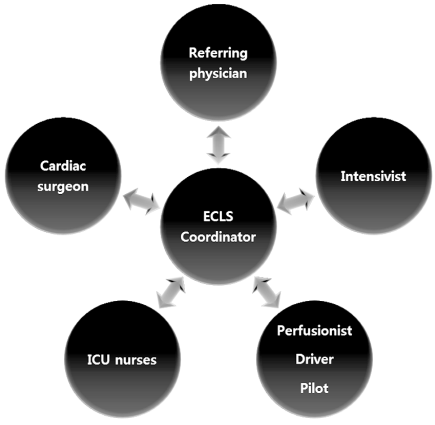

Fig. 2. Diagram of the collaborative process of transporting a patient on extracorporeal life support.

include patients who were sent to other hospitals by our hospital system. The hospital day was counted from the day of initial admission.

1) Transportation

The initial transportation request was made through the Samsung Medical Center referral system or directly to an ECLS team physician. Our ECLS coordinator arranged two physicians including an intensivist who would care for the patient in our intensive care unit, and a physician who would oversee transportation. The coordinator also arranged a perfusionist and a nurse, or an emergency medical technician, who would participate in the transportation process (Fig. 2).

We prefer to use the Prolonged Life Support System (PLS, Maquet Inc., Rastatt, Germany), because it is furnished with a manual crank which is useful when the battery is not charged. We used an emergency bypass system (EBS, Terumo Inc, Tokyo, Japan) if PLS was not available. We also prepared a ready-to-use circuit for system exchange if the patient was on a different system prior to transport.

We usually requested to minimize the number of continuous intravenous medicines because we had to prepare the same number of infusion pumps. In cases involving helicopter transport, we asked for medicines to be prepared in a 50-ml syringe to fit the built-in syringe pumps in our helicopter.

2) Device management

If the patient was on a PLS system, we simply changed the device to our PLS system. If the patient was on an EBS system, we attempted to change the system to our PLS system before transport. When our PLS system was not available, we used an EBS system with a Quadrox-D oxygenator which is more durable than the original EBS oxygenator. The circuit change was performed by our transport leader.

3) Family management and consent

Prior to transportation, our team leader met with family members to explain the risks and benefits of transport. Because there is some degree of risk in transporting an ECLS patient, a thorough interview with family members is mandatory. We did not receive written consent. For helicopter transport, one family member was allowed to accompany the patient in the vehicle, because a family member is often needed for paperwork and consent. For ambulance transport, the family was advised to follow the ambulance and was not permitted to accompany the patient in the transport vehicle.

RESULTS

1) Case 1

A 42-year-old female patient was admitted to another facility for dyspnea and lower leg edema. On hospital day 3, the patient had a sudden cardiac arrest and underwent venoarterial ECLS. We were contacted by the patient's physician for further evaluation and management. Using an ambulance and our EBS system, we brought the patient to our center without complications.

On arrival, the patient was alert without any signs of neurologic damage. We inserted an intraaortic balloon pump to facilitate ECLS weaning. The patient was weaned off ECLS on hospital day 8. The intraaortic balloon pump was removed on hospital day 11. A cardiac muscle biopsy revealed cardiac amyloidosis with severe left ventricular systolic dysfunction.

The patient's condition improved and she was transferred to the general ward on hospital day 20. However, she had pancytopenia and a fever. She had sudden cardiac arrest on hospital day 24. After cardiopulmonary resuscitation, she received intensive care again. Although the patient recovered slowly, neither she and nor her family desired further treatment. The patient signed a do-not-resuscitate order and she died on hospital day 33.

2) Case 2

A 35-year-old male patient was referred to our hospital. Initially he was admitted for pneumonia, but he became hypotensive in spite of antibiotic therapy. Finally, he was placed on venoarterial ECLS because of stress-induced cardiomyopathy on hospital day 5.

His intensivist and family wanted to transfer him to our hospital and contacted us for further management. The hospital where he was receiving treatment was 157 km from our facility. We considered helicopter transport, but there was no landing site in close proximity to the referring hospital. We drove to the hospital in an ambulance with a PLS system. On arrival, we changed the patient's ECLS machine to our PLS system and transported the patient to our center without complications (Fig. 1).

We were able to wean the patient off ECLS on hospital day 13. The next day the patient was extubated and continued on antibiotic therapy. He was discharged without significant complications on hospital day 21.

3) Case 3

A previously healthy 10-year-old boy was caught beneath a large sport utility vehicle. He was admitted to another institution and suffered from bilateral hemo-pneumothorax and respiratory distress syndrome. Despite ventilator care, his pulmonary function worsened and he ultimately was placed on venoveno ECLS on hospital day 11. Because there was severe air leakage from the chest tube, he underwent thoracoscopic lung repair. However, there was severe bleeding which required reoperation. He was referred to us for further management on hospital day 16.

We used an ambulance as the transporting vehicle and a PLS system for ECLS. We changed the patient's ECLS system to ours on arrival. The driving distance to the referring hospital was 41 km and the duration of transport was 42 minutes. The transport was successful without complications. We reopened the chest, controlled the bleeding and removed the hematoma for the left hemothorax immediately after transfer. He was completely dependent on the artificial lung and his tidal volume was less than 50 ml at a plateau pressure of 30 cmH_2O. We let the patient awake since he was tolerable with the ECLS. His recovery as slow, but we were able to remove ECLS on hospital day 48. He was discharged 68 days after the motor vehicle accident.

4) Case 4

A 40-year-old male patient was referred to us for transportation and further management. He had an inhalation lung injury from a fire accident. After 2 days, he was not able to be oxygenated adequately by a ventilator. Venovenous ECLS was initiated via the femoro-femoral approach.

After communicating with the patient's physician, we concluded that he was completely dependent on ECLS for oxygenation and the ECLS flow was not stable. To reduce transport time, we decided to use a helicopter. This was our first experience transporting a patient on ECLS by helicopter. We prepared for the helicopter flight with extensive discussion and simulations and then transported the patient to our institution.

While he was still in the referring hospital, we exchanged our EBS system for the device that the patient was using. ECLS flow can be quite variable according to the patient's posture and movement. During transportation, his arterial oxygen saturation was unstable between 80% and 90%. We performed meticulous ventilator and ECLS management in the vehicle.

On arriving at our hospital, the ECLS cannulation was modified to the internal jugular-femoral configuration from the femoro-femoral for stable ECLS. The patient suffered from severe infection including bacteremia and pneumonia. There was also a severe airway burn injury. The patient was successfully weaned off ECLS on hospital day 7. Sixteen days after the fire event, he was weaned from a ventilator. Although the airway injury recov-

Table 1. Patient profile and transportation summary

Patient number	Sex/Age (yr)	Diagnosis	ECLS type	Mode of transport	Travel distance	Pump	Oxygenator	ECLS weaning	Survival to discharge
1	Female/42	AMI	VA	Ambulance	17 Km	Terumo SP	Terumo EBS	Yes	No
2	Male/35	SCMP	VA	Ambulance	157 Km	Rotaflow	Quadrox	Yes	Yes
3	Male/10	ARDS	VV	Ambulance	41 Km	Rotaflow	Quadrox	Yes	Yes
4	Male/40	ARDS	VV	Helicopter	30 Km	Terumo SP	Quadrox	Yes	Yes

ECLS: extracorporeal life support; AMI: acute myocardial infarction; VA: venoarterial; SCMP: stress induced cardiomyopathy; ARDS: acute respiratory distress syndrome; VV: venovenous.

Table 2. Patient clinical outcomes

Patient number	ECLS weaning	Days on ECLS	Survival to discharge	Total hospital stay	Residual disability
1	Yes	5	No	28	NA
2	Yes	8	Yes	22	None
3	Yes	32	Yes	68	None
4	Yes	5	Yes	55	Vocal cord dysfunction

ECLS: extracorporeal life support.

ered slowly, the patient's ability to swallow was not satisfactory. We performed percutaneous gastrostomy and discharged him 55 days after the fire accident.

A summary of the patients' profiles and outcomes are shown in Tables 1 and 2.

DISCUSSION

The use of ECLS for refractory heart or lung failure has been on the rise in Korea and many other countries due to the technical innovation of extracorporeal circulation. The device is available in most large hospitals in Korea and most physicians working in the intensive care unit are familiar with a percutaneous cannulation technique. Because patients requiring ECLS can have many different cardiac or pulmonary problems and complications from ECLS, such as thromboembolism, bleeding, limb ischemia, or left ventricular distension, the process of initiating ECLS support and weaning patients from ECLS can be complex and difficult.[6] Furthermore, family members may want to move the patient for better care or for convenience. Because of the short history of ECLS in Korea and the lack of experience, many physicians are reluctant to allow a patient on ECLS to be transported to another institution.

We started the first ECLS program in Korea and we have received many patients on ECLS from other institutions since then. From these experiences, we have found ECLS transport must be managed differently from other relatively simple transportation. There are many difficulties that should be considered with regard to ECLS transport, including many intravenous medicine adjustments, dual oxygen supply for the ventilator and ECLS, the patient's posture, body temperature, ECLS circuit change, battery and electricity. Therefore, we established an ECLS transportation program at our medical center. The referral was accepted only when we have an available bed in the intensive care unit and an available ECLS device. We did not consider transporting a very unstable or futile patient. Otherwise, we accepted all transport requests.

The ECLS transportation program is a comprehensive patient referral and care process.[7,8] Our SMC referral center, coordinator, critical care physicians, and cardiac surgeons are involved in the entire transportation process. After initial contact, the risks and benefits for patients are extensively discussed. When a patient is selected for transport to our facility, the referral center and our ECLS coordinator communicate with the team of the referring hospital. After the patient arrives at our center, a quick examination and decisions about further treatment are made immediately and the patient is given a hospital identification number. This process has been possible since March 2013, when the department of critical care medicine was organized in Korea. Since then, we have experienced three consecutive cases of successful transportation and aftercare of ECLS patients (patients 2-4).

There were some limitations to this study. We had a small number of cases and the duration of the ECLS transportation program was relatively short (1 year). This was a retrospective observational study without a control group. However, we are summarizing and sharing our initial ECLS transportation experiences and emphasize the importance of planned and sophisticated transportation.

In conclusion, there are situations that require inter-hospital transportation of a patient on ECLS. Our experience shows that the collaborative team approach may improve not only trans-

portation safety, but also patient outcomes.

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