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A cost-effectiveness analysis of stays in intensive care units

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Abstract *Objective*: To evaluate patient outcome and the efficiency of stays in intensive care units (ICUs).
Design: Prospective study.
Setting: Seven ICUs of teaching hospitals in the Paris area.
Patients: Two hundred eleven stays including one in three consecutive patients admitted from September to November 1996.
Measurements and main results: For each patient, the following information was collected during the ICU stay: diagnosis, severity scores, organ failures, workload, cost and mortality. A cost-effectiveness ratio was computed for 176 stays with at least one organ failure, at hospital discharge and 6 months later. Quality of life was measured with EuroQol questionnaires 6 months after discharge in 64 patients representing 62 % of the patients contacted. The mean total ICU cost per stay was US$ 14,130 (± 6,550) (higher for non-survivors – US$ 19,060, median 10,590 – than for survivors – US$ 12,370, median 5,780). The incremental cost-effectiveness ratio was US$ 1,150 per life-year saved and the incremental cost-utility ratio was US$ 4,100 per quality-adjusted life-year (QALY) saved, without discounting. These results compare favourably with other health-care options. However substantial variations were observed according to age, severity, diagnosis, number of organ failures and discount rate. Intoxication had the lowest ratio (US$ 620/QALY) and acute renal insufficiency the highest (US$ 30,625/QALY).
Conclusions: This work provides medical and economic information on ICU stays in teaching hospitals and enables comparisons with other health-care options.

Key words Intensive care · Health-care costs · Resource allocation · Hospital costs · Cost-benefit analysis · Quality-adjusted life-years · EuroQol

Introduction

Intensive care medicine accounts for approximately 5 % of hospital admissions and about 15–20 % of their budgets [1]. But the perception of intensive care as a costly speciality is based upon a purely accounting approach. Allocated resources have to be related to outcome in terms of a performance assessment, and particularly the patient's preferences. On the whole, studies on the quality of life (QOL) after intensive care have shown positive outcomes [2, 3, 4]. Nevertheless in papers concerning cost measurement as well as quality of life assessment after intensive care unit (ICU) discharge, lack of standardization of parameters and of analysis methods is apparent. Performance is assessed through computation of standardized mortality ratio from severity scores such as SAPS II [5]. But these are not individual measurements, and at best only allow comparisons between ICUs [6]. Moreover, cost is not involved, and is not considered as a performance marker. Very few studies address the cost and the quality of life after intensive care [7, 8]. The aim of the present study was to evaluate, from the hospital perspective, the efficiency of management and the outcome of patients severely ill on the ICU, and quality of life after hospital discharge.

Patients and methods

Since 1993, the intensivists of hospitals in Paris and its suburbs (Assistance Publique-Hôpitaux de Paris, AP-HP) have used a common database (CubRea) covering 15,000 stays each year in 30 ICUs [9]. A clustering multivariate study classified ICUs in three groups: "long stays", "severe stays" and "standard stays". Long stays had a mean length of stay of 12 days (versus 7 days in the database) and severe stays had an ICU death rate of 24 % (versus 17 % in the database). Standard stay had a mean length of stay of 5 days and an ICU death rate of 16 %. A prospective study was performed in the autumn of 1996 in seven ICUs, representative of each of these three groups. A number of 200 patients was estimated to provide precise data about the costs of stays.

Patients

One in three consecutive stays was prospectively recorded. The main clinical and laboratory data were collected: diagnosis, organ failures defined from the thesaurus of the SRLF (i.e. the French language intensivists' society), tests and procedures and medical workload through Omega scoring system [10]. Recorded outcomes were living status at the ICU and on hospital discharge.

Costs

Direct costs are attributed to a patient's care; they can be divided into variable and fixed costs. Variable costs depend on the workload level: nursing staff requirement and medical expenditures. Direct variable costs were precisely measured through a micro-costing method. Data on the direct medical expenditures were derived from daily monitoring sheets: unitary consumption of costly drugs and disposables (valued at AP-HP central pharmacy prices), blood products (valued at national list prices) and procedures (internal and external procedures were valued at AP-HP internal prices, or at market standard cost, without time of nursing staff) were costed. In assessing the mean length of each care, nursing and auxiliary nursing costs were estimated on the strength of interviewing a nurse and a head nurse in each unit. The total nursing time of each stay can be calculated by adding all the care required during the stay. Nursing time was valued at daily standard costs (+ insurance contributions), according to the rank, using 1996 rates.

Other direct costs, fixed costs, are independent of the workload level: medical staff, head nurses. They were computed from monthly salaries in proportion to each length of stay.

Indirect costs do not concern the actual patient's care. They are mainly overheads: heating, lighting, hostelry, cleaning, administration, management and building amortization; they were calculated from internal tariffs with respect to length of stay. Costs of non-ICU stays were valued from daily cost, using a retrospective payment system with tariffs weighted according to specialization: medicine US$ 480/day, surgery US$ 770/day. They were not included in the main cost-effectiveness analysis, but in the sensitivity analysis.

The US dollar in 1996 was close to FF 6. Euro, which was not present at that time, is FF 6.5. One pound (£) was valued at US$ 1.67, and one Canadian dollar at US$ 0.85.

Effectiveness

Cost-effectiveness was focused on patients with at least one organ failure: renal, circulatory, respiratory or coma, requiring vital support. Units of effectiveness were preserved life-years, i.e. life expectancy (LE) according to age and gender. Incremental effectiveness (ΔE) was the number of preserved years related to intensive care, compared to a virtual "doing nothing" strategy with a theoretical certainty of death.

$\Delta E_i = LE_i * S_i$ for stay i (S = 0 if death/S = 1 if survival)

Effectiveness at 6 months was computed in the same way. In order to refine LE, we used the MacCabe score, which simply estimates the patient's prognosis 3 months before hospitalisation [11]. This score, currently used by intensivists, distinguishes three groups:

- non-fatal or non-underlying disease: LE = "natural" life expectancy from data of the National Statistics Institute.
- ultimately fatal within 5 years: LE = 5 years (maximum)
- rapidly fatal within 1 year: LE = 1 year (maximum)

ΔE was computed at hospital discharge and 6 months later. If readmission to intensive care or death occurred within 6 months, life-years saving was scored as 0.

Incremental cost-effectiveness ratio

Incremental cost (ΔC) was the difference between the costs of alternative strategies, i.e. cost of intensive care stay (versus doing nothing). The cost-effectiveness ratio ($\Delta C/\Delta E$) was defined as net cost of stay expressed in monetary units (US dollars in 1996) divided by net effectiveness saving, expressed in life-years:

$$\Delta C/\Delta E = \sum_{i=1}^{n} \Delta C_i / \sum_{i=1}^{n} \Delta E_i \quad n = \text{number of stays}$$

Quality of life

Six months after hospital discharge, each surviving patient was sent a letter including the generic health-related self-assessment questionnaire EuroQol-5D [12] comprising five dimensions of health giving rise to 243 health states with related tariffs, and a visual analogue scale (VAS). EuroQol is a cardinal scale, relevant for quality-adjusted life-years (QALY) computation and economic appraisal [13]. Where necessary, this survey was completed by a new letter and/or by phone. Patients lost to follow-up were sought through record offices, in order to establish their living status, at least. Utility scores were QOL values derived from EuroQol scores. Quality of life was taken as zero during hospital stay and as half of the EuroQol score for the period between hospital discharge and questionnaire response, measured in years. Quality of life was considered to be stable starting from the response [14]. Incremental quality-adjusted life expectancy (QALE) was the product of incremental effectiveness at 6 months with quality of life scores:

$$QALE_i = (\Delta E_i * QOL_i) + (\text{time to response} * QOL_i/2)$$

Incremental cost-utility ratio

Cost-utility ratio (ΔC/ΔU) was defined as the cost of all stays expressed in monetary terms divided by total QALE, expressed in expected QALYs:

$$\Delta C/\Delta U = \sum_{i=1}^{n} \Delta C_i / \sum_{i=1}^{n} QALE_i$$

Discount

Costs were not discounted because only intensive care expenses were considered. In contrast, future health benefits were discounted according to generally accepted rates (3 and 5%) [15].

Sensitivity analysis

The sensitivity analysis was conducted on the costs and on the consequences (QALY). The cost-effectiveness and cost-utility ratios were computed including the costs of hospital stay, before and after intensive care stay, according to the category (surgery or medicine). Three scenarios were evaluated according to the patient outcome (Table 6):

1. Worst case: all people with unknown living status at 6 months have died, and living people who did not respond to the questionnaire have the lowest observed value of quality of life (i.e. 5).
2. Best case: all people with unknown status are alive, and living people who did not respond to the questionnaire have the highest observed value of quality of life (i.e. 95).
3. Basic case: people with unknown living status have been attributed a status estimated from a logistic regression equation including SAPS II, Omega score and length of stay, while all living people with unknown health status have a value of quality of life estimated from a linear regression equation including SAPS II.

Statistical methods

Groups were compared by means of Student's *t*-test and the χ^2 test for continuous and categorical data, respectively. Comparisons concerning lengths of stay and costs were performed after logarithmic transformation, to improve the symmetry of distributions. Relations between patient characteristics and living status at the time of follow-up were modelled through logistic regression, while the relation to quality of life was ascertained by linear regression. A p value less than 0.05 was considered significant. All analyses were performed with SAS statistical software.

Results

The representativeness of our sample was good (Table 1). Comparison with the whole database revealed no significant difference in the main characteristics except for mean severity score, which was higher in our sample according to sampling design ($p < 0.05$), and for proportion of surgical patients ($p < 0.01$).

Of 211 patients, 52 died in hospital. Twelve foreign patients without any local address or proxy could not be contacted and so were excluded from the analysis. Twenty-six patients died within 6 months after hospital discharge and 18 patients were lost to follow-up. Of the 103 remaining patients, 64 returned a complete or almost complete questionnaire within 300 days of hospital discharge; two returned insufficient information and 29 were known to be alive, but did not answer. The statuses of eight patients were known only after 300 days and were thus censored.

The mean length of stay of 176 patients with at least one organ failure was 9 days (median 4 days) and hospital death rate was 29%. For these patients the mean total cost per stay was US$ 14,310 (median US$ 6,550) (Table 2). Direct costs accounted for US$ 11,720, comprising US$ 10,350 for variable costs (medical expenditures and nursing time) and US$ 1,370 for fixed costs (medical staff and head nurse). The mean total cost for 125 surviving patients was lower (US$ 12,370, median US$ 5,780) than the mean total cost for the 51 people who died (US$ 19,060, median US$ 10,590). The cost per surviving patient was US$ 20,150. Effectiveness was not positively correlated with cost (number of saved years = $64.4-12.8*\ln_{10}(\text{cost})$).

Cost-effectiveness analyses were performed on 176 patients on discharge, and on 121 six months later (Table 3). On average the incremental cost-effectiveness ratio was not high (US$ 1,150/year). Age, initial severity and number of deficiencies had a large impact. Categories of diagnosis, which also depended on the patient's age, gave large variations (US$ 270/year for intoxication cases, US$ 9,495/year for acute renal failure).

The global EuroQol score was 52.7 using the VAS and 62.9 using tariffs. There were highly significant differences ($p < 0.001$) from national surveys values in the general population [16, 17] which indicated a mean VAS of 82.5 and mean tariffs of 86. Moderate pain and anxiety were the most frequently mentioned problems in our sample (Table 4).

Cost-utility analysis at 6 months after discharge was performed on 121 patients (45 living and of known EuroQol status, and 76 dead) (Table 5). Global cost-utility ratio was US$ 4,110/QALY without discount. Discounting rates had a large influence on the results, and a discount of 5% gave an almost two-fold higher ratio (Table 6). There was substantial discrepancy according to age, severity, diagnosis and number of deficiencies. In-

Table 1 Sample and CubRea database parameters in 1996

Characteristics	Terms	Sample	Database
Number of stays		211	16117
Mean age (SD)		55.4 (19.5)	54 (19.4)
Gender (%)	Male/female	55.9/44.1	58.2/41.8
Mean length of stay (SD)		7.9 (11.1)	7.5 (12.6)
Type of admission (%)	Medical	81.5	86.7
	Scheduled surgical	9	6.2
	Unscheduled surgical	8.5	7.1
MacCabe (%)	0/1/2	60/26/14	64/22/10
Mean SAPS II (SD)		37.6 (20.9)	35.5 (21.3)
Intensive care death (%)		21.8	16
Hospital death (%)		26.1	21.3
Main diagnosis (% of stays)	Acute respiratory failure (without chronic respiratory deficiency)	26.5	18.7
	Coma	17.1	16.2
	Anuric renal failure	10.9	4.8
	Intoxication	10.9	15.9
	Left ventricular failure	9.5	6.6
Supply (% of stays)[a]	Respiratory	53.6	46.6
	Circulatory	35.3	32.7
	Renal	11.6	7.4
Average total Omega (SD)		119.6 (162.9)	94 (192.7)
Average daily total Omega (SD)		12.9 (9.3)	11.8 (8.7)

[a] Definition of supply: *Respiratory*: any form of mechanical ventilation; tracheotomy. *Circulatory*: use of vasoactive drugs (excluding low dose of dopamine); intra-aortic balloon; electric shock. *Renal*: haemofiltration or haemodialysis

Table 2 Components of cost (US$)

Components	Mean	Median	SD
Drugs	550	130	930
Units of blood products	390	0	1,110
Tests and procedures	2,700	1,440	3,620
Medical supplies	900	410	1,290
Nursing staff	5,800	2,360	8,210
Total variable direct costs	10,350	4,490	14,060
Total fixed direct costs	1,370	790	1,550
Total indirect costs	2,590	1,290	3,410
Total ICU costs	14,310	6,550	18,840
Total non-ICU costs	6,680	2,120	11,460

toxication still gave the lowest ratio (US$ 620/QALY) and acute renal insufficiency the highest (US$ 30,625/QALY).

Discussion

Cost-effectiveness analyses can contribute to assessment of performance in intensive care medicine. A major issue is the choice of an alternative strategy, which may involve a "doing nothing" option. The latter may be real, as in simple control of aneurysm [18], or virtual as in theoretical non-treatment of Hodgkin disease [19]. In intensive care, two options have already been used: a doing nothing strategy [14, 20] and a theoretical admission to a medical ward, which implies major assumptions regarding death rates and length of stay [8]. Precise data concerning consumed resources and patient outcome would not be available, except in an historical perspective. We then assumed that an alternative strategy such as standard ward care would not be relevant from a medical or an ethical viewpoint, and we focused our analyses on patients with at least one organ failure, i.e. with high risk of death without intensive care. Moreover, the hospital death rate was 2.8 % among 36 patients without any organ failure and their admission to an ICU may be questionable [21].

Our results may not be representative of all ICUs in Europe as our study, in purpose, concerned only medical ICUs in teaching hospitals. Moreover the sampling scheme put emphasis on units with longer or more severe stays, with the aim of improving the precision of cost data.

Assessing and comparing intensive care costs is difficult because of case-mix and various methods of costing. Case-mix description is not yet standardised for ICUs, as it is for hospitals with diagnosis-related groups. So we strove to measure individual costs on a stay basis and to identify diagnostic categories. Micro-costing is then the most relevant method, but as the cost of information is high, it was restricted to variable direct costs. Internal tariffs generally represent an acceptable ap-

Table 3 Cost-effectiveness (C/E) ratios at hospital discharge (*CRD* chronic respiratory disease)

Category	Subgroups	Number	Life expectancy (years)	Effectiveness (years) (SD)	Total cost per stay (US$) (SD)	C/E ratio (US$/year)
Global		176	15.3	12.4 (15.9)	14,310 (18,840)	1,150
Age	< 40 years	37	29.6	24.6 (24.4)	13,820 (22,480)	560
	40 < 65 years	60	15.5	12.9 (14.0)	17,590 (21,280)	1,365
	≥65years	79	8.5	6.4 (6.0)	12,050 (14,380)	1,885
Type of admission	Medical	145	15.6	12.6 (16.2)	13,900 (14,390)	1,105
	Scheduled surgical	15	12.8	10.3 (8.1)	16,980 (13,540)	1,650
	Unscheduled surgical	16	15.4	12.5 (18.4)	15,520 (18,700)	1,240
SAPS II	< 20	21	30.1	30.1 (21.4)	7,910 (16,170)	260
	20 < 35	61	16.3	15.5 (15.1)	9,200 (11,920)	595
	35 < 50	49	12.1	10.4 (12.7)	18,850 (22,570)	1,810
	> 50	45	10.6	2.2 (5.5)	19,280 (20,950)	8,765
Number of deficiencies[a]	1	82	18.9	17.6 (17.3)	9,190 (12,320)	520
	2	56	12.4	8.8 (14.5)	17,730 (21,710)	2,015
	> 2	38	11.8	6.7 (10.6)	20,320 (23,070)	3,030
Diagnosis	Acute respiratory failure (without CRD)	56	12.5	10.3 (14.8)	15,580 (14,860)	1,510
	Acute respiratory failure (with CRD)	19	8.1	7.5 (10.8)	19,220 (22,340)	2,560
	Coma	35	21.5	14.7 (17.2)	11,900 (22,840)	810
	Acute renal failure	23	8.8	2.9 (7.2)	27,530 (26,160)	9,495
	Intoxication	17	26.7	25.7 (20.5)	6,960 (9,430)	270

[a] Defined as organ failure requiring supply (see Table 1)

proximation to the costs of medical staff and overheads [15]. A combination of the two methods was used to estimate total costs. Our median total cost per stay was $ 6,550. A review of the literature to 1995 indicated an average cost per ICU stay of between US$ 2,200 and 5,700 [22]. More recently Chaix et al. found a mean total cost per ICU stay of £ 6,279 [23]. Heyland et al., according to the length of stay groups (fewer or more than 14 days) computed an average ICU cost per stay of Can$ 4,290 or 37,760 [20]. Mean total daily costs are more similar: the US$ 1,590 computed in our study is very close to the US$ 1,500 of Noseworthy et al. [24] and the Can$ 1,565 of Heyland et al. For patients requiring prolonged mechanical ventilation, an incremental cost-effectiveness ratio of US$ 4,700 per life-year saved is reported in one study [25]. For patients with prolonged stays (more than 14 days) in our study, we found a cost-effectiveness ratio of US$ 4,350, very close to the Can$ 4,350 per life-year saved of Heyland et al.

Wide case-mix observed in intensive care points to the value of using international generic scales to assess quality of life. Economic evaluation requires a cardinal scale, such as EuroQol. Among the few cost-utility studies performed in intensive care, we found only one that

Table 4 Distribution of patients in each EuroQol dimension

EuroQol dimension (%)	Dimension 1 (No problem)	Dimension 2 (Moderate problem)	Dimension 3 (Severe problem)	Total
Mobility	57.8	40.0	1.6	100
Self care	80.3	13.1	6.6	100
Usual activities	50.0	38.7	11.3	100
Pain/discomfort	20.6	66.7	12.7	100
Anxiety/depression	35.5	51.6	12.9	100

Table 5 Cost-utility (C/U) ratios at 6 months (*CRD* chronic respiratory disease)

Category	Subgroups	Number	Effectiveness (years) (SD)	Utility (SD)	QALY (SD)	Total cost per stay (US $) (SD)	C/U ratio (US $/ QALY)
Global		118	7.6 (11.7)	0.63 (0.28)	3.9 (9.7)	15,480 (19,270)	4,110
Age	< 40 years	14	11.6 (23.2)	0.93 (0.12)	10.6 (21.3)	18,100 (22,250)	1,710
	40 < 65 years	39	8.9 (12.8)	0.58 (33)	4.4 (9.3)	18,810 (23,420)	4,500
	≥65 years	65	5.9 (6.0)	0.63 (0.24)	2.1 (3.6)	12,920 (15,340)	6,265
Type of admission	Medical	94	7.4 (11.4)	0.61 (0.31)	3.7 (9.6)	15,750 (20,390)	4,465
	Scheduled surgical	12	7.5 (6.3)	0.71 (0.31)	3.7 (3.9)	13,205 (8,320)	3,550
	Unscheduled surgical	12	9.1 (17.4)	0.70 (0.23)	5.7 (13.9)	15,670 (18,910)	2,740
SAPS II	< 20	7	24.3 (20.7)	0.64 (0.31)	17.4 (21.6)	14,990 (27,250)	1,065
	20 < 35	36	11.4 (12.7)	0.68 (0.31)	7.2 (12.9)	10,180 (13,650)	1,515
	35 < 50	34	8.1 (9.5)	0.57 (0.22)	4.4 (7.2)	19,820 (24,350)	7,535
	> 50	41	1.8 (5.5)	0.52 (0)	0.4 (2.3)	16,620 (16,720)	46,005
Number of deficiencies[a]	1	45	13.9 (15.4)	0.66 (0.32)	8.4 (14.7)	10,685 (14,440)	1,350
	2	41	3.3 (5.5)	0.55 (0.26)	1.6 (4.7)	15,955 (18,470)	20,420
	> 2	32	4.1 (6.7)	0.65 (0.19)	3 (5.8)	21,615 (24,340)	12,270
Diagnosis	Acute respiratory failure (without CRD)	38	4.4 (6.0)	0.61 (0.23)	2.3 (4.4)	16,540 (14,260)	11,970
	Acute respiratory failure (with CRD)	11	5.3 (5.8)	0.52 (0.24)	2.3 (4.4)	25,430 (27,420)	14,365
	Coma	27	11.8 (17.0)	0.67 (0.35)	7.7 (16.0)	14,215 (25,640)	2,160
	Acute renal failure	21	2.2 (6.4)	0.57 (0.07)	1.3 (3.9)	25,790 (26,710)	30,625
	Intoxication	10	21.9 (21.3)	0.71 (0.43)	15.3 (22.8)	9,520 (11,730)	620

[a] Defined as organ failure requiring supply (see Table 1)

Table 6 Cost-utility ratios at 6 months according to sensitivity analysis and discount rate

	Number	Total cost per stay (US $)	Effectiveness (years)	Utility (QALY)	C/U ratio (US$/QALY) discount 0 %	C/U ratio US$/QALY) discount 3 %	C/U ratio (US$/QALY) discount 5 %
ICU stay							
Actual case	118	15,480	7.6	3.9	4,110	5,870	7,775
Best case	176	14,310	11.3	9.9	1,440	2,150	2,925
Worst case	176	14,310	8.2	2.6	5,435	7,690	10,135
Base case	176	14,310	11.2	7.4	1,945	2,895	3,935
ICU and non-ICU stay							
Actual case	118	22,410	7.6	3.9	5,945	9,200	11,260

used EuroQol [26], and two [7, 8] using the QALY method, which is still recommended for cost-utility analysis [13]. Our cost-utility ratios match those of Kerridge et al. [8] who obtained a range of US$ 700–4,200/QALY. Ridley [7] computed ratios between £ 800 and 7,400/QALY according to diagnostic categories, with a 5 % discount rate (Table 5).

Many and various cost-utility ratios are available in the health-care field. Most recent studies showed a wide range: US$ 24,200 /QALY for aneurysmal brain surgery [18], US$ 176,817/QALY for lung transplantation [27], US$ 2,740/QALY for Hodgkin treatment [19], US$ 3,190/QALY for treatment of diabetic eye disease [28] or US$ 598,487/QALY for vaccination against pneumococcal bacteraemia after age of 85 [29]. Among them the cost-utility ratios of our study appear moderate.

Although age-adjusted, our quality of life results appeared significantly lower than those of national surveys using EuroQol questionnaires. Our responding sample predominantly consisted of elderly patients, frequently with chronic underlying diseases. This larger decrease in QOL scores after ICU discharge among elderly patients was also noted by Vazquez et al. [30].

Our QOL questionnaire response rate was 62 %. Non-respondents were generally young, male and had spent longer in the ICU, as noted by other authors [31, 32]. We considered data mainly obtained by mail in compliance with methodological rules, though among elderly patients the validity of EuroQol may require interviewers [33]. The costs of stay of non-respondents have to be considered. They are higher than average, but survival rate and life expectancy are also higher, since these patients are younger, so we cannot determine in which direction these missing data modify the final cost-utility ratio.

Discounting is necessary but raises some questions. Discount rates were applied to the life expectancy of each surviving patient, to give a theoretical mean projection, which will not necessarily be reached by every patient. Moreover, health benefits for the youngest people with the longest life expectancy are somewhat penalized by the life expectancy discount.

In summary, this pilot study, performed in compliance with the economic evaluation guidelines in health and medicine [15], may help to define efficiency criteria for ICUs. The results suggest that patient management in ICU results in moderate cost-effectiveness and cost-utility ratios among health-care options, in spite of variations related to case-mix.

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