Hospital Costs Of Extracorporeal Life Support Therapy

Annemieke Oude Lansink-Hartgring, MD¹; Berber van den Hengel, MD¹; Wim van der Bij, MD PhD²; Michiel E. Erasmus, MD PhD³; Massimo A. Mariani, MD PhD³; Michiel Rienstra, MD PhD⁴; Vladimir Cernak, MD PhD⁵; Karin M. Vermeulen, PhD⁵; Walter M. van den Bergh, MD PhD¹; on behalf of the Dutch Extracorporeal Life Support Study Group

Objectives: To conduct an exploration of the hospital costs of extracorporeal life support therapy. Extracorporeal life support seems an efficient therapy for acute, potentially reversible cardiac or respiratory failure, when conventional therapy has been inadequate, or as bridge to transplant, but unfortunately, no evidence in randomized controlled trials is delivered yet.

Design: Single-center retrospective exploratory cohort cost study. The study is performed from a hospital perspective with a time horizon of patients' complete hospital admission in which they received extracorporeal life support.

Setting: ICU of a university teaching hospital in The Netherlands.

Patients: All 67 consecutive adult patients who were admitted to the ICU of the University Medical Center Groningen in the period 2010–2013 and received extracorporeal life support treatment.

Intervention: None.

Measurements and Main Results: The bottom-up microcosting method was used except when stated otherwise. Medical costs were estimated by multiplying every registered healthcare consumption with unit prices. Unit prices were largely based on Dutch reference prices. For each patient, the personnel costs and material costs were assessed in detail. The costs of extracorporeal life support were differentiated in costs of procedures and costs of daily surcharge of therapy. Procedure-related costs were subdivided in costs of devices and disposables, costs of additional human resources, and surgery hours. The mean total hospital costs were €106.263 (€83.841 to €126.266) per patient ($145,580). On average, 52% of the total costs arose from hospital nursing days and 11% of direct procedure-related extracorporeal life support costs. Surgery and diagnostics represented a vast amount of the remaining costs.

Conclusions: This large and detailed economic evaluation of hospital costs of extracorporeal life support therapy in the Netherlands showed that mean total hospital cost of extracorporeal life support treatment is €106.263 per patient. The majority of the costs are composed of nursing days. (Crit Care Med 2016; 44:717–723)

Key Words: cost analysis; critical care; extracorporeal life support; hospital costs

The indication for extracorporeal life support (ECLS) by means of extracorporeal membrane oxygenation (ECMO) is acute, potentially reversible cardiac or respiratory failure, when conventional therapy has been inadequate (1). In addition, ECLS can also be used in patients with chronic respiratory or cardiac failure as a bridge to transplant and to support cardiopulmonary resuscitation, that is, extracorporeal cardiopulmonary resuscitation (ECPR) (2).

ECLS seems an efficient therapy for cardiac and respiratory failure, but unfortunately, no undisputed evidence in randomized controlled trials has been delivered yet. The increased use during the H1N1 pandemic in 2009, the Conventional ventilation or ECMO for Severe Adult Respiratory failure trial published that same year, and advances in device technology...
enhanced interest in the utilization of ECLS in adults (3–5). The CESAR trial was the first adult trial performed for cost comparison between ECMO-based management and mechanical ventilation for severe adult respiratory distress syndrome (ARDS). Mean healthcare costs per patient were more than twice as high for patients allocated to consideration for treatment by ECMO than for those allocated to conventional management. Mean healthcare costs in the first 6 months per patient in the ECMO-based group were $119,551 (5).

Scarc resources are a reality in healthcare systems, and major concerns exist about rising costs. There is a constant challenge to maximize health benefits within the resources available, which increases the search for cost-effective therapies (6). Interpreting and comparing cost-effectiveness of ECLS between studies are technically difficult because methodology in cost analyses varies significantly, which makes direct comparisons between patient populations difficult.

Because ECLS is an established therapy in neonates and, to a lesser account, in pediatric patients, most economic evaluations involve these patient groups (7–12). In neonatal patients, the largest prospective economic evaluation concerned 185 neonates with severe respiratory failure and was conducted alongside a randomized controlled trial. This study and the later published Cochrane review showed that ECLS was cost-effective in neonates with severe respiratory failure (8, 13). ECMO generated an incremental cost per life year gained of £13,385 ($21,630) and an incremental cost per disability-free life year gained of £23,566 ($38,082) over a 7-year time horizon (8).

The Netherlands has a private healthcare insurance system where every person has a mandatory insurance with a standard premium independent of income. This insurance covers most essential care, that is, specialist care in hospital. Although there is a registration of ECLS in the hospital administration in the Netherlands, it does not lead to a separate financial compensation; in other words, the reimbursement is the same regardless of the patient received ECLS or not.

Currently, no detailed information on hospital costs of ECLS therapy is available.

The primary aim of this study was therefore to conduct a detailed exploratory cost assessment to gain insight into the hospital costs related to ECLS therapy.

**PATIENTS AND METHODS**

**Study Design**

We performed a single-center retrospective exploratory cost study in the University Medical Center Groningen (UMCG) in the Netherlands. All consecutive patients (more than 18 years old) who were admitted to the ICU of the UMCG in the period 2010–2013 and received ECLS treatment (Maquet Cardiohelp) were included in this study. The cost study is performed from a hospital perspective with a time horizon of patients’ complete hospital admission in which they received ECLS. The bottom-up microcosting method was used for all cost calculations unless stated otherwise.

**Study Endpoints**

The primary endpoint was the hospital costs. Secondary endpoint was hospital mortality.

**Data Collection**

Our analysis is largely based on prospective gathered data derived from the Dutch National Intensive Care Evaluation (NICE) registry. In the NICE registry database, demographics, the presence of chronic diseases and comorbidities, reason for admission, ICU course, and outcome characteristics are prospectively collected for every ICU patient.

Patient medical records and patient records of the clinical perfusion department were analyzed to collect data regarding indication and duration of ECLS therapy and information about surgical technology and procedures during ECLS therapy. Information on healthcare consumption of all included patients was used to estimate costs during hospitalization.

Regarding the costs directly related to the ECLS intervention itself, a distinction was made between costs of additional human resources, surgery hours, and costs of devices and disposables. Costs were divided in mean costs of ECLS positioning and procedures and costs of daily surcharge of ECLS therapy. The costs for ECLS procedures, such as connection to ECLS, a cannula or system change, and the removal of ECLS, were independent of duration. The daily surcharge of ECLS therapy was dependent of duration of ECLS therapy.

Four ECLS procedures were assessed in detail for all patients: ECLS connection, ECLS cannula switch, ECLS system switch, and ECLS removal. For each patient, the personnel costs and material costs were assessed in detail. Extra personnel costs were estimated by expert opinion or by analyzing real-time procedure durations. If an ECLS procedure was performed during another surgery, for example, cardiac surgery or lung transplantation, no extra personnel costs were calculated; the ECLS procedure was considered to be part of the surgery. The location where a procedure took place and the cannulas used were extracted in detail from the patient files. In this way, a price per procedure per patient was calculated. For each procedure, the costs of all patients were averaged, so that a mean costs per procedure could be allocated to each patient.

Apart from the costs of the four ECLS procedures, a daily surcharge for the use of the ECLS was calculated. With regard to the daily personnel costs, expert opinion indicated that a resident or intensivist spends no extra time on the daily care of an ECLS patient, compared with a general ICU patient. This time for direct patient care is included in the standard price for one nursing day according to Dutch reference prices. The perfusionist visits the patient three times a day, and in contrast with the time spent by nurses and ICU physicians, the perfusionist working hours are not included in the price for one nursing day and thus added to the total costs. Also, a daily price for the depreciation of the device used for ECLS is calculated in accordance with the step-by-step plan postulated by the Dutch manual for costing (14). The daily surcharge for one ECLS day is set on €313.15 based on €79.50 for the work of the perfusionist and €233.65 for daily depreciation of the ECLS. The daily costs for ECLS use are determined for each patient separately.
Data collection for cost analysis was performed by analyzing healthcare consumption. Medical costs were estimated by multiplying registered healthcare consumption with unit prices. Unit prices were largely based on Dutch reference prices in order to facilitate comparisons with other economic evaluations (14). When standard prices were not available in the context of this current study, medical costs were estimated by consulting the hospital financial records to retrieve the most recent (2012) hospital unit prices. Because this economic evaluation is performed from a hospital perspective and covers the hospital admission in which the patient receives ECLS therapy, only the direct medical costs were included for cost analysis. For example, transports to the hospital and out-patient visits are not included in these costs.

In our evaluation, prices were used from different years. These prices need to be converted to a base year using consumer price indices. Our base year was set on 2013, and the consumer price indices were used to convert the prices to our base year (14).

The following resource quantities were identified: nursing days, medication, functional examinations (i.e., bronchoscopy, ECGs, and lung function testing), imaging tests, transplantation costs, renal replacement therapy, screening, surgery and anesthesiology costs, laboratory tests, microbiology costs, blood products, and procedural costs of ECLS therapy.

In order to estimate the costs of ECLS therapy based on indication, all patients were categorized into six different subgroups: respiratory bridge to recovery, respiratory bridge to transplant, cardiac bridge to recovery, cardiac bridge to transplant, cardiac postcardiotomy, and ECPR. Our subgroup categorization follows the Extracorporeal Life Support Organization (ELSO) registry definitions for indication (15), but we split our respiratory patients into two categories and cardiac patients into 3 categories because of different patient characteristics within the general groups as described previously (16).

We searched PubMed for hospital cost analysis/resource use in ECMO/ECLS in adults. We also handsearched the reference lists of included articles to identify additional articles. The electronic literature search strategy was last updated January 30, 2015.

The medical ethics committee of the UMCG reviewed the study and waived the need for approval (METc 2014/011).

**Statistical Analysis**
Both mean and sd and median and interquartile range were calculated for all primary and secondary outcome variables as appropriate. In order to calculate alternative CIs surrounding the estimates of mean costs, bootstrapping was performed to generate 5,000 replications of the original data set. Based on the 2.5th and the 97.5th percentile score, the CI was determined.

**RESULTS**
All 67 patients who received ECLS therapy during the study period were included in this cost analysis. One patient received ECLS therapy twice within one ICU admission. These two ECLS runs were seen as one long ECLS run, and duration times of the two runs were summed. Patient demographics and baseline characteristics are shown in Table 1.

### TABLE 1. Patient Demographics

| Patient, No. | All Patients, n = 67 | Respiratory Bridge to Recovery, n = 11 | Respiratory Bridge to Transplant, n = 27 | Cardiac Bridge to Recovery, n = 8 | Cardiac Bridge to Transplant, n = 2 | Cardiac Postcardiotomy, n = 5 | Extracorporeal Cardiopulmonary Resuscitation, n = 14 |
|-------------|----------------------|---------------------------------------|-----------------------------------------|----------------------------------|---------------------------------|---------------------------------|----------------------------------|
| Age (yr)    | 46 ± 15              | 44 ± 12                               | 48 ± 14                                 | 40 ± 25                          | 66 ± 7                          | 47 ± 17                         |
| Caucasian race, n (%) | 62 (92)               | 9 (82)                                | 26 (96)                                 | 8 (100)                          | 2 (100)                         | 5 (100)                         | 12 (85)                          |
| Female sex, n (%) | 44 (66)               | 9 (82)                                | 20 (74)                                 | 4 (50)                           | 1 (50)                          | 2 (40)                          | 8 (57)                           |
| Body mass index (kg/m²) | 25 ± 5                | 25 ± 6                                | 23 ± 4                                  | 26 ± 6                           | 29 ± 8                          | 34 ± 4                          | 26 ± 4                           |
| Acute Physiology and Chronic Health Evaluation II scorea | 23.7 ± 12.5           | 23.6 ± 7.4                            | 21.7 ± 6.9                             | 25.2 ± 10.1                     | 18.0 ± 11.3                     | 25.0 ± 8.4                      | 27.5 ± 12.5                     |
| Renal replacement therapy, n (%) | 31 (46)                | 7 (64)                                | 11 (41)                                 | 4 (50)                           | 0                               | 3 (60)                          | 6 (43)                           |
| Extracorporeal life support duration (hr) | 135 ± 163             | 132 ± 141                             | 197 ± 166                               | 166 ± 272                      | 99 ± 74                         | 23 ± 12                         | 44 ± 43                          |
| ICU LOS (d) | 18 ± 22              | 25 ± 25                               | 26 ± 26                                 | 12 ± 11                         | 11 ± 0.7                        | 6 ± 8                           | 7 ± 10                           |
| Hospital LOS (d) | 38 ± 45               | 43 ± 46                               | 61 ± 53                                 | 13 ± 11                         | 27 ± 11                         | 13 ± 20                         | 13 ± 20                          |
| In-hospital mortality, n (%) | 44 (68)                | 6 (54)                                | 14 (52)                                 | 6 (75)                           | 2 (100)                         | 4 (80)                          | 12 (85)                          |

LOS = length of stay.  
aData were incomplete in three cases.  
Data are given as n (%) or mean ± sd.
The first application of ECLS therapy in a patient in our hospital was in 2010. That year, the sum of all ECLS days was 40. The sum of all ECLS days grew rapidly; in 2011, it was 89, the following year 140, and in 2013, it increased to 174 days. Mean and median duration of ECLS treatment were 135 and 91 hours (range, 1–824) for all 67 patients. The total duration of ECLS treatment differs largely between patient categories with the “respiratory– bridge transplant” as the longest with a median of 148 hours followed by “respiratory bridge to recovery” category with a median of 114 hours. The shortest duration was seen in the postcardiotomy patients with a median duration of 21 hours.

Overall survival-to-hospital discharge was 23 of 67 patients (32%); this was 5 of 11 (45%) for respiratory bridge to recovery, 17 of 27 (48%) for bridge to lung transplantation, 2 of 8 (25%) for cardiac bridge to recovery, 0 of 2 (0%) for cardiac bridge to bridge/heart transplantation, 1 of 5 (20%) for postcardiotomy patients, and 2 of 14 (14%) in ECPR patients.

The mean total hospital cost, including pre-ECLS and post-ECLS stay and procedures, was €106,263 (95% CI, €83,841 to €126,266) ($145,580). Nursing days constitute 52% of the total costs (Table 2). The total mean cost for all four ECLS-related procedures was €9,804. The mean material cost of ECLS connection was €5,794, cannula change was €4,302, and oxygenator switch was €4,722. The cost of ECLS therapy (procedures and costs of daily surcharge) was €11,948 per patient during the hospital admission (11%). The healthcare consumption covered in the other resource quantities is responsible for 37% of the total costs (Table 2). An overview of the hospital costs, specified by patient category, is shown in Table 3.

### TABLE 2. Total Hospital Costs of All Patients (n = 67)

| Resource Quantity                          | Mean (sd) | % of Total | Median | Minimum | Maximum |
|--------------------------------------------|-----------|------------|--------|---------|---------|
| Nursing days                               | 55,464 (64,357) | 52         | 31,155 | 2,377   | 334,068 |
| Extracorporeal life support procedural cost| 11,874 (2,129)  | 11         | 11,369 | 10,117  | 20,764  |
| Other resource quantities                  | 38,924 (34,520) | 37         | 34,000 | 1,792   | 200,195 |
| Functional examinations                    | 2,009 (2,644)  | 2          | 1,033  | 0       | 11,525  |
| Imaging                                    | 2,146 (2,317)  | 2          | 1,390  | 0       | 10,412  |
| Transplantation                            | 1,774      | 2          | 0      | 0       | 22,890  |
| Renal replacement therapy                  | 3,755 (9,323)  | 4          | 598    | 0       | 57,723  |
| Screening                                  | 23 (83)     | 0          | 0      | 0       | 531     |
| Other                                      | 706 (1,255)   | 1          | 0      | 0       | 7,127   |
| Surgeries                                  | 13,105 (12,000)| 12        | 13,573 | 0       | 48,420  |
| Anesthesiology                             | 163 (3,514)   | 0          | 0      | 0       | 1,229   |
| Laboratory                                 | 3,655 (3,514) | 3          | 0      | 243     | 17,253  |
| Microbiology                               | 4,071 (5,600) | 4          | 2,267  | 0       | 34,454  |
| Blood products                             | 7,511 (8,565) | 7          | 4,467  | 0       | 51,892  |
| Total                                      | 106,263 (95,933)| 83,751    | 14,580 | 546,572 |

All costs are in Euros.

**DISCUSSION**

In this large study of hospital costs in ECLS-treated patients, we found a mean total hospital cost of €106,263 per patient. More than half of the total hospital costs arise from hospital nursing days and about 11% from direct ECLS procedure–related costs. Of the remaining, surgery and diagnostics form a vast amount of costs.

The amount of total hospital costs ranges largely, depending on the indication and subsequent type of ECLS and therefore length of stay. The patients in the category “respiratory – bridge to transplant” have the highest mean total hospital costs, caused in part of their extended hospital stay. The lowest total hospital costs are found in the ECPR category, probably because these patients had a short duration of ECLS treatment and hospital admission, which is mainly because of the worse outcome in combination with a policy of withdrawal of medical support as soon functional recovery is considered futile.

The survival rates reported here are lower than seen in most other studies, as well as in the ELSO registry. Research studies tend to take place at big centers with well-established ECMO protocols, and the ELSO registry receives self-reported data from a consistent group of large ECMO centers. When looking at an individual center, starting their ECLS program patient selection is the key to success. This is best shown for our postcardiotomy group where ECLS was used as a heroic final effort but too late and therefore futile.

With a total of 67 patients analyzed, our study is the largest economic evaluation using the bottom-up microcosting approach, providing a detailed insight of hospital costs in adult patients treated with ECLS in the Netherlands. The different
resource quantities were assessed in detail for each patient, by using reference prices from the Dutch manual. Own unit cost calculations were only used when reference prices are not available. Using the bottom-up microcosting method, a reliable statement about the contribution of ECLS therapy in total hospital costs can be made. Also, these methods result in a large generalizability of the findings, especially for Europe.

In the largest economic and efficacy assessment of ECMO in ARDS most importantly for outcome was whether a patient was transferred to an ECMO-based management center, not always receiving ECMO treatment (5). The indirect costs and significant follow-up after hospital discharge were also taken into account. The calculated cost/nursing day is based on the number of organs supported. The costs used were based on hospital billing systems and not according to the bottom-up method (14). Therefore, direct comparison is not possible.

Several other studies assessed hospital costs of ECLS treatment with widely varying total hospital costs, as summarized in (16–19) Table 4.

A small Norwegian economic analysis was performed in 2007 containing 14 consecutive ECLS patients of which nine were adults. Indications for ECLS were both respiratory and cardiac failure. The mean estimated total hospital cost was found to be €153,403 (17). They used a top-down calculated standard ICU nursing day price and added costs generated by excess resources, such as physicians, anesthesiologist, perfusionists, respiratory physiotherapists, and other staff members. In our study, we considered an ECLS patient not to be significantly different in daily care from other ICU patients, except for the extra resources used during ECLS procedures and the visits by a perfusionist. This different approach of the ECLS costs may explain the difference in the total hospital costs. Considering their small population and wide interquartile range, the results seem to be a less accurate estimation of true costs compared with our study.

A case series of 10 patients from Portugal with influenza H1N1–related ARDS found a median cost of total hospital admission of €44,857 per patient (18). Costs were retrospectively analyzed by using both bottom-up and top-down approaches. In our study, the 11 patients in the "respiratory bridge to recovery" category, probably the best comparable subgroup of patients, had a median cost of €86,603 despite a shorter duration of ECLS treatment (6 vs 22 d) and ICU length of stay (19 vs 36 d). Although we had one extremely expensive patient (total hospital cost of €353,392), the difference in costs is remarkable. Because the sample size for this specific subgroup is small, the difference might be explained by coincidence or by more variety in complexity in our patients.

The difference between charges and cost is another pitfall in estimating costs as illustrated by two studies from the Unites States. Trends in volume, outcome, and resource use in ECMO in adults were studied by analyzing the Nationwide Inpatient Sample (NIS) in the United States for the period 1998–2009 and 2006–2011 (16, 19). In the NIS database, the costs were estimated using the total hospital charges for each patient.

Total hospital charges averaged $344,009 per admission, with average charges per day of $40,588, with a hospital length of stay of 18 days for the period 1998–2009 (16). For the latest period, the NIS database was adjusted using the cost-to-charge ratios for each hospital, to converse charge data to cost estimates. The total hospital costs were $120,000 per patient and less than $10,000 per day (19).

Total hospital charges as reported in the NIS represent hospital billing, not actual expenditures or reimbursement. The relationships among hospital charges, hospital costs, insurance reimbursement, and patient copayments are complex and complicate the extrapolation of these results to an estimation of the true societal cost for ECMO.

In addition, the NIS database is an admission-based database that has a risk of underestimating the total charges. Because a patient can upgrade to a higher level of care institution during the ECMO run and the charges are then split between two admission records. This limitation primarily affects the accuracy of an analysis of the absolute magnitude of resource use. So, both the use of charges instead of costs in the analysis and differences between the healthcare systems may account for big differences in cost estimates. For example, compared with the Netherlands, the United States has more ICU beds (20.0 vs 8.4 per 100,000 population), more ICU admissions (1,923 vs 466 per year per 100,000 population), and higher healthcare spending per capita (around €4,380 vs €2,190), making critical care more expensive (20).

Certain limitations of our study must be appointed. Firstly, this is not a study comparing ECLS treatment with conventional

### Table 3. Hospital Cost Per Category

| Patient Category                     | Mean Total Hospital Cost (95% CI) | Mean Cost Per Hospital Day |
|--------------------------------------|----------------------------------|----------------------------|
| All patients                         | €106,263 (€83,841–€126,266)      | €2,796                     |
| Respiratory bridge to recovery       | €110,553 (€61,012–€168,471)      | €2,571                     |
| Respiratory bridge to transplant     | €153,345 (€115,479–€197,785)     | €2,513                     |
| Cardiac bridge to recovery           | €69,803 (€42,515–€101,861)       | €5,369                     |
| Cardiac bridge to bridge/transplant  | €66,971t                        | €2,480                     |
| Cardiac postcardiomyotom             | €68,582 (€54,076–€98,532)        | €5,275                     |
| Extracorporeal cardiopulmonary resuscitation | €51,997 (€34,970–€73,100)   | €3,999                     |

*Due to the low (n = 2) number in this group, no CI was calculated.*
treatment and neither did we have a matched control cohort. This means that we can only calculate the costs associated with ECLS treatment, not the additional costs of ECLS treatment compared with conventional treatment. Secondly, the main cost item, nursing days, which is responsible for more than half of the total hospital costs, is calculated using the gross costing method. Included in the standard price for one nursing day are averaged personnel time involvement and an averaged amount of medication costs. We assumed that ECLS patients did not use more expensive medication than other patients admitted on ICU, although this is dependent on the average complexity of patients admitted to the ICU, which largely differs per type of ICU or country. Anticoagulation therapy is mandatory for ECLS patients but hardly distinctive. Furthermore, the price of the commonly used anticoagulants is so low that it is negligible in the total cost (21). Studies on medication use in ECLS patients focus on pharmacokinetics of commonly used drugs in the ICU to optimize drug therapy in this patient group and not on ECLS-specific drugs (22–24). When extracting the calculated contribution of medication in our study, the medication forms 4% of the total costs versus 2% founded in the Norwegian cost study (16). In both cases, the contribution of medication is thus relatively low.

Another potential methodological limitation has to do with the hospital unit prices used for the analysis. Unit prices for individual codes are calculated to cover total hospital expenditures of all patients. Using this hospital, unit prices in a very specific patient population potentially give an underestimation of the cost for these resource quantities. However, we considered the alternative to manually adapt unit prices not to be appropriate because it would have induced more uncertainty.

With respect to the calculation of the ECLS procedure costs, the use of other ECLS systems than the Maquet Cardiohelp we used in our patients might be cheaper to assemble and maintain. However, ECLS procedure–related costs account for only 11% of total costs. The calculation of the daily surcharge for the ECLS device is based on the number of total ECLS days in 2013 that were more than in the three prior years included in our analyses. Increase of ECLS therapy in the future is likely, but to what extent and what the consequences for daily cost of the device will be is not taken into account. In adult respiratory cases, the ELSO registry reports an increase of 176%, from 480 patients in 2009 to 846 patients in 2012 (25). In order to be able to integrate this variability on cost analysis, more insight in the growth of ECLS therapy in adults needs to be gathered as with more use; the average costs per patient might be reduced.

Our method potentially underestimates the costs for direct personnel included in the fixed price for one nursing day because ECLS treatment is still an upcoming treatment and therefore more resource demanding compared with standard treatments on the ICU. There are also costs involved in training and education of personnel according to ELSO guidelines, which recommends a 24- to 36-hour didactic course, hands-on water drill sessions, extensive laboratory training in new ECLS centers, and bedside training of new ECL specialist of 16–32 hours (26).

Considering the future growth of ECLS treatment, also experience with ECLS patients will expand. Therefore, in theory, ECLS patients can become less time consuming for direct personnel, such as nurses, which also decreases the average costs. In this manner, our study method of bottom-up microcosting evaluation anticipates on future developments of ECLS therapy, and the estimate of total costs stays applicable for a longer period.

Furthermore, with regard to controlling the healthcare costs generated by the application of ECLS treatment, it should be recommended to concentrate ECLS treatment to a limited amount of centers. It is known that a rise in procedure volume has a positive effect on the healthcare quality and, as can be expected, to a certain degree on the costs as well (1).

This exploratory study of the total hospital costs of ECLS therapy in adults with respiratory or cardiac failure is the first step in assessing its cost-effectiveness. As ECLS therapy might be effective in terms of life saving, the definition of cost-effectiveness in this case is having an additional benefit worth the additional costs. Further studies must focus on cost-utility analysis, in which utility measures are used to assess outcome, for example, quality-adjusted life-years.

### CONCLUSIONS
The mean total hospital cost of ECLS treatment is €106,263 per patient. From our study, it can be deduced that 52% of the

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### TABLE 4. Results of Systematic Review of Extracorporeal Life Support Cost Studies

| Study | Study Period | Country | Design | Mean | Median | Cost/Day of Hospitalization |
|-------|--------------|---------|--------|------|--------|-----------------------------|
| Mishra (16), n = 14 | 2007 | Norway | Cost top-down calculation with standard prices | €175,907 | €157,916 | €3,415 |
| Maxwell (19), n = 8,753 | 1998–2009 | United States | Hospital billings | €251,126<sup>a</sup> | Not available | €29,629<sup>a</sup> |
| Roncon (17), n = 10 | 2009–2011 | Portugal | Cost prices bottom-up and top-down approaches | Not available | €44,857 | €1,370 |
| Sauer et al (19), n = 2,004 | 2006–2011 | United States | Hospital billings adjusting using cost-to-charge ratios | Not available | €87,600<sup>a</sup> | < €7,300<sup>a</sup> |

<sup>a</sup>Calculated to Euros using an exchange rate of 1$ USD = 0.73 Euros.
costs are composed of nursing days, 11% to procedural-related costs, and 10–30% to surgery (depending on the patient category). Subsequently, one can use this proportion of costs to estimate the cost for his own hospital. This study is a good starting point for further investigation of the cost-effectiveness of ECLS therapy. Then, interpretation of the total hospital costs in context to the outcome of ECLS patients is possible.

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APPENDIX 1. DUTCH EXTRACORPOREAL LIFE SUPPORT STUDY GROUP

Walter M, van den Bergh, MD, PhD, Department of Critical Care, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Wim van der Bij, MD, PhD, Department of Pulmonary Diseases and Lung Transplantation, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Vladimir Cernak, MD, PhD, Department of Anesthesiology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Henk Eerhuis, MD, PhD, Department of Anesthesiology, Onze Lieve Vrouwe Gasthuis, Amsterdam, The Netherlands; Michiel E. Erasmus, MD, PhD, Cardiothoracic Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Berber van den Hengel, MD, Department of Critical Care, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Jacinta J. Maas, MD, PhD, Department of Intensive Care Medicine, Leiden University Medical Center, Leiden, The Netherlands; Massimo A. Mariani, MD, PhD, Department of Cardiothoracic Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands; Karin M. Vermeulen, PhD, Department of Epidemiology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands;