

Inter-hospital transports on extracorporeal membrane oxygenation in different health-care systems

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Abstract: The feasibility and the recognition of the possibility to transport patients on extracorporeal membrane oxygenation (ECMO) aroused in the 1970s. The number of transporting facilities worldwide was less than 20 in the beginning of the second Millennium. In 2009 the H1N1 pandemic and a publication showing survival benefit for adult patients transported to a hospital with ECMO resource increased both awareness and interest for ECMO treatment. The number of transport organizations increased rapidly. As of today, the number of transport organizations increases world-wide, though some centers where ECMO is an established treatment report decreasing numbers of transports. Since the introduction of the more user-friendly equipment (ECMO-2 era) increasing numbers of low-volume ECMO centers perform these complex treatments. This overview is based on the current literature, personal experience in the field, and information from the authors' network on the organization of ECMO transport systems in different settings of health care around the globe. Registry data since the entry into ECMO-2 shows that the number of ECMO treatments matter. The more treatments performed at a given center the better the patient outcome, and the better these resources are spent for the population served. A Hub-and-Spoke model for national or regional organization for respiratory ECMO (rECMO) should be advocated where central high-volume ECMO center (Hub) serves a population of 10 to 15 million. Peripheral units (Spokes) play an important part in emergency cannulations keeping the patient on ECMO support till a mobile ECMO team retrieves the patient. This ECMO team is preferably organized from the Hub and brings competencies for assessment and decision to initiate ECMO treatment bedside at any hospital, for cannulation, and a safe transport to any destination. To conclude, most ECMO transport organizations are reflections of the health care paradigm within which they act. Most transport organizations are established by the staff within who recognize the need. The legal space seems open in most countries; anyone may set up a transport organization anywhere. Quality follow-up varies. Some keep track of adverse events and report whereas most transport entities do not seem to prioritize this. There is no international body for ECMO transports. Such would be the key for definitions, support, networking, and a registry that successively would increase knowledge concerning adverse events, morbidity and mortality.

Keywords: Extracorporeal membrane oxygenation (ECMO); transport; mobile; inter-hospital; organization

Submitted Jun 20, 2017. Accepted for publication Jul 17, 2017.

doi: 10.21037/jtd.2017.07.93

View this article at: <http://dx.doi.org/10.21037/jtd.2017.07.93>

Introduction

Since 1975 when the very first inter-hospital transfer of a patient on Extracorporeal membrane oxygenation (ECMO), a procedure later described by Bartlett *et al.* (1), the need for transports have continuously increased. During the following three decades, a limited number of ECMO centers performed transports on ECMO. However, shortly after the onset of the H1N1 pandemic between 2009 and 2010 such transport systems became a necessity. Some countries had the experience and an infra-structure for long distance transports of intensive care patients, but less experience of transports on ECMO (2). In a short timeframe emergency hospitals and intensive care departments had to organize and establish routines for transfers of patient on ECMO. The international experience suggested transports on ECMO to be safer as compared to a transfer of an unstable refractory respiratory failure patient supported with conventional ventilation (3,4). At that time information and support was to be found at centers that already had well developed ECMO transport organizations and years of experience from more than 100 transports (5-8). Today the Extracorporeal Life Support Organization (ELSO), publish guidelines that are updated regularly (9).

The CESAR trial by Peek *et al.* (4) 2009 that showed benefit also for adult patients treated on ECMO compared to conventional ventilation was timely published as the H1N1 pandemic started to sweep around the globe. Regarding survival, the ECMO treated H1N1-population seemed to benefit (10). As the pandemic struck younger people several governments increased reimbursement to health care which boosted the development of adult respiratory ECMO (rECMO). At that time the thoracic and general intensive care units (ICU) performing rECMO was geographically not as dense as today. In less than a decade ECMO became more than just a method for postoperative cardiac failure. rECMO developed into an accepted last resort organ supportive therapy for the surgical and medical ICU patients with severe refractory respiratory and/or combined cardiac and respiratory failure, e.g., acute respiratory distress syndrome, and septic syndromes including cytotoxic heart failure (11). In context of timing, the H1N1 pandemic did speed up development of ECMO products and the ECMO-2 era (12-14) was entered with new approaches to patient care: more user friendly and improved designs of centrifugal pumps, membrane lungs, and dual lumen cannulae for veno-venous ECMO. The new equipment became available for most of the industrialized world.

During the first five years or so after the pandemic the

awareness about the benefit from ECMO increased and several organizations for mobile ECMO were started. The total number of adult ECMO treated patients and need for transfers increased. In parallel hospitals started to add "ECMO center" to their curriculum. This was to be expected after the almost simultaneous entry into ECMO-2 (12), the CESAR trial results (4), and the observed favorable outcome of the H1N1 patients. Although the total number of adult ECMO treatments still increase, in the last few years some ECMO centers with transport capacities report decreasing numbers of ECMO retrievals. The explanation given suggests the fact that more ICUs in the periphery perform ECMO themselves. Will this be safe?

Overview and results

Several studies based on data from the ELSO Registry (9) with today more than 450 member centers and 89,000 ECMO treatments, all show the number of annual ECMO runs to correlate to survival. The higher the number, the better the outcome. For the pediatric and neonatal populations (15,16), the cut-off is to perform at least 20 to 30 annual ECMOs runs to do significantly better than the low-volume centers (defined as five or fewer runs per year). Further, the lower limit for a positive learning curve and maintenance of competence require at least 20 treatments per annum. A center performing 31 or more annual treatments decreases odds ratio for mortality by 40% compared to the low-volume unit (17). For adult rECMO, Combes *et al.* (18), ECMONet, proposed the lower number to be 12 rECMOs at a center performing a minimum of 20 treatments per year. Their proposal for the organization of adult rECMO was to consolidate all rECMO patients to regional or national high-volume rECMO centers preferably at tertiary hospitals serving approximately a population of two to three million. A more realistic population size calculated from actual incidence figures for adult ECMO requiring acute respiratory failure of 0.40/100,000 and year (unpublished data), would be 10 million for a center treating all ages and 15 million if only treating adults. The conclusion was based on best interest for the population served concerning costs, resources spent, complications, and above all increased survival. Hence, it is hard to find arguments to defend the continuance for a provider of rECMO who performs less than 20–30 annual treatments, unless there is no one to partner up with. The latter would not occur in many industrialized countries today. On the other hand, it is the

only way to go when evolving in most parts of the world where ECMO is not established.

Today, well developed systems for mobile ECMO are run in the United Kingdom (19,20), Australia (2,21), Italy (10,22-24), France (25,26), Sweden (7,27-29), and the USA (5,30-33). Regional differences may exist within the same country, and the situation in total is not as uniformly organized in Germany (34), France (35,36), Belgium (personal communication), or South Norway (37). Many hospitals around the globe are in the phase of starting, or have a few years of active duties but the number of transports are low as in Brazil (38), Qatar (39), Japan and the University Hospital of North Norway (personal communication).

Different health care systems, staff and the organization of their mobile teams are different. It is more the local experience, climate, health care culture, and funding and resources that form how these teams finally will be organized, staffed etc. (2,15,23,24,30,31).

When looking for general information concerning legislation, regulations and requirements concerning the actors in different countries, there is very little or no control by governmental authorities or bodies. In most countries, any health care provider or even private companies may start a transport company, even for ECMO patients. Legislation and permits seem to be of importance when it comes to the billing for costs, e.g., in the USA. To date, one private company offer ECMO transport services in USA. In the United Kingdom, the National Health Service (NHS) (19) mandates the number of ECMO centers.

Discussion

The “Hub-and-Spoke” model was introduced by Combes *et al.* (18). The high-volume ECMO center serves as the hub in a wheel where the spokes constitute centers with the capability and experience to commence ECMO and support the patient for hours or days till that individual can be transferred to the high-volume unit by a mobile ECMO team. In situations of a new pandemic or major catastrophe, the resources at the high-volume center may be best utilized in treating the more severe and complex cases, but the “straight-forward” rECMO runs could be performed at these cooperating hospitals (spokes). In the Hub-and-Spoke model the ECMO transport organization is proposed to be located at or best integrated in the high-volume ECMO center’s organization.

To offer ECMO services with patient’s best and the economy of the population served as first priorities, safe and

effective ECMO transport organizations are required. The rationale for the mobile ECMO teams is to assess, decide and commence ECMO fast and safe before transferring that patient to the high-volume ECMO center.

What is a safe transport? Arriving alive with no adverse events during the transport seems reasonable. What about disability free survival (40)? Not much has been published concerning adverse events and complications. In fact, there are no solid or uniform definitions. Not much has been reported concerning fatalities during transport either. The largest retrospective study on complication by Ericsson *et al.* (29) showed life threatening complications to occur in at least one of 30 transports. The sum of all adverse events that required some decision occurred in approximately 30% of the 514 scrutinized ECMO transports. The authors suggested a risk grading for adverse events during ECMO transports. Of the 89,000 treatments in the ELSO Registry, a significant number would have been transported between hospitals on ECMO and incidents have passed, but most likely not been reported. Maybe the teams do not have the tools or experience to take note of the minor events that may present an early warning for the big catastrophe? “*What you don’t look for, you won’t find.*”. Or the lack of full transparency caused by a competitive environment. On the other hand, there are no international definitions of “Adverse events”. There is no major database or registry from which data can be retrieved.

Conclusions

The Hub-and-Spoke model for national or regional organization for rECMO should be advocated. A central high-volume ECMO center serves a population of approximately 10 million if serving all age groups, or 15 million if an adult rECMO center. In the model surrounding cooperative units take an important part in support for emergency cannulation and keeping the patient on ECMO support till a mobile ECMO team transfers the patient elsewhere.

The mobile ECMO team is preferably organized from the high-volume ECMO center. The mobile ECMO team should have experience in prehospital emergency care, ECMO and critical care, ECMO technology and physiology. The team brings competencies for assessment and decision to initiate (or defer) ECMO treatment bedside, for cannulation, and a safe transport to the planned destination.

It seems as if most ECMO transport organizations are reflections of the health care system they act within. Most are creations of their own. Some keep track of

adverse events, most probably do not, at least nothing is reported. There are to date no international body, or any other mutual organization dealing with the ECMO transport issues, definitions and concerns. A registry would successively build up data over time leading to knowledge concerning adverse events, morbidity and mortality. At present we will listen to the high-volume ECMO transport organizations and learn from them, and hope they do follow-ups and make these public.

If a society finds ECMO to bring back good value for its population, the most cost effective way in most part of the world would be to strive to organize in accordance with the Hub-and-Spoke model. Thus, mobile ECMO teams will be around for years to come.

Acknowledgements

The author is thankful to Associate Professor Jan Hultman, ECMO Centre Karolinska, for editing the language.

Footnote

Conflicts of Interest: LM Broman is a member of the independent research consortium European ECMO Advisory Board, the EuroELSO Workgroup for Innovative Technologies, and the ELSO Workgroup for Adult ECMO. LM Broman is also a member of the Medical Advisory Board of Eurosets Srl, Medolla, Italy.

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Cite this article as: Broman LM. Inter-hospital transports on extracorporeal membrane oxygenation in different health-care system. *J Thorac Dis* 2017;9(9):3425-3429. doi: 10.21037/jtd.2017.07.93