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Onnen Moerer
Alexandra Schmid
Michael Hofmann
Anja Herklotz
Konrad Reinhart
Karl Werdan
Heinz Schneider
Hilmar Burchardi

Direct costs of severe sepsis in three German intensive care units based on retrospective electronic patient record analysis of resource use

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O. Moerer (✉) · H. Burchardi
Department of Anesthesiology, Emergency, and Intensive Care Medicine,
University Hospital Göttingen,
Robert-Koch-Strasse 40,
37070 Göttingen, Germany
e-mail: omoerer@gwdg.de
Tel.: +49-551-399561

A. Schmid · H. Schneider
HealthEcon Ltd., Steinentorstrasse 19,
4001 Basel, Switzerland

M. Hofmann · K. Reinhart
Clinic for Anesthesiology and Intensive Care,
Friedrich Schiller University,
Bachstrasse 18, 07743 Jena, Germany

A. Herklotz · K. Werdan
Department of Medicine III,
Martin Luther University,
Klinikum Kroellwitz,
Ernst-Grube Strasse 40,
06120 Halle, Germany

Abstract *Objective:* To determine the direct costs of severe sepsis patients in German intensive care units (ICUs). *Design:* Retrospective electronic data analysis. *Setting:* Three adult intensive care units (surgical/medical) in three university hospitals in Germany. *Patients:* 385 patients identified by standard definitions as suffering from severe sepsis. *Measurements and results:* A bottom-up approach was used to determine the direct ICU cost on actual resource use (medication, laboratory tests, microbiological analysis, disposables, and clinical procedures) for patients with severe sepsis. To determine the total direct costs, center-specific personnel and basic bed ("hotel") costs were added to total resources consumed. Average hospital mortality of severely septic patients was 42.6%. Mean ICU length of stay (LOS) was 16.6 days. Survivors stayed on average 4 days longer than nonsurvivors. The mean direct ICU costs of care were 23,297± 18,631 euros per patient and 1,318 euros per day. In comparison, average daily charges being paid for an ICU patient by the health care system in Germany are 851 euros (based on official statistics). Nonsurvivors were more expensive than survivors in total direct costs (25,446 vs. 21,984 euros) and in per day direct cost (1,649 vs. 1,162 euros). Medication makes up the largest part of the direct costs, followed by expenses for personnel. *Conclusions:* Patients with severe sepsis have a high ICU mortality rate and long ICU LOS and are substantially expensive to treat. Nonsurviving septic patients are more costly than survivors despite shorter ICU LOS. This is due to higher medication costs indicating increased efforts to keep patients alive.

Keywords Intensive care · Health-care costs · Hospital costs · Cost of treatment · Sepsis

Introduction

Sepsis is a well-documented disease process. Literature relating to its history, incidence, risk factors [1, 2, 3, 4] and customized probability models using the Simplified Acute Physiology Score II [5] or the Sequential Organ Failure Assessment [6] for patient outcomes contribute to our knowledge of this complex pathological condition. However, information relating to the actual costs associated with sepsis are lacking. In a previous study [7] we focused on the epidemiology of sepsis and severe sepsis in Germany and estimated between 44,000 and 95,000 severe sepsis cases per year. A recently published European epidemiological study classified 24% of infectious patients as severely septic according to the ACCP/SCCM criteria [8]. As severely septic patients are generally treated by expensive intensive care [9, 10, 11], the extent of resources consumed in treating this disease can be presumed to be considerable.

The lack of standardized models for determining the cost of intensive care [12] combined with inadequate documentation of intensive care unit (ICU) costs [13] prevents a fast and easy solution when undertaking cost of disease studies in intensive care. The majority of studies on ICU costs are done by using top down methods which average consumed resources across all patients [12]. However, the costs of treating specific subgroups of ICU patients or even the variation in costs within individual patients [14] can be assessed only by bottom-up analysis [15, 16]. This is extremely laborious if no patient data management system (PDMS) is available. Such PDMS allows a complete documentation of resource use combined with a catalogue of costs for every item and activity even if they were not originally aimed at this purpose [17].

The goal of the present study was to estimate the patient-specific direct intensive care costs in severe septic patients. For this purpose direct variable patient costs were analyzed by a bottom-up approach using electronically available patient records of three German ICUs combined with a top-down analysis of costs on personnel and hotel costs to assess retrospectively the total direct ICU cost per patient.

Materials and methods

The electronic records of 385 severely septic patients (223 men, 162 women; mean age 58±16.5 years) were retrospectively evaluated from the period 1997–2000, covering a total of 6399 days of ICU treatment. Center-specific clinical and resource-use data were available from three adult ICUs in Germany, the university hospitals in Göttingen (n=68), Halle (n=91), and Jena (n=226) possessing electronic patient records of severe sepsis patients. The ICUs in Göttingen and Jena are mainly surgical and that in Halle medical. Patient data were obtained from all included patients but resource use data were available for only 294 patients. Surgical patients accounted for 242 cases (63%), with 53 scheduled for elective surgery and 189 for emergency procedures of various kinds (Table 1). In 48 patients there were more than two operations during the ICU stay; 31 of 61 trauma cases were polytrauma. The other 143 patients (37%) were nonsurgical and therefore underwent no mayor surgical invention during the ICU stay and did not suffer from trauma. Infection was present on ICU admission in 162 cases (42%), and infection was acquired in the ICU in 238 cases (62%).

An underlying infection in these patients was defined on the basis of clinical history, clinical symptoms, laboratory findings, and physical examination suggesting the presence of infection and/or a known or suspected source of infection with positive bacteriological cultures. The definition of severe sepsis followed the ACCP/SCCM criteria [1], according to which sepsis is associated with organ dysfunction, hypoperfusion abnormality, or sepsis-induced hypotension in the absence of any other explanation. The cost perspective of this study was the individual ICU patient, from the hospital point of view. Since the period of analysis exceeded 1 year, direct variable costs on resource consumption were discounted to their present values by using an actualized cost catalogue for the years 1998 and 1999. General demographic patient data such as age, sex, reason for admission, acute diseases, interventions, length of ICU and hospital stay (LOS), and data on ICU and hospital outcome (survivors or nonsurvivors) and infection (on ICU admission and/or acquired in ICU) were collected.

Table 1 Proportion of nonsurgical and surgical patients and specialties involved (one patient could have been operated on in more than one specialty and more than once per ICU stay)

	n	%
Type of patient		
Nonsurgical	143	37
Surgical	242	63
Surgical scheduled	53	14
Surgical emergency	189	49
Type of surgery		
Neurosurgery	103	24
ENT/orofacial surgery	13	3
Thoracic surgery	32	8
Cardiac surgery	10	2
Abdominal surgery	151	36
Orthopedic/trauma surgery	69	16
Vascular surgery	27	6
Gynecology	9	2
Urology	8	2

To obtain the patient specific costs two approaches were combined:

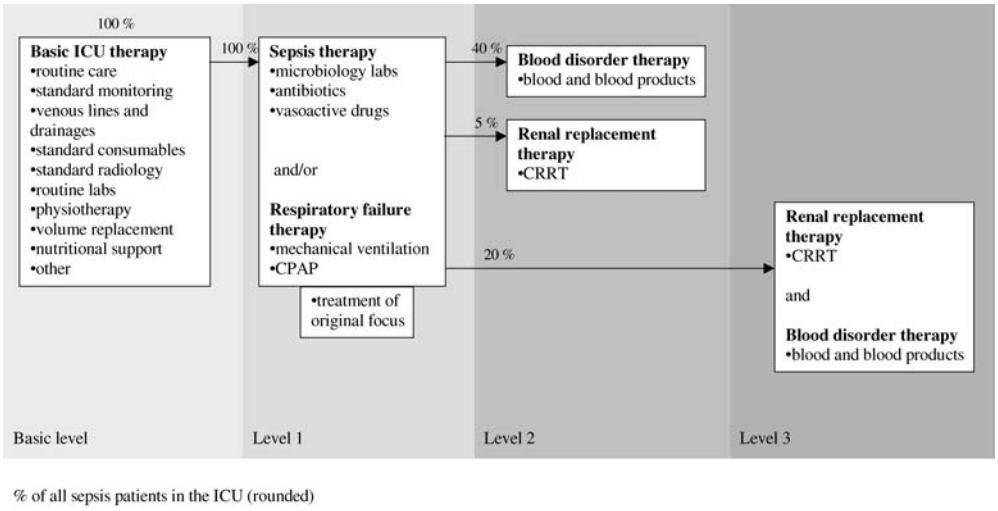
Variable costs

Assessment of resources used (excluding staff time), i.e., the type and frequency of drugs, fluids administered, consumables (e.g., syringes, tubes, catheters), laboratory and microbiological analyses, and diagnostic procedures (e.g., radiography) were analyzed for the individual patient. These resource data were extracted electronically from a bedside-based PDMS in which all activities related to a patient were documented. Center-specific costs for the assessed resources were collected independently. Current hospital purchasing costs for drugs, disposables, nutrition, and blood products were calculated. Per package costs were transformed into unit costs when necessary. Routine laboratory and microbiology expenses were calculated for current costs (i.e., including proportional staff costs). The purchasing and current costs were provided by clinical experts and pharmacists from each hospital involved. In a few situations in which center-specific cost information was not available comparable costs from one of the other institutions were substituted.

Defined treatment modalities served as the basis for the classification of specific resource use. These treatment modalities and services were derived initially from a literature review and were finally defined after discussion with several clinical experts:

- Basic ICU therapy
  - Routine medication
  - Standard monitoring
  - Standard consumables
  - Standard radiology
  - Routine laboratories
  - Volume replacement
  - Nutritional support
  - Blood and blood products not included in blood disorder therapy
- Sepsis therapy
  - Antibiotics
  - Cardiovascular drugs
  - Microbiology laboratories
  - Sepsis-specific disposables
  - Treatment of original focus

Fig. 1 Treatment model



- Respiratory failure therapy
  - Mechanical ventilation
  - Continuous positive airway pressure
- Blood disorder therapy
  - Blood
  - Blood products
- Renal replacement therapy
  - Continuous renal replacement therapy (hemofiltration, hemodialysis)

With these treatment modalities we constructed the treatment model shown in Fig. 1, which illustrates the sequential course of sepsis according to variations in organ failures.

Fixed costs

Intensive care staff costs per day of care were calculated for each center by dividing the summarized gross incomes for nurses and physicians (except physiotherapy) of the specific ICU with the days of care. Basic bed costs per day ("hotel costs") which includes costs for nonclinical support services, maintenance, energy, and hospital administration, and which is equally distributed over all clinical departments. This information was obtained from the hospital administration. Not included were equipment and investment costs or depreciation.

Only ICU costs were assessed. Costs of operations and costs occurring at the regular ward were purposely omitted since it is virtually impossible to differentiate what part of the stay in regular ward is due to sepsis and what part to the underlying disease. Therefore this conservative approach was chosen.

All collected data were compiled in a database. Specific costs for each patient and staff and hotel costs based on patient specific ICU LOS were summarized to obtain the total cost per patient. Finally, the mean of all patients was calculated. Data were analyzed using MS Access 97, Excel 7.0, and SPSS 11.0. Differences in costs of subgroups, LOS, and mortality were tested statistically by the Mann-Whitney *U* test. A probability of randomness (*p*) value of 0.05 or less was accepted as significant. Because of possible underreporting of used resources in PDMS a sensitivity analysis (cost increase of 10% or 20%) was performed for variable direct costs. All costs were calculated in German currency but are given here in euros; the conversion rate was 100 German marks to 51.129 euros.

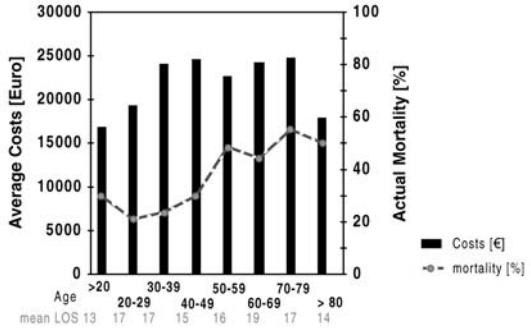


Fig. 2 Distribution of costs and mortality in relation to age in patients with severe sepsis

Results

ICU mortality of all patients evaluated was 35.6%. Overall hospital mortality was 42.6% (Table 2). Mortality was related to age (Fig. 2), the onset of infection, and the concomitant organ failure (indicating the severity of disease). There was no sex-related difference in mortality (43% vs. 42%) (Table 2). The highest mortality was seen in patients with infections on admission. Of the 164 nonsurvivors 83.5% died in the ICU. The application of various treatments was investigated according to the previously established treatment scheme and showed the following:

- Basic ICU therapy: allocated to all patients over the entire ICU stay
- Respiratory failure therapy: 368 patients (95.6%) were mechanically ventilated or were treated with continuous positive airway pressure over 74.5% of all ICU days
- Renal replacement therapy: in 103 patients (26.8%) dialysis or hemofiltration were performed over 10.2% of all ICU days

Table 2 Mortality in patients with severe sepsis

Patient group	*n*	ICU nonsurvivors		Hospital nonsurvivors	
		n	%	*n*	%
All patients evaluated	385	137	35.6	164	42.6
Sex					
Men	223	81	36.3	96	43.0
Women	162	56	34.6	68	42.0
Infection					
Infection on admission[a]	162	67	41.4	77	47.5
Infection acquired[a]	238	74	31.1	89	37.4
Organ-failure therapy					
Only respiratory failure therapy	113	14	12.4	27	23.8
Respiratory failure and blood disorder therapy	161	53	32.9	58	36.0
Respiratory failure and renal dysfunction therapy	14	7	50.0	9	64.3
Respiratory failure, blood disorder, and renal dysfunction therapy	84	59	70.2	65	77.4

Patients can belong to both groups

Table 3 Mean/median direct ICU cost per severely septic patient (in euros)

Component	Mean ±SD	Median	95th percentile	%
Medication	9,304±10,002	6,143	28,854	40
Routine laboratories	2,337±2,235	1,653	7,288	10
Microbiology	882±1,139	520	2,175	4
Disposables	753±531	653	1,636	3
Hotel costs	1,518±1,457	1,074	4,434	7
Staff costs	8,503±7,242	6,761	23,595	36
Total direct costs	23,297±18,631	18,221	62,500	100

- Blood disorder therapy: 252 patients (65.5%) were treated with angiotensin III, platelet concentrate, fresh-frozen plasma, or immunoglobulins on 17.9% of all ICU days
- Sepsis therapy: 354 patients (91.9%) were concomitantly treated with antibiotics and vasoactive drugs during 67.3% of all ICU days

Together with the basic ICU therapy, all severely septic patients had sepsis therapy and/or respiratory failure treatment; 40% received additionally a blood disorder therapy but no renal dysfunction therapy, 5% were treated with hemodialysis or hemofiltration but received no blood disorder therapy, and 20% received all therapies possible (Fig. 1).

For the entire patient population, the average LOS in the intensive care unit was 16.6±14.4 days and hospital LOS was 32.5 ±25.0 days. LOS varied substantially with whether infection was present on admission, by type of treatment, and depending on survival. Patients with ICU-acquired infection generally stayed somewhat longer in the unit than those with infection on ICU admission (18.2 vs. 16.7 days). Survivors stayed significantly longer in the ICU and in hospital than nonsurvivors (18.4

Table 4 Mean daily therapy costs for survivors and nonsurvivors (in euros); hotel and staff costs are not included

Therapy	Survivors	Nonsurvivors	*p*
Basic ICU therapy	414	677	<0.001
Sepsis therapy	165	211	0.012
Respiratory failure therapy	9	9	0.134
Renal replacement therapy	56	40	0.387
Blood disorder therapy	445	745	0.005

Table 5 Mean total ICU costs of nonsurgical and surgical patients with severe sepsis (in euros); surgical vs. nonsurgical, surgical vs. nonsurgical survivors, surgical vs. nonsurgical nonsurvivors, $p<0.05$

	Mean ±SD	Median	95th percentile
Nonsurgical	13,995±11,416	9,372	42,531
Survivor	14,498±12,017	9,308	43,555
Nonsurvivor	13,309±10,749	9,763	46,053
Surgical	25,412±19,386	20,295	64,723
Survivor	23,630±16,424	21,516	62,534
Nonsurvivor	28,831±23,565	20,295	83,001

Table 6 Mean detailed ICU costs of nonsurgical and surgical patients with severe sepsis (in euros)

	Basic ICU	Staff	Hotel	Sepsis therapy	Blood therapy	Ventilation therapy	Renal therapy	Total
Nonsurgical	4,021±3,667	6,291±6,860	1,501±1,885	1,763±1,529	1,326±2,144	139±162	211±109	13,995±11,416
Survivor	3,091±2,386	6,994±6,344	1,752±1,696	1,890±1,545	954±1,422	140±203	349±177	14,498±12,017
Nonsurvivor	5,313±4,689	5,312±7,555	1,151±1,987	1,577±1,521	1,698±2,675	135±179	177±3	13,309±10,749
Surgical	9,900±8,517	9160±7,262	1,527±1,350	2,511±2,487	3,170±6,003	118±86	313±577	25,412±19,386
Survivor	8,856±7,429	9,746±6,965	1,609±1,304	2,246±1,960	1,656±42473	117±89	423±532	23,630±16,424
Nonsurvivor	11,878±9,944	8,161±7,729	1,388±1,431	3,008±3,191	5,305±8429	120±81	287±590	28,831±23,565

vs. 14.4 days, $p<0.001$). The type of patient (medical vs. surgical) also had a significant effect on LOS, with those undergoing surgical procedures staying longer (18.8 days) than medical patients (13.0 days, $p<0.001$). Regarding the specific-organ failure treatments, respiratory failure therapy and sepsis therapy were applied on most days of the ICU stay, while blood disorder therapy and renal dysfunction therapy were administered for a limited time period only.

The average total direct costs of a septic patient were 23,297±18,631 euros. These expenditures were composed of four groups of resources, including basic bed costs and staff costs (without physiotherapy). The mean direct costs per patient were as follows: medication, 9,304 euros; routine laboratories, 2,337 euros; microbiology, 882 euros; disposables, 753 euros; hotel costs, 1,518 euros; staff costs, 8,503 euros (Table 3). The mean direct costs per day were: medication, 527 euros; routine laboratories, 133 euros; microbiology, 50 euros; disposables, 43 euros; hotel costs, 86 euros; staff costs, 480 euros. These figures yield 1,318 euros as mean total direct cost per day. Medication made up the largest part (40%) of the total direct cost, followed by staff costs (36%) and routine laboratories (10%; Table 3). Nonsurvivors were more expensive than survivors in total per patient costs (25,446 vs. 21,984 euros, n.s.) as well as in daily cost (1,649 vs. 1,162 euros, $p<0.001$). The total expenditures per patient in regard to the age distribution and mortality rate are shown in Fig. 2. The costs of the previously defined treatment groups were also calculated, and daily costs of survivors were compared with nonsurvivors, showing similar differences (Table 4). Average total costs for surgical patients were nearly twice as high (25,412 euros) as for nonsurgical patients (13,995 euros, $p<0.001$). Patients who underwent emergency procedures were most expensive, with 26,408 euros per patient (Tables 5, 6).

Discussion

Data on the costs of care due to sepsis are rarely found in the literature. In contrast to the findings of clinical studies, the results of economic evaluations cannot be readily transferred from one country to another. Country-specific health care systems, reimbursement rates, and regulations as well as different cost factors and pricing prevent an easy comparison. Sepsis patients are normally treated in ICUs, and ICU treatment is very expensive [9, 10, 11, 18]. The continuing pressure to contain health care costs and the current restructuring of the German reimbursement system are creating an urgent need for detailed cost evaluations in intensive care, but precise data concerning consumed resources are often not available. Some German hospitals are now using PDMS. Although intended primarily for clinical data collection and treatment support, PDMS offers the possibility of resource use assessment [17]. The present study made great use of PDMS, enabling a bottom-up calculation of the variable ICU costs for severely septic patients. In such a documentation system all resources are expected to have been recorded. An internal evaluation showed an underestimation of about 10% for drugs and about 20% for disposables/procedures. These findings suggest small underestimation of the variable and total costs per patient. However, sensitivity calculations (increase in variable per patient costs up to 10%) showed that the variation in mean total costs still range well within the reported standard deviation.

The results of this retrospective analysis may not be representative of all ICUs in Germany, as the evaluation was carried out at only a few university hospitals. However, the patient sample evaluated here seems representative of the overall population of severely septic patients in Germany, based on the fact that our data concur with data from other analyses. The observed mortality of 42.6% is comparable to that reported by other studies [19, 20, 21], and the observed mean ICU LOS of 16.6 days is identical to that which was found in a different population of septic patients in Germany [22].

Overall hospital mortality was found to be 42.6%. Mortality increased with age (Fig. 2) but showed no gender difference, which is in agreement to previously described findings [19]. Mortality of patients admitted to the ICU with sepsis was considerably higher than that of those who acquired sepsis later in the ICU (47.5% vs. 37.4%), indicating that the progression of the pathophysiological cascade of sepsis is an important factor regarding the ultimate (fatal) outcome. This is supported by the increased mortality observed under two or more organ failure and is particularly high under a combination of respiratory and renal failure (Table 2).

The mean LOS of patients in German ICUs is 3.0 days [22]; however, these figures from 349 ICUs include a large number of patients who spend less than 24 h in the ICU, mostly for short-term postoperative recovery. Considering only ICU patients with an LOS of at least 24 h, the mean ICU LOS is about 6 days [23]. In contrast, the mean ICU LOS of a severely septic patient increases to 16.6 days. Survivors spend more time in the ICU than nonsurvivors (18.4 vs. 14.4 days). In patients admitted to the ICU with sepsis the ICU LOS increases to 18.2 days but remains unchanged at 16.7 days if sepsis is acquired during the ICU stay. By comparison, a previous study at the University of Göttingen found that the mean ICU LOS of nonseptic (noninfectious) patients is 4.0 days (excluding patients with LOS <24 h) [24].

Despite shorter ICU LOS the total cost of nonsurvivors was found to be higher than that of survivors of sepsis (25,446 vs. 21,984 euros), which is in agreement with similar findings in the literature [25, 26, 27]. The difference between nonsurvivors and survivors is even higher in regard to the costs per day (1,649 vs. 1,162 euros), indicating an increased use of resources in nonsurvivors in an attempt to reverse the expected fatal outcome. Although these increased efforts occur over a shorter period of time, the total costs are higher in nonsurvivors. Medication and staff costs make up two-third of the total direct costs.

The average daily costs of a severely septic patient were found to be 1,318 euros. By comparison, Edbrooke et al. [28] recently assessed for the UK average daily costs of septic patients in the United Kingdom to be about US$ 900 (1,080 euros). On the other hand, the German health care system offers reimbursement of 851 euros per ICU, which represents a reasonable estimate of the daily costs of an average ICU patient (average "hotel costs" and additional ICU payment) [29]; however, the actual daily costs of treating a septic patient are 1.5-fold higher.

Similarly, when comparing the mean total treatment cost of a standard ICU patient who spends an average of 6.0 days in a German ICU, and who causes total expenditures of 5,105 euros, the septic patient costs 23,297 euros, i.e., expenses per case that are about fivefold higher. The estimated total costs of nonseptic patients – spending on average 4 days in the ICU [30] – are considerably lower than for septic patients (3,404 vs. 23,297 euros), indicating that septic patients consume more resources over a longer period of time. The difference in mean ICU LOS of 12.6 days is certainly the most important factor in explaining the variance in total cost between septic and nonseptic patients.

Comparing the costs of severe septic patients who underwent surgical procedures with nonsurgical patients showed that expenses increased in the surgical group not only due to a longer ICU stay but also due to an increased use of resources (although costs of operative procedures were not included), despite the fact that mortality was higher in nonsurgical patients. In critically ill surgical patients the surgical procedure often causes an initial postoperative deterioration. In these patients the higher costs of drugs, blood, and blood products reflect the postoperative stabilization phase.

A total of 6,226,000 patient-days were spent in German ICUs in 1999 (German Hospital Association, DKG, oral communication), entailing total ICU costs for the year of 5,298.3 million euros. Considering the above mentioned range of 44,000–95,000 patients with severe sepsis, the costs of severe sepsis consume between 19% and 42% of the total ICU expenditures in Germany.

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