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Effectiveness and efficiency of intensive care medicine: variable costs in different diagnosis groups

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Background: To establish the effectiveness of ICU treatment and the efficiency in the use of resources in patients stratified according to 10 diagnosis and two levels-of-care. To propose strategies aimed at reducing costs and improving efficiency in each patient group.

Methods: Multicentre prospective observational study. ICUs enrolled two cohorts of up to 10 consecutive patients with ICU stay ≥48 h. Each with one of these diagnoses: trauma, brain-trauma, brain-hemorrhage, stroke, acute-on-chronic-obstructive-pulmonary disease, lung-injury/acute respiratory distress syndrome, heart failure, and scheduled/unscheduled abdominal surgery. The presence of active-life support divides high from low level-of-care treatments. Variable ICU costs were collected daily (bottom-up) for 21 days. We evaluated effectiveness (hospital survival) and efficiency (hospital-survivors variable-cost as a ratio of overall cost).

Results: Forty-two Italian general ICUs recruited 529 patients in 5 months. Mean ICU variable-costs significantly differed with diagnosis and level-of-care. Costs were positively affected by ICU length-of-stay, by duration of active-treatment. Outcome variably influenced costs. Medians of variable-costs per patient (1715 Euro) and patient-groups efficiencies (60.7%) identified four possible combinations between (low and high) cost and (low and high) efficiency groups. Moreover, efficiency was better than effectiveness in stroke, brain-hemorrhage and trauma, while it was worse in heart failure, acute-on-COPD or acute-lung injury. Overall ICU cost attributed only to survivors ranged from 699 (scheduled surgical) to 5906 (unscheduled surgical) Euro. Cost of non-survivors distributed to all patient was between 95 (scheduled-surgical) to 1633 (unscheduled-surgical) Euro.

Conclusions: Analysis of variable patient-specific cost was used as a tool to assess intensive care performance in patient subgroups with different diagnosis and levels-of-care.

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Key words: ICU performance; variable costs; effectiveness; efficiency; cost-effectiveness; diagnosis; level of care; GiViTI.

Aging, comorbidity, costly diagnostic and therapeutic interventions and scarcity of resources call for improvements in the efficiency of medical care. Practical, accurate and sensitive measures of resource use in intensive care units (ICU) are strongly needed (1–4). However, cost-effectiveness analysis in intensive care medicine is difficult.

The majority of studies of cost-effectiveness analysis in this field looked at the beneficial effects of different therapies, interventions or supportive measures for specific conditions (1, 4). Of note, in order to establish the beneficial effect of ICU treatment as a whole, the standard arm for comparison should be the 'doing nothing strategy' with a theoretical certainty of death (4, 5). Studies on effectiveness of standard critical care medicine among ICUs or groups of ICU patients using cost or cost-proxy-effectiveness ratios are few (6–8).

Intensive care unit patients have very heterogeneous conditions and large variability in terms of severity of illness, length and complexity of treatment, even within the same diagnosis group. Moreover, ICU activity does not refer to single diseases or procedures. Rather, it consists of a collection of different interventions in patients with different diagnoses.

* The complete list of study participants is reported in the Acknowledgements.

Generally, studies in critical illness tend to lump all ICU patients together (1, 4).

We planned an observational, prospective study to assess the performance of intensive care medicine in predefined diagnostic groups stratified according to the level of care provided. This study analyzed only variable costs, i.e. the ones mostly dependent on pathology and intensity of treatment. Cost-effectiveness analysis attempts to provide tools for decision making in circumstances where resources are scarce.

Methods

The GiViTI ICU-cost project was carried out from June to October 1999. Each ICU had to enrol two cohorts of minimum five to maximum of 10 consecutive adult patients with ICU stay $\geq$48 h. Each cohort was selected among the following most prevalent diagnosis groups in Italian ICUs [trauma, brain trauma, non-traumatic brain hemorrhage, stroke, acute exacerbation of chronic obstructive pulmonary disease (COPD), acute lung injury/acute respiratory distress syndrome (ALI/ARDS), heart failure, scheduled or unscheduled abdominal surgery (9)], as decided by the Coordinating Center.

Age, gender, diagnosis, organ failure at admission (respiratory: immediate need of artificial ventilation/CPAP-respiratory weaning after anesthesia was not considered failure-; cardio-circulatory: immediate need of vasoactive support; cerebral: Glasgow coma score <8), Simplified Acute Physiological Score II (SAPS) (10), ICU and hospital outcome were collected for all patients. The Nine Equivalents Nursing Manpower Score (NEMS) (11) was recorded daily. Six NEMS items relating to organ support (monitoring, mechanical ventilation support/continuous positive airway pressure (CPAP), multiple vasoactive medication, supplementary ventilatory care, single vasoactive medication, dialysis) were used for classifying intensity of daily medical treatment in the ICU (12). Level of care (LC) was considered high (HLC) in case of monitoring coupled with active support of respiration, and/or with multiple vasoactive drugs, or with a less active support of at least two organs (supplementary ventilatory care, single vasoactive drug, dialysis). All other interventions were classified as low level of care (LLC).

Patients who spent the entire ICU stay in LLC (less critically ill) were analyzed separately. The recruited sample was not representative of the admitted population, indeed we expected roughly the same number of patients in each diagnosis group as a result of the combination of the number of enrolling ICUs with the occurrence of each typology. Nevertheless, each diagnosis group contained a sufficient number of patients to describe the impact of intensive medicine on this diagnosis.

Cost analysis

Management strategy adopted by ICUs was assumed to be average current clinical practice based on available evidence. Using the 'bottom up' approach, we collected the daily information related to actual patient care and the level of implementation of each intervention for each enrolled patient. Then we computed the patient-specific variable costs (13).

Our analysis was designed to assess cost variation among different groups of patients excluding personnel costs. This cost could have precluded the possibility of detecting any difference, being either by far the most important factor of cost or depending upon ICU organization (variable within the same country). Clinical record data form was developed electronically and validated by means of three independent data collections in different samples of two, three and 29 ICUs. Data on drugs, diets, infusions and blood products, laboratory and imaging tests, surgical interventions, therapeutic procedures, consultations from other departments, disposable, and special beds were gathered until ICU discharge or for a maximum of 21 days. Each single item collected was expressed in money terms by means of its cost in Euro (€). Items costing less than 20 Euro per week were excluded.

The average variable cost of the whole ICU stay was determined in each diagnosis group. A further stratification was made between survivors and-non-survivors. We determined the influence on cost of length of stay (LOS), of ICU days spent in HLC [a proxy of the intensity of the process of care responsible for the consumption of physiological patient reserve (14),], and of ICU and hospital mortality.

We calculated the effectiveness of intensive medicine performance in treating different groups (actual hospital survival), the technical efficiency of intensive medicine for different groups (13), computed as the ratio between ICU cost per hospital survivors and ICU cost of all treated patients, the overall ICU cost attributed only to survivors (ICU cost of all treated patients/number of hospital survivors) and the average cost of non-survivors distributed to all patient (ICU cost of hospital non-survivors/number of treated patients).

Statistical methods
Data are reported as means and 95% confidence intervals (95% CI). Differences in cost among diagnosis groups were evaluated with one-way variance analysis (ANOVA) and linear contrasts by Scheffé test. The main clinical determinants of ICU variable cost (LOS, HLC days, ICU and hospital mortality, and their interactions) were evaluated with multiple regression analysis by a backward stepwise method.

Results

Forty-five ICUs recruited 529 patients, their characteristics are shown in Table 1. Since there were only 43 patients who received minor organ support (eight trauma, three brain hemorrhage, seven stroke, four acute COPD, five unscheduled and 16 scheduled abdominal surgery patients) they were analyzed as a single LLC group. Therefore, the case-mix comprised nine different diagnosis groups in which patients received HLC and one LLC group containing a mix of diagnosis.

Table 1

Demographic and clinical characteristics of the enrolled case-mix.

Patients/ICUs	529/42
Trauma	71/10
Brain trauma	74/9
Brain hemorrhage	98/12
Stroke	22/7
Acute on COPD	84/15
ALI/ARDS	71/13
Heart failure	44/9
Unscheduled abdominal surgery	28/8
Scheduled abdominal surgery	37/9
Age in years, mean (SD)	59.2 (18.94)
Male (%)	68.6
Source of patient (%)	
Emergency room	44.6
Hospital ward	28.2
Operative theatre	19.5
Other ICU	7.7
Associated diagnosis (%)	
None	60.7
One	29.3
$\geq$ Two	10.0
Reason for admission (%)	
Monitoring	14.0
One organ failure	61.2
$\geq$ Two organ failures	24.8
Organ failure on admission (%)	
Respiratory	56.5
Cardiovascular	15.9
Neurological	37.2
SAPS II, median	36.6
Days of ICU stay, mean (SD) median	11.1 (13.5) 6
Days of Hospital stay, mean (SD) median	21.4 (19.2) 16
ICU mortality (%)	26.9
Hospital mortality (%)	32.3

Length of stay, HLC-ICU days, effectiveness, variable cost per patient, overall ICU cost attributed only to survivors and cost of non-survivors distributed to all patient in each diagnosis group, are reported in Table 2. Cost per hospital survivors and non-survivors are reported in Table 3. A total of 66 patients out of 529 were treated for more than 21 days, the extra-days correspond to 15.5% of the total of 5717 ICU days. As a sensitivity analysis we assumed that all excluded days had the same cost as the 21st day, hence, the surgical unscheduled, brain hemorrhage, brain trauma, heart failure, ALI/ARDS, and trauma patient variable costs can be expected to increase by 8–19%. Acute on COPD cost showed the greatest increase, approximately 45%.

According to regression analysis (Table 4) ICU variable cost increases with LOS (stroke, abdominal surgery, LLC groups) or with HLC days (trauma, brain trauma, brain hemorrhage, COPD, ALI/ARDS, heart failure). Moreover, hospital mortality increases cost in scheduled abdominal surgery. ICU mortality increases cost in COPD and unscheduled abdominal surgery, while it decreases cost in LLC and brain hemorrhage patients. A withdrawal policy in LLC group (interactions between ICU mortality and LOS) and a significantly shorter LOS in brain hemorrhage group (data not shown) are able to explain these reductions.

The ICU variable cost per patient was different among diagnosis groups (Table 2). The ICU variable cost overall ICU cost attributed only to survivors ranks in decreasing order: unscheduled abdominal surgery, ALI/ARDS, trauma, brain hemorrhage, brain trauma, stroke, acute COPD, heart failure, LLC patients, and scheduled abdominal surgery patients. The average cost of non-survivors distributed to all patient ranks as follows: unscheduled abdominal surgery, ALI/ARDS, brain hemorrhage, trauma, acute COPD, heart failure, stroke, brain trauma, LLC, and scheduled abdominal surgery patients.

Cost-efficiency relationship of ICU treatment per diagnosis group is shown in Fig. 1. The superimposed lines, showing the median values of variable cost per patients (1715,00 €) and of the patient-groups efficiency (60.7%), identify four areas: less expensive and less efficient ICU groups (stroke, heart failure), more expensive less efficient groups (brain hemorrhage, unscheduled abdominal surgery, ALI/ARDS), more expensive more efficient groups (acute COPD, brain trauma, trauma) and less expensive more efficient groups (scheduled abdominal surgery, and the mix of LLC patients).

Table 2

Length of stay (LOS) and days in high level of care (HLC) during the study-period, treatment effectiveness (hospital survival rate – %), ICU variable patients costs (€), overall ICU cost attributed only to hospital survivors and cost of non-survivors distributed to all patients in the diagnosis groups of patients treated with high level of care and in the group of patients who received minor organ supply (LLC).

	n	LOS	HLC days	Effectiveness	ICU cost*	ICU overall cost attributed to survivors	ICU cost of non-survivors distributed to all patients
Trauma	63	12.8 (10.9–14.6)	9.4 (7.6–11.1)	82.5 (71.4–90.0)	4422.6 (3747.2–5097.9)	5358.1	890.7
Brain trauma	74	9.4 (7.8–10.9)	7.2 (5.8–8.7)	78.4 (67.7–86.2)	2933.9 (2386.4–3481.3)	3743.2	405.9
Brain haemorrhage	95	9.6 (8.1–11.2)	8.3 (6.9–9.8)	48.4 (38.6–58.3)	2548.8 (2034.4–3063.2)	5263.8	1045.0
Stroke	15	4.8 (2.3–7.3)	3.6 (1.7–5.5)	33.3 (15.2–58.3)	968.6 (415.2–1522.1)	2905.8	415.9
Acute on COPD	80	10.5 (9.0–12.0)	6.6 (7.5–10.4)	71.3 (60.5–80.0)	1884.1 (1570.5–2197.6)	2644.3	709.2
ALI/ARDS	71	12.2 (10.7–13.8)	10.3 (8.7–11.9)	63.4 (51.8–73.6)	3645.0 (3014.8–4275.3)	5751.0	1631.2
Heart failure	44	6.3 (4.3–8.3)	5.5 (3.6–7.5)	59.1 (44.4–72.3)	1323.1 (883.3–1762.8)	2239.0	682.0
Unscheduled abdominal surgery	23	7.9 (5.0–10.8)	6.1 (3.4–8.7)	52.2 (33.0–70.8)	3081.6 (1795.1–4368.1)	5906.4	1633.1
Scheduled abdominal surgery	21	2.1 (1.5–2.7)	0.8 (0.3–1.3)	90.5 (71.1–97.4)	632.5 (434.4–830.7)	699.1	94.9
LLC group	43	3.3 (2.2–4.3)	–	88.4 (75.5–94.9)	822.1 (559.0–1085.2)	930.3	158.1

*ANOVA: $P < 0.0001$.
Values are mean (95% confidence interval).

Discussion

In order to provide tools for decision making in the distribution of the limited resources, we tried to assess the performance of intensive care medicine in patients with medium-long stay, stratified according to nine prevalent admission diagnosis (9), in a group of Italian ICUs. Despite scheduled abdominal surgery, patients are not comparable with unplanned admission (15) they were included because they represent about 25–30% of ICU population and because they were admitted for instability due to major surgery coupled with comorbidities or poor physiology.

We evaluated the use of resource by collecting patient-specific variable costs with the bottom-up approach. Indeed, we excluded personnel costs because they are high, strictly dependent on local ICU organization, and difficult to be reliably charged to a single patient. All these characteristics tend to reduce more than highlight cost differences related to diagnosis, physiological status, and intensity of treatment.

It was shown that stratification of patients according to severity of illness at admission allows a more precise evaluation of the cost/effectiveness ratio (8). However, neither peak of severity occurs on the 1st day of ICU stay nor patients with the same severity score on admission but different diagnosis, will receive similar complexity of ICU stay (12, 15). To keep all patients receiving HLC at any stage of ICU stay (12) and those receiving only minor organ supply, we left in each diagnosis group only patients receiving HLC, and pooled together all the others, whichever the diagnosis (Table 2).

The variable cost per patient is highly dependent on diagnosis. It increases, from 632 € in HLC scheduled abdominal surgery patients, to 4423 € in trauma patients. This cost is variably underestimated because of restricted collection periods. Taking into account the determinants of ICU costs as inferred by multivariate regression (Table 4), one can achieve the containment of costs by reducing LOS (in stroke, abdominal surgery and LLC) or by accurately weighing the intensity of care (HLC days) in trauma, brain trauma, brain hemorrhage, acute on COPD, ALI/ARDS, heart failure). Accordingly, death in the ICU decreases the cost of patients who die within a short time (brain hemorrhage) or who die without organ support (LLC patients). On the contrary, death in ICU (COPD and unscheduled abdominal surgery) and in hospital (scheduled abdominal surgery) increases

Table 3

Variable ICU cost (€) and variable daily cost for hospital survivors and-non-survivors in the diagnosis groups of patients treated with high level of care and in the group of patients who received minor organ supply (LLC).

	n	Hospital survivor patients ICU cost	*n*	Hospital dead patients ICU cost
Trauma	52	4279.0 (3581.6–4976.4)	11	5101.3 (2777.9–7424.6)
Brain trauma	58	3225.4 (2560.3–3890.5)	16	1877.1 (1259.6–2494.7)
Brain haemorrhage	46	3105.6 (2256.3–3954.8)	49	2026.1 (1434.4–617.7)
Stroke	5	1658.3 (520.8–2795.8)	10	623.8 (0–1257.3)
Acute on COPD	57	1648.9 (1302.0–1995.9)	23	2466.7 (1814.1–3119.4)
ALI/ARDS	45	3177.4 (2411.0–3943.7)	26	4454.4 (3361.3–5547.6)
Heart failure	26	1084.9 (587.3–1582.5)	18	1667.1 (827.9–2506.3)
Unscheduled abdominal surgery	12	2776.2 (809.0–4743.4)	11	3414.7 (1434.0–5395.4)
Scheduled abdominal surgery	19	594.2 (400.6–787.8)	2	996.6 (0–7905.7)
LLC group	38	751.4 (557.5–945.3)	5	1359.5 (0–3856.4)

Values are mean (95% confidence interval).

the variable cost when patients die with unrestricted allocation of resources.

In addition to cost-containment, we can improve the use of resource, i.e. the efficiency of intensive treatment. Efficiency (variable costs for hospital survivors as a percentage of the cost spent on all patients in the same group-Fig. 1) identifies brain hemorrhage, ALI/ARDS and surgical unscheduled as the patients using a high volume of monetary-resources less efficiently, while the scheduled abdominal surgery patients admitted to receive intensive care and patients on the ICU for minor organ support (11, 12) made the best use of the fewer resources spent. At variance, we found the poorly efficient but-non-expensive groups of stroke and heart failure patients and the highly expensive/highly efficient groups of trauma patients with or without brain injury. Finally, acute COPD group represents the median of efficiency and costs.

Interestingly some conditions (in this study brain trauma, brain hemorrhage, stroke- Fig. 1), show a better overall efficiency in the use of monetary resources (by 8–27%) than treatment effectiveness (Table 2) because the ICU cost of non-survivors (as a result of a short LOS and intensity of care) was less than that of survivors (Tables 3 and 4 regression for brain hemorrhage). These conditions are characterized by brain failure which is at the same time the more dramatic and the more evident (e.g. brain death) proof of the futility of prolonged intensive care. Hence, any improvement in the (poor) efficiency of brain hemorrhage and stroke care, as well as of the (good) efficiency of brain trauma, should rely on improvements in effectiveness of their specific treatments.

On the other side, we found a number of conditions (acute COPD, ALI/ARDS, heart failure) whose efficiency in the use of monetary resources was worse (by 8–11%) than their treatment effectiveness because the

Table 4

Multivariate linear regressions describing covariates of variable ICU cost in the diagnosis groups of patients treated with high level of care (HLC) and in the group of patients who received minor organ supply (LLC).

	Length of stay (LOS)	Mortality (M)	Interaction (INT)	Formula	R^2
Trauma	HLC days	–	–	$7.3744 + 0.0845*LOS$	0.6373
Brain trauma	HLC days	–	–	$6.9265 + 0.1034*LOS$	0.6695
Brain haemorrhage	HLC days	ICU	–	$6.5673 + 0.1145*LOS - 0.2942*M$	0.6348
Stroke	All days	–	–	$4.9175 + 0.2588*LOS$	0.6300
Acute on COPD	HLC days	ICU	–	$6.2867 + 0.0980*LOS + 0.3545*M$	0.6860
ALI/ARDS	HLC days	–	–	$7.0825 + 0.0819*LOS$	0.4689
Heart failure	HLC days	–	–	$6.0383 + 0.1222*LOS$	0.6171
Unscheduled abdominal surgery	All days	ICU	–	$6.5834 + 0.0781*LOS + 0.8766*M$	0.6815
Scheduled abdominal surgery	All days	HOSPITAL	LOS*HOSP	$5.2706 + 0.4065*LOS + 3.2934*M - 1.6307*INT$	0.6359
LLC group	All days	ICU	LOS*ICU	$5.5074 + 0.2925*LOS - 1.5034*M - 0.2020*INT$	0.5548

Formulas give the natural logarithm of ICU variable cost. For all patients length of stay (either all days or HLC days) was positively related to ICU cost. Mortality (M: either in ICU or in hospital) intervenes to variably modify ICU cost. In a few groups an interaction between LOS and M exists which further corrects the relationship.

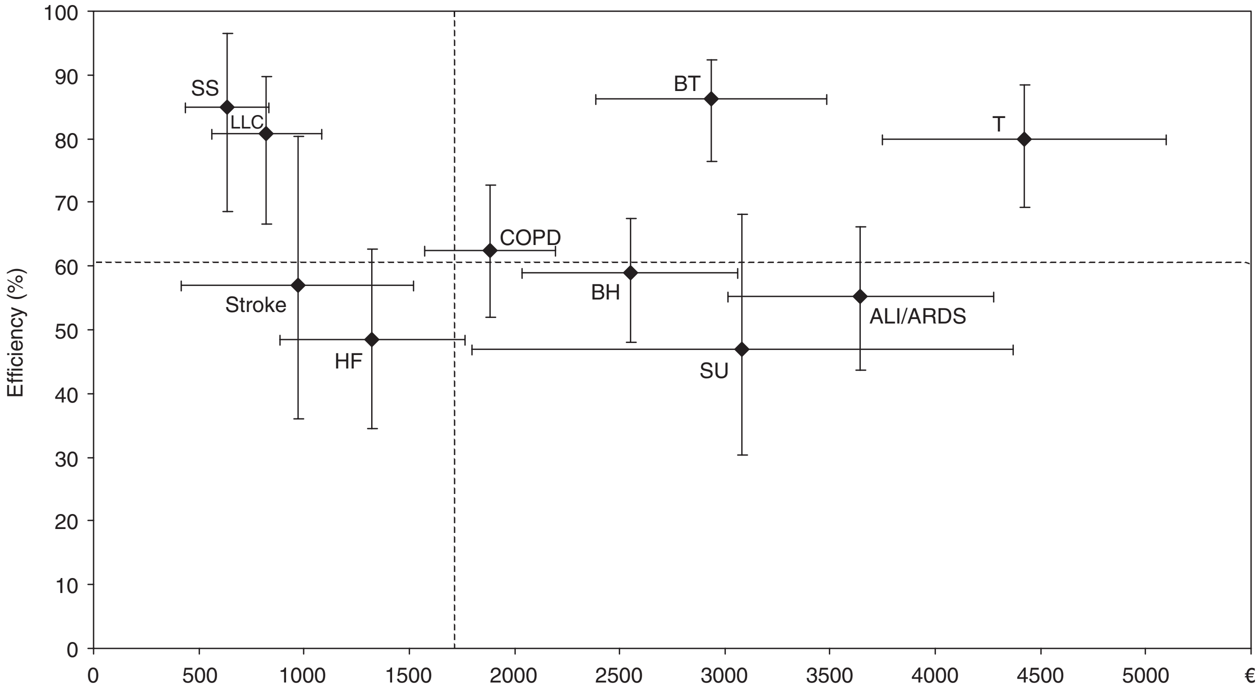

Fig. 1. Relationship between mean (95% confidence intervals) values of ICU variable cost and efficiency (percentage of the ICU variable cost of treated patients that was spent per hospital survivors) for patient groups. All patients included in diagnosis groups were treated with active vital support (high level of care), the patients of the LLC group received only minor organ supply. The dotted lines show the median value of the patients cost (1715,00 €) and the median value of patient-groups efficiency (60.7%). ALI/ARDS, acute lung injury/acute respiratory distress syndrome; BH, non-traumatic brain hemorrhage; BT, brain trauma; COPD, acute exacerbation of chronic obstructive pulmonary disease; HF, heart failure; LLC, low level of care; SS/SU, scheduled/unscheduled abdominal surgery; T, trauma.

ICU cost for non-survivors was higher than that for survivors (Tables 3 and 4 regression for COPD). Careful day by day evaluation of complexity and duration of care in poorly responding patients may improve efficiency, particularly for expensive acute COPD and ALI/ARDS patients.

Care of unscheduled abdominal surgery patients has a high ICU cost (Tables 3 and 4), poor effectiveness and efficiency. In this group, patients also tend to die after ICU discharge, this implies that a substantial physiological reserve was consumed during ICU stay, affecting post-ICU survival (14). The achievement of physiological stability at the end of ICU stay (avoiding any premature or inappropriate ward discharge), and/or improved ward care is therefore desirable.

Furthermore, implications from overall ICU cost attributed only to survivors, and cost of non-survivors distributed to all patients (Table 2) fit with diagnosis-related cost/efficiency analysis. All these data underline the importance of categorizing the case-mix while dealing with ICU costs. Moreover, even if costs alone do not determine physicians' treatment decisions, cost analysis per diagnosis can contribute to the decision-making process regarding the distribution of the scarce resources.

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References

1. Chalfin DB, Cohen IL, Lambrinos J. The economics and cost-effectiveness of critical care medicine. *Intensive Care Med* 1995; **2**: 952–61.
2. Heyland DK, Gafni A, Kenerman P, Keenan S, Chalfin D. How to use the results of an economic evaluation. *Crit Care Med* 1999; **27**: 1195–202.
3. Rubenfeld GD. Cost-effectiveness considerations in critical care. *New Horizons* 1998; **6**: 33–44.
4. Second ATS Society workshop on outcome research. Understanding costs and cost-effectiveness in critical care. *Am J Resp Crit Care Med* 2002; **165**: 540–50.
5. Sznajder M, Aegerter P, Launois Y, Guidet B, Cub Rea. A cost-effectiveness analysis of stays in intensive care units. *Intensive Care Med* 2001; **27**: 146–53.
6. Iapichino G, Radrizzani D, Colombo A. Efficienza di utilizzo delle risorse impiegate in reparti di Terapia Intensiva di area urbana. *Minerva Anestesiol* 1991; **57**: 103–10.
7. Rapoport J, Teres D, Lemeshow S, Gelbach S. A method for assessing the clinical performance and cost effectiveness of intensive care units: a multicenter inception cohort study. *Crit Care Med* 1994; **22**: 1385–91.
8. Smithies MN, Bihari D, Chang R. Scoring system and the measurement of ICU cost effectiveness. *Reanim Med Urgence* 1994; **3**: 215–21.
9. Apolone G, Bertolini G, D'Amico R et al. The performance of SAPS II in a cohort of patients admitted to 99 Italian ICUs. *Intensive Care Med* 1996; **22**: 1368–78.
10. Iapichino G, Radrizzani D, Bertolini G et al. Daily classification of the level of care. A method to describe clinical course of illness, use of resources and quality of intensive care assistance. *Intensive Care Med* 2001; **27**: 131–6.
11. Spangerberg JFA, van de Poel JHR, Iapichino G. Management control in the ICU. In: Miranda DR, Williams A, Loirat P, eds. *Management of intensive care. Guidelines for better use of resources.* Dordrecht: Kluver Academic Publishers 1990; 103–23.
12. Iapichino G, Morabito A, Mistraletti G, Ferla L, Radrizzani D, Miranda DR. Determinants of post-intensive care mortality in high-level treated critically ill patients. *Intensive Care Med* 2003; **29**: 1751–6.
13. Iapichino G, Radrizzani D, Ferla L et al. Description of trends in the course of illness of critically ill patients. Markers of intensive care organization and performance. *Intensive Care Med* 2002; **28**: 985–9.
14. Le Gall JR, Lemeshow S, Saulnier F. A new simplified acute physiology score (SAPS II) based on a European-North American multicenter study. *JAMA* 1993; **270**: 2957–63.
15. Miranda DR, Moreno R, Iapichino G. Nine equivalents of nursing manpower use score (NEMS). *Intensive Care Med* 1997; **23**: 760–5.

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