Measuring technical efficiency of output quality in intensive care units

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Presents some examples of the implications derived from imposing the objective of maximizing social welfare, subject to limited resources, on ethical care patients management in respect of quality performance of health services. Conventional knowledge of health economics points out that critically ill patients are responsible for increased use of technological resources and that they receive a high proportion of health care resources. Attempts to answer, from the point of view of microeconomics, the question: how do we measure comparative efficiency in the management of intensive care units? Analyses this question through data from an international empirical study using micro-economic measures of productive efficiency in public services (data envelopment analysis). Results show a 28.8 per cent level of technical inefficiency processing data from 25 intensive care units in the USA.

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Critical patient care

Intensive care units (ICU) are an organizational innovation based on the idea that critically ill patients need constant observation and care and quick actions at certain moments; in order to achieve better care for this kind of patient the best option is to keep them together close to the most sophisticated equipment and the most qualified staff, rather than dispersing them. The objective of intensive care medicine is centred on diagnosis and treatment for critically ill patients having a high risk of dying to give them back their previous state of health and life quality in so far as this is technologically feasible with the available knowledge. Some authors distinguish critical care medicine from intensive care medicine and consider the former to involve treating critically ill patients with highly specialized technological means, including care from transport management, urgency ward, surgical operation to intensive care unit. So far as this paper is concerned, the concept of critical patient care will be used in reference to the intensive and critical care carried out in specialized units within the hospital organization: intensive care units, coronary units, burns units, neonatal intensive care units, transplant care units, etc.

In the last few years public policies of cost containment have placed critical patient care under a central focus because such care has been said to bear great responsibility for the increase in health expenditure. It is a widespread custom in health economics to put the consumption of an increasing proportion of health expenditure down to care of critical patients and especially to ICUs, since they *intensively* concentrate staff and the most sophisticated equipment. According to this interpretation, the quick diffusion of technological innovations has been responsible for the increase in the intensity of resources per patient (one of the main reasons used to explain the increase in health expenditure in real terms throughout recent decades), so that the highest expression of this phenomenon lies with the ICUs: the cost per stay in an ICU can be four or five times higher than the cost per patient of the rest of a hospital's services. That is to say, we may be witnessing a cost concentration in the last period of life of (critical) patients, gaining for them only a somewhat reduced number of years of life and, besides, offering them a quality of life which may be rather precarious.

Conventional views base their suspicions on three groups of empirical observations:

1. The impact of the diffusion of technological innovations on health expenditure: between 1980 and 1990 the intensity of resources per patient increased at an accumulative average annual growth rate of 2.5 per cent in EU countries[1].
2. A relatively small proportion of the population, and one which is advanced in years, consumes a high proportion of the resources addressed to health, probably in the last period of life: 5 per cent of individuals belonging to a public Spanish mutual benefit society consumed 52 per cent of health expenditure in 1992; individuals aged 65-79 years bear a health expenditure per person of more than twice that of the individual of average age, so that, although they comprise 17.6 per cent of the total population, they stand for 37.9 per cent of the total expenditure[2]. As part of the Medicare Programme (USA), it has been shown that in 1988 the 5.1 per cent of elderly patients who died were responsible for 27.2 per cent of that year's expenditure[3].
3. International literature has been pointing out for a long time that those patients who pass away use more health resources and cause more expenses than do those who survive[4].

The results of empirical studies carried out in the past few years have introduced subtle distinctions into conventional views on critical patients care, both regarding the technological issue and the expenditure concentration. A far from negligible number of critical patients treated in ICUs and in other services do not survive. A review of the studies on expenses for the Medicare Programme over the last ten years[5] caused by patients who die allows some relevant comments on critical patient management to be made:

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- The intensity of resources assigned to patients who die does not increase faster than does that of the rest of patients: technological change has an equal effect on them all.
- The concentration of resources in a very small group of the total population diminishes; that is to say, the expenditure concentration in the last years of life, though being high, has a tendency to be lower.
- The highest costs are incurred by the treatment of critical patients with very concrete conditions: patients suffering from neoplasm, nephritis, chronic obstructive lung disease and chronic liver failure.
- The intensity of resources diminishes commensurably with age: the older the patient is, the less the amount of resources needed: this can be a sign that older and weaker aged individuals are treated in a less aggressive way than are younger patients. Those aged patients who died and who received intense treatment are the youngest of that population group.

Thus, it seems that neither the use of new technologies nor the increase in intensity of resources deployed is exclusively essential to critical patient care, and the expenses are less concentrated on patients who do not survive treatment. Moreover, the problem lies in the uncertainty of predicting critical patient care outcomes (death or survival) in order to determine whether resources are used inappropriately or not. So the arguments underpinning conventional views are insufficient to show whether the scale of inappropriate use is higher or lower than in other patient care. That is to say, they do not allow us to state whether there is an excess or a default in the resources assigned to critical patient care. Whether the problem is greater or smaller in ICUs than in other health services is a question to be clarified empirically (in terms of cost outcomes).

Russell's[6] estimation in 1979 concerning US hospitals calculated that almost 20 per cent of hospital costs (1 per cent of GDP) were attributable to ICUs. The estimation of the figure for 1990 reached 28 per cent of hospital costs[7]. According to the results of my estimation ICUs in Spain stand for 8.5 per cent of hospital expenditure and 0.26 per cent of GDP. These figures are significantly lower than those for the USA, but are closer to those of Canada (0.2 per cent of GDP in 1986).

Global data allowing ICUs' effectiveness to be compared are rather scarce. A multi-centre study carried out on 13,152 consecutive admissions in 137 ICUs from 12 countries in Europe, the USA and Canada (European and North American Study of Severity Systems) provides some useful data from which to draw comparisons. The mortality rate in these units ranged between 13.8 per cent in Switzerland to 32.4 per cent in the UK[8]. The usefulness of mortality rates for comparing the effectiveness of the various ICUs is somewhat limited though. The previous severity of patients' conditions has an effect on them and, besides, the concept of "effectiveness" represented is not relevant as a technological alternative to an ICU. The mortality rate is influenced by the level of severity in patients admitted to ICUs: admitting patients who are not seriously ill would lead to a lower mortality rate, but would not mean greater effectiveness. The appropriate concept of effectiveness would be the improvement in the state of health experienced by patients admitted to ICU (survival probability and quality-adjusted life years or QALY) in relation to the state of health achieved in cases where patients had not used this service. In order to apply this concept properly, knowledge of the survival probability and QALY without ICU should be made clear.

Techniques of productive efficiency measurement

The efficiency analysis in ICUs comes up against problems because of difficulties in measuring the outcome obtained and the resources used. This problem, however, is common to all hospital services: difficulties in measuring the outcome and in quality adjustment are numerous. In any case, without an accurate measurement of the outcome and resources, the measurement of efficiency in ICUs cannot be dealt with operationally. Productive efficiency measurement in these units is a partial approach to their relative efficiency (efficiency "intra" ICUs). The objective of *productive efficiency* seems to be an outcome that can always be expected from ICU management, since it is compatible with any other objective that may be stated (for instance, the criterion of equality of opportunity for treatments with the same diagnosis irrespective of the level of severity and the expectation of recovering the previous state of health): for a certain combination of resources (and, therefore, for a certain budget), it should not be possible to obtain a better result. Productive efficiency is one of the conditions for services' performance quality: no criterion can justify low productivity or resources are being wasted[9].

Productive efficiency can be divided into *technical* efficiency and *assignative* or *price* efficiency. The difference between them lies in the consideration of resource price and, therefore, of cost. *Technical* efficiency deals with maximizing the outcome in view of the amount of resources and their combination (the proportion of each factor being used by each unit of outcome). Alternatively, technical efficiency can be defined as minimizing the cost in view of the level of outcome anticipated, with a concrete combination of resources. *Assignative* or *price* efficiency applies when, taking for granted technical efficiency, the combination of resources is modified according to their price and marginal productivity, in such a way as to minimize the cost.

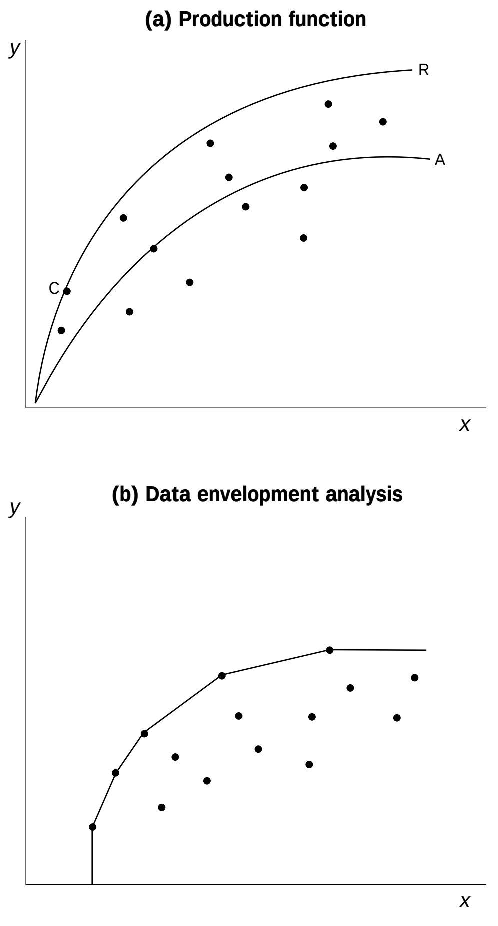
Some conventional indicators of ICU activity show deficiencies in measuring efficiency. In some cases, they can measure only the resources used (number of doctors or nurses per patient) or the intermediate product (length of the stay), but they say nothing about the outcome. On the other hand, these indicators do not help to distinguish which part of the observed differences in the various units is due to inefficiency and which is due to the effect of other exogenous factors (that is to say, high and low ratios both of costs and of effectiveness are compatible with inefficiency).

The usual way of establishing the measurement of productive efficiency is through frontier approximations. The concept of "frontier" means that only those units which work on the frontier are efficient: any point on the frontier shows the greater amount of outcome that can be achieved with a given level of resources, and it shows also the minimum amount of resources needed to produce a given level of outcome. Inefficiency is identified with the distance that separates each unit from the frontier. In order to estimate productive efficiency, production functions (relationship between the different inputs and the output) and cost functions (relationship between the output and the costs) are used. Using production functions, one can estimate only technical inefficiency, since no information about the price of the factors is being used (input proportions are only data). Using cost functions, one can measure global productive efficiency, although technical and assignative efficiencies cannot be distinguished.

The problem with efficiency estimates in each unit is how to estimate the frontier when it is unknown and must be approximated starting from the observation of units which, presumably, have a certain level of inefficiency. The estimation of cost or production functions starting from the observed data (resources used, cost and outcome obtained in different ICUs, for instance) would not produce any information about the level of efficiency. Let us suppose that a unit produces one product or outcome (y) using only one resource (x), as it is represented in Figure 1a. The dots on the graph stand for the different observed combinations of outcomes and resources. The estimated production function for these units would be curve A, based on the average behaviour expected from the sample. The distance between each of the combinations observed and that expected (represented by curve A), that is to say, the residual of the econometric estimation, does not correspond only to variations of efficiency since it also represents aleatory influences beyond the control of each unit and statistical interferences (errors in measurement and omitting variables).

The methods of frontier approximation (for both production and costs) applied to the measurement of efficiency try to estimate the frontier on the basis of the observation of those units which show the better practice: those which better transform resources into outcomes. These methods can be classified into two groups: parametric methods (or

Figure 1
Derivation of a best practice production frontier



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regression models) and non-parametric methods (or linear programming).

Parametric methods presuppose a concrete functional form for the function under estimation (for instance, a Cobb-Douglas production function). In *deterministic* parametric models, after the production (or cost) function is estimated (curve A in Figure 1(a)), the whole function is moved until all residuals are not positive and at least one of them is zero (production function) in order to find the frontier. The curve resulting from this movement, whose estimation can be obtained through ordinary least squares, stands for the best practice. That is to say, if all the units represented in Figure 1(a) transformed the resource (x) into the outcome (y) as efficiently as does unit C, all the points would meet on curve R: the distance between each observed point and those expected (curve R) stands for the level of inefficiency.

When one estimates the frontier of production (or of cost), clarifying the confusion between inefficiency, aleatory effects and statistical interferences which are together in the residual (distance of each combination of resource/outcome from the frontier), parametric models of a *stochastic* kind are used. These methods divide the residual into a first element which gathers the aleatory effects and the statistical interferences of a second element which stands for inefficiency; in order to achieve that, some assumptions on the statistical behaviour of the first element are introduced and estimation through corrected ordinary least squares with a maximum likelihood method is used[10,11].

The most usual *non-parametric method* is a linear programming technique: data envelopment analysis (DEA). The non-parametric approximations avoid the confusion of econometric approximation between the functional specification errors and inefficiency itself. However, programming is a deterministic method and mingles statistical interferences with inefficiency. In this case, the specification of a concrete functional form is not needed. For similar units with one resource and one outcome (Graphic 1-B), the frontier is found graphically by joining the observations of the most efficient units (those which, with a given amount of resources, achieve the highest outcome): the inefficient units are enveloped in those that are efficient. The inefficiency of each unit is determined also by the distance between this one and the frontier, whose measurement is carried out using mathematical programming techniques. With this method the presence of outliers may distort the results.

Approximations to the best practice frontier are giving rise to an increasing number of applications to health services. Almost all the studies on productive efficiency in hospitals analyse the behaviour of the centre as a whole. For instance, in a recent estimation of the stochastic cost frontier for a 1,739 sample of US hospitals[12], an inefficiency equivalent to 13.6 per cent of the cost was found. Difficulties when detaching information on costs from information on outcome are probably the reason for the rare application of these approximations of frontier to the productive efficiency estimation of individual hospital services. One exception is the paper by Finkler and Wirtschafter[13], who use data envelopment analysis to estimate productive inefficiency of obstetric services in nine US hospitals: productive inefficiency ranged from 35 per cent in the least efficient service to 0 per cent in the one representing the best practice, with an average equivalent to 11.1 per cent of cost per case.

Are intensive care units efficient?

It can be established, simplifying reality a little, that ICUs treat three different kinds of patient:

1 patients who are not seriously ill but who are monitored in order to prevent their high risk of worsening;
2 patients who have an acceptable probability of recovery and who receive a treatment only available in ICUs; and
3 patients who are so seriously ill that intensive care is probably the only way of lengthening their life.

Which concepts of cost and outcome are relevant in order to make decisions on patients' assignation (selection of cases being admitted) to ICUs instead of referring them to conventional treatment in the other hospital services? Economic costs for the treatment of patients in ICUs are the costs to the patient (discomforts, isolation, physical and psychological suffering, loss of dignity and chance of survival with an acceptable life quality); the costs to the family (both financial and psychological); the costs for the hospital staff, and the costs to society (for instance, loss of social welfare when health resources are used uselessly in refusing to let the patient have a decent death). Limiting this observation to direct costs for the health system, ICU costs should be defined according to the opportunity cost of resources[14]: the increase of expense caused by patients who have been looked after in ICUs in relation to the expense that would have been produced if this technology was unavailable (incremental cost). For instance, a critically ill patient suffering from a primary biliary cirrhosis subjected to a

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liver transplant: what expense would he have caused had he not been a recipient of a transplant? The expense we must consider is the incremental cost: the expense of the transplant minus the expense of the non-transplant.

The outcomes of ICUs could be evaluated according to mortality rates (in ICUs, in the hospital, after the discharge from hospital) by using mortality prediction models (acute physiology and chronic health evaluation –APACHE; simplified acute physiology score – SAPS; mortality probability model – MPM); though life-quality related to health provides a broader view on outcome measurement, using quality-adjusted life years (QALY). In the same way as for costs, the relevant outcome is the incremental outcome: the measure to which the patient treatment in ICU has improved the outcome in relation to conventional treatment (not ICU). The selection of cases to be admitted in ICUs becomes a relevant factor of efficiency in the management of these units (cost per avoided death; cost per QALY). This is especially relevant when it has been observed that 8 per cent of the most expensive patients, which amount to half the cost of an ICU, stand for an observed mortality rate of 70.6 per cent, whereas the other 92 per cent stand for only 20 per cent[15].

Productive efficiency measurement enables us to identify the level of efficiency in ICUs irrespective of selection of cases. Bearing in mind the combination of cases that have actually been admitted in each ICU, which of those units has been more efficient in relative terms? That is to say, once the patient has been admitted to intensive care (apart from the marginal profit and cost of this decision), what is the relationship between effectiveness and treatment costs for each patient? Whatever the combination of cases from the three above-mentioned kinds of patient admitted may be, it is reasonable to expect any ICU management to be efficient in production.

Although studies that identify explicitly efficient ICUs are not available, the treatment of information by two recent studies involving a high number of patients enables us to make an approach, with certain limitations, to this identification. The study by Rapoport, Teres, Lemeshow and Gehlbach[16] analyses the behaviour of 25 ICUs in US hospitals included in the ENAS study, with a total of 3,397 patients. The study by Shortell *et al.*[17] analyses 42 North American ICUs with 17,440 patients.

In this paper, we pay attention to efficiency measurements in ICUs with regard to the quality of clinical outcomes, rather than the amount of production (number of patients treated). The analysis of technical efficiency which takes into account clinical quality is an innovation with regard to earlier studies.

A way of measuring by approximation the quality of clinical outcome is through patient severity-adjusted mortality rates (or survival rates). The observed mortality rate may be risk-adjusted by using mortality prediction models when the patient is discharged from hospital which are based on various clinical data on the patient when he was admitted or a short time after. What is being proposed is the use of $MPMII_0$ as a mortality prediction model in order to elaborate a standardized survival rate. This model uses the following patient variables when he or she is admitted:

- coma or deep stupor;
- heart rate > 150 beats/min;
- systolic blood pressure 3/4 > 90 mm Hg;
- chronic renal insufficiency;
- cirrhosis;
- metastic neoplasm;
- acute renal failure;
- cardiac dysrhythmia;
- cerebrovascular incident;
- gastrointestinal bleeding;
- intracranial mass effect;
- age (10-year-olds ratio);
- cardiopulmonary resuscitation prior to admission;
- mechanical ventilation;
- non-elective surgery.

Operationally, the adjusted mortality rate is defined as the quotient between observed mortality and expected mortality according to these models. If we assign the index value of 100 to the ICU with the highest value of the inverse of the adjusted mortality rate (1/SMR) (the most effective one, once mortality caused by severity is controlled for), we can obtain a relative order of ICUs according to the measurement of their outcomes. This new index will be appointed as the relative index of effectiveness (quotient 1/SMR rescaled), in which the reference is the unit having the best practice. Available data show variations of up to 100 per cent in severity adjusted mortality rates.

Using $MPMII_0$ (mortality probability model calculated at the patient’s admission), Rapoport *et al.*[16] found that, among intensive care units from 25 North American hospitals, the less effective unit has a mortality rate equivalent to 28.7 per cent of the most effective one. Table I shows the index of relative effectiveness calculated by using data from the 25 hospitals in the study by Rapoport *et al*. Using the same mortality prediction model, we have found that the less effective unit in 17 Spanish hospitals has an effective-

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ness equivalent to 28.3 per cent of the most effective[18]. Shortell *et al.*[17] find that the ICU with the worst adjusted mortality rate, using the predictions of model APACHEIII, has an effectiveness equivalent to 53.2 per cent of the most effective one (that with the best practice).

In the absence of other data on the resources used by patients admitted to ICUs, the length of the stay of these patients can be a proxy of the resources used. In order to draw comparisons, we must calculate the severity-adjusted weighted days. One way to establish this adjustment is to use the predictions of the mortality models as indices for each patient's severity. An additional adjustment is to weight the amount of resources corresponding to the first day's stay in a different way from that used for the rest of the stay. A relative index of the resources used in each ICU, adjusted according to the severity of patients' conditions and using the unit with the greatest resource consumption (the worst practice) as the 100 base, is presented in Table I using data from the 25 hospitals[16]. According to these results, the hospital that uses less resources per patient (hospital K) consumes 53.3 per cent of the resources of the hospital with the highest consumption (hospital Q) and achieves an effectiveness which is 51.4 per cent inferior to that of the best hospital.

Table I
Ratios of relative effectiveness and resources used in 25 intensive care units

Hospital	Effectiveness	Resources	Effectiveness: resources ratio
A	0.404	0.724	0.655
B	0.537	0.616	0.818
C	0.593	0.874	0.613
D	0.497	0.679	0.738
E	0.577	0.718	0.725
F	0.287	0.632	0.544
G	0.843	0.621	0.858
H	0.591	0.817	0.637
I	0.666	0.597	0.886
J	0.435	0.747	0.651
K	0.664	0.533	1.000
L	0.442	0.642	0.761
M	0.472	0.655	0.758
N	0.489	0.733	0.682
O	0.340	0.874	0.512
P	0.516	0.962	0.533
Q	0.486	1.000	0.498
R	0.416	0.715	0.666
S	1.000	0.825	0.682
T	0.475	0.710	0.705
U	0.648	0.590	0.913
V	0.538	0.724	0.722
W	0.430	0.622	0.778
X	0.935	0.771	0.701
Y	0.462	0.629	0.787
Average	0.550	0.720	0.713

The index of adjusted effectiveness and the resource index together are insufficient to analyse the productive efficiency of these units. Table I shows an index that relates effectiveness and resources in a totally arbitrary way; in other words, a 10 per cent above average effectiveness and a 10 per cent superior to average resource consumption are seen as equivalent. According to the index of relative effectiveness/resources, with the described adjustment, the most efficient hospital (the best effectiveness/resources relation) is hospital K, with an average technical inefficiency of 28.7 per cent for the 25 hospitals.

Figure 2 shows the relationship between the adjusted survival rate and the average adjusted stay for each of the 25 hospitals. Both figures are represented with the average value as 100. In graphical terms, hospitals K, U and S are on the frontier that approximates the technical efficiency in production, which is estimated by using data envelopment analysis (DEA). In other words, we could say that hospitals on the frontier are those that have the best cost/effectiveness relation in the whole analysed group: they reflect the best practice in transforming resources into outcome.

Table II shows the results corresponding to an index of technical efficiency for the 25 hospitals, arrived at by DEA. The index that corresponds to the second column reflects the proportion to which the amount of resources used could be reduced to achieve the same outcome if each hospital operated on the best practice frontier (minimizing inputs). The three hospitals on the frontier (K, S and U) have a unitary index. The other hospitals are inefficient, hospital F being the least efficient: this ICU could have obtained the same outcome by using a little more than the 40 per cent of resources that it had used. For the whole group of 25 ICUs, the technical inefficiency is equivalent to more than a quarter of the resources used (28.8 per cent).

The third column of Table II shows the potential savings in terms of resources if each ICU operated on the best practice frontier, calculated in weighted days per patient.

Discussion

This approach to measurement or identification of inefficiency in intensive care units has some limitations that must be taken into account when interpreting results. The four

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most important limitations are briefly discussed below:

1 We analyse exclusively technical inefficiency; thus, a hospital which is technically efficient could be admitting to its intensive care unit patients who experience a valueless improvement of their health at a much higher cost than if they had been treated at other levels of assistance (which affects the global efficiency of selection of patients for admission). That is to say, ICUs can be very efficient in the treatment of patients who did not need admission to these units. On the other hand, from the point of view of social welfare, this is best expressed by saying that:

   > the priority in the admission in an intensive care unit should be correlated to the probability that care in the ICU was substantially of benefit to the patient rather than a treatment without intensive care; those patients with very good or very bad prognosis should not be admitted[19].

2 The measurement of the result based on the survival rate when the patient is discharged from hospital is still an imperfect way of measuring the efficiency: it limits the result to one unique dimension (survival) and to one unique moment in time (discharging), when the relevant item would be the quality-adjusted years of life gained by the decision in favour of treatment in an ICU.

Figure 2
Production frontier for 25 ICUs

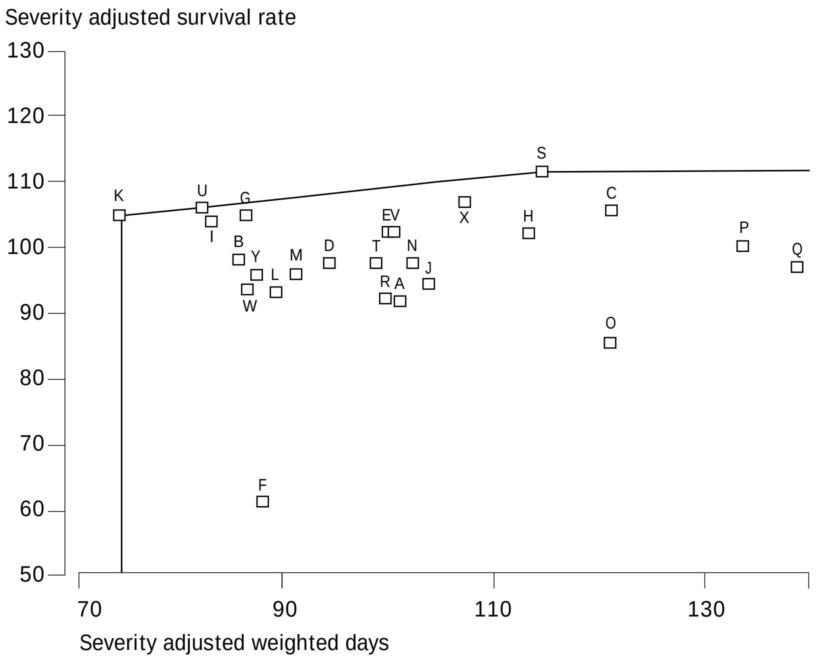

Table II
Technical efficiency in 25 intensive care units

Hospital	Minimum resources for observed outcome	Potential savings (weighted days)
A	0.61812	8.0
B	0.79650	4.2
C	0.63708	13.0
D	0.71682	7.1
E	0.71765	7.2
F	0.40652	15.2
G	0.85776	2.5
H	0.63014	7.5
I	0.88257	2.1
J	0.62172	10.5
K	1.00000	0.0
L	0.72926	7.5
M	0.73262	5.2
N	0.66054	7.8
O	0.46677	19.9
P	0.52339	17.2
Q	0.48203	13.4
R	0.62941	10.6
S	1.00000	0.0
T	0.68363	9.7
U	0.99858	0.0
V	0.71531	8.8
W	0.74192	5.7
X	0.79180	6.0
Y	0.75928	7.1
Average	0.71198	

3 The most imperfect measurement in the information presented is that concerning resources used in the treatment of each patient. The average risk-adjusted stay has been used as a proxy of resources deployed; this is equivalent to presupposing a direct and linear relationship between the degree of severity (risk of death) and the necessity of health resources, which does not correspond to reality. A greater risk is not necessarily equivalent to a greater expense or, what amounts to the same thing, mortality prediction models are not useful for predicting resource consumption directly. Resource consumption may increase the risk level of patients treated in ICUs rises to intermediate risk levels; these intermediate risk levels are what cause the greater expense; on the other hand, patients with a higher risk level have been observed to cause a lower cost because of their short survival and/or the small assignation of less resources by the hospital staff owing to the lower probabilities of them recovering health[15]. In the two international studies mentioned in this paper the correlation between mortality rate and average

stay, both adjusted by the levels of risk of the patients treated, is very low. That is to say, if the average stay is a good approximation to the level resource consumption, variations in effectiveness would be independent of the amount of resources consumed. However, according to Shortell *et al.*[17], the explanatory factors in adjusted mortality rate are the technological availability (a measurement of the intensity of resources) and the degree of specialization.

An unjustified assumption is that the amount of resources used in a day's stay is the same in all hospitals if it corresponds to the same ordinal number in the stay days of a patient. One alternative means of improving the measurement of resources in intensive care units could be to use a specific method such as the therapeutic intervention scoring system (TISS), or – more advisable still – to estimate a more flexible functional form in order to approximate the real curve that relates severity to resources.

4 Finally, we should point out that data envelopment analysis is a useful deterministic method when measuring the average inefficiency (28.8 per cent in this case), but it predicts individual inefficiency imperfectly as it mingles inefficiency with statistical interferences.

An additional working path, at present under development, is to focus on the development of a resource prediction model in order to standardize resource consumption appropriately. The use of DEA needs to be increased with the adoption of a new approach with multiple inputs and outputs. Moreover, efficiency indices should be subjected to multivariate analysis in order to determine the factors associated with inefficiency.

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