

Predictors of inappropriate hospital days in a department of internal medicine

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- Background** This study aimed to identify predictors of inappropriate hospital days in a department of internal medicine, as a basis for quality improvement interventions.
- Methods** The appropriateness of 5665 hospital days contributed by 500 patients admitted to the Department of Internal Medicine, Geneva University Hospitals, Switzerland, was assessed by means of the Appropriateness Evaluation Protocol. Predictor variables included patient's age and sex, manner of admission and discharge, and characteristics of hospital days (weekend, holiday, sequence).
- Results** Overall, 15% of hospital admissions and 28% of hospital days were rated as inappropriate. In multivariate models, inappropriate hospital days were more frequent among patients whose admission was inappropriate (odds ratio [OR] = 5.3, 95% CI : 3.1–8.4) and among older patients (80–95 years: OR = 3.6, 95% CI : 1.7–7.0, versus <50 years). The likelihood of inappropriateness also increased with each subsequent hospital day, culminating on the day of discharge, regardless of the total length of stay.
- Conclusions** This study identified both the admission and the discharge processes as important sources of inappropriate hospital use in a department of internal medicine. The oldest patients were also at high risk of remaining in the hospital inappropriately. Surprisingly, long hospital stays did not generate a higher proportion of inappropriate days than short hospital stays. This information proved useful in developing interventions to improve the hospitalization process.
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Eliminating unnecessary health care may both reduce the costs and improve the quality of care. Because hospital care accounts for almost half of total health care expenditures in most developed countries, inappropriate hospitalization is an important concern. Substantial levels of unnecessary hospital use have been reported in several countries,^{1–10} but few centres were able to reduce inappropriate care as a result of such studies.^{11–13}

Avoiding inappropriate hospital care is difficult in part because the mechanisms that yield inappropriate days are multifactorial. The likelihood of a hospital day being inappropriate may depend, to various degrees, on patient characteristics, on the organization of in-hospital care, and on the co-ordination between hospital care and the rest of the health care sector. As for any other complex health problem, identification of risk factors

for inappropriateness is crucial for the understanding of this phenomenon. Unfortunately, only few studies^{14–16} have sought to identify risk factors for inappropriateness of hospital days.

In this paper, we examined the appropriateness of days spent in the hospital by a cohort of patients admitted to a department of internal medicine of a teaching hospital in Geneva, Switzerland. The study aimed to identify patient and hospitalization characteristics associated with inappropriateness. The ultimate purpose of the study was to facilitate a reassessment of hospitalization processes, leading to interventions to reduce inappropriate stays.

Methods

Study setting and sample

This study was conducted at the Department of Internal Medicine of a public teaching hospital (Geneva University Hospitals, Geneva, Switzerland).¹⁷ Between November 1994 and February 1995, a systematic 1:2 sample of admitted patients was

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drawn from computer-generated patient lists until a sample size of 500 was reached. All selected patients were included in the study. Study procedures were approved by the Hospital board.

Study variables and data collection

The main outcome variables was the appropriateness of each hospital day, assessed by trained research assistants using a slightly modified version of the Appropriateness Evaluation Protocol.^{1–3,18} Evaluations were conducted at least twice weekly for each patient. The chief reasons for inappropriate days were assessed using the Delay Tool.^{19,20} Information was abstracted from medical and nursing records, and was complemented by discussions with clinic staff whenever necessary.

Predictor variables included patient characteristics (age, sex), characteristics of the hospital stay (appropriateness of admission, admission and discharge processes, length of stay), and characteristics of each hospital day (day of week, Christmas-New Year holiday period, rank of each day during the hospital stay). Information on all predictors was available from routine records.

Appropriateness Evaluation Protocol (AEP) instrument

The AEP uses 27 criteria to assess the appropriateness of each hospital day (11 relate to medical services, 7 to nursing services, and 9 to patient health status). To adapt the instrument to local needs, we added five day-specific appropriateness criteria (day of patient death, patient on weekend leave, experimental treatment for which hospitalization is desirable, and investigations for which hospitalization is either necessary or desirable). The AEP also measures the appropriateness of hospital admissions, using 17 criteria which pertain to clinical stability of the patient, necessity of medical interventions, and planned surgical procedure within 24 hours. An admission is deemed appropriate if one or more of these criteria is satisfied.¹⁷

Research assistants were trained during the pilot phase of the study. Inter-rater reliability of the AEP assessments was tested on 50 patients both during the pilot phase and in the middle of the study, when each patient was evaluated by the two abstractors, and by the first author. Three-way kappa coefficients were 0.81 (95% confidence interval [CI] : 0.70–0.92) for appropriateness of admissions, and 0.78 (95% CI : 0.73–0.83) for appropriateness of hospital days.

Analysis

The sample size allowed the 95% CI of the proportion of inappropriate days to have a width of $\pm 2\%$, assuming a proportion of 30%, a mean of 10 days per admission, and a doubling of variance due to the correlation of observations obtained in the same patient.

Proportions of days rated as inappropriate were computed overall, and for subgroups of patients and hospital days. To account for the interdependence of observations made in the same patient, standard errors were estimated using methods for cluster sampling,²¹ as implemented on EpiInfo 6.0.²² The overall 'design effect' (the ratio of true variance to naive variance, computed assuming independence of all observations) was 6.3, indicating stronger within-patient clustering of inappropriate days than we anticipated.

To further assess the equity in the distribution of hospital resources among patients, we plotted the cumulative percentage of appropriate and inappropriate hospital days against the cumulative percentage of patients (in economics, this is called the Lorenz curve;²³ this tool was recently applied to descriptions of exposure-disease associations²⁴). When the Lorenz curve equals the identity function, the distribution of resources is perfectly equitable; the closer the curve is to the lower right corner, the greater the inequity.

To explore associations between continuous predictors and inappropriateness, we used non-parametric regression,²⁵ and for multivariate analyses, logistic regression models.²⁶ Because standard error estimates on odds ratios (OR) would be inaccurate in the presence of within-patient clustering, we obtained CI from a bootstrap procedure:²⁷ the logistic regression model was estimated in a large number of subsamples ($N = 399$) derived from the original study sample. These subsamples were of the same size as the original sample (500 patients), but were obtained with replacement (thus a patient can appear once, more than once, or not at all, in any given subsample). Confidence intervals were then obtained from the empirical distribution of regression coefficients. Analyses were programmed using macro language in SPSS-Windows.

Results

Sample characteristics

During the study period, 500 patients were enrolled and followed until discharge, for a total of 5665 days of hospitalization. There were 282 men and 218 women, 16–95 years old (mean 65.9, standard deviation 18.5, quartiles 55, 68, and 81 years). Length of stay ranged from 1 to 60 days (mean 11.3, standard deviation 8.4, quartiles 6, 9 and 15 days). Seventy-six (15%) hospital admissions were rated as inappropriate by the AEP.¹⁷ Most patients (321, 64%) were admitted after triage at the Emergency Department, 121 (24%) were admitted directly, upon request by the patient's physician, and 58 (12%) were transferred from other hospital wards, mostly (55 patients) from the medical intensive care unit. Forty-five (9%) patients died in the hospital. Among those discharged alive, 314 (63%) returned home, and 141 (28%) were transferred to another health care facility.

Distribution of inappropriate hospital days

Using the modified version of the AEP, 1584 (28%) hospital days were rated as inappropriate (using the more stringent original version of the instrument, the proportion was 31%). The number of inappropriate days per patient ranged from 0 to 32 (mean 3.2, standard deviation 4.4, quartiles 0, 1 and 5 days). Overall, 223 (45%) patients had no inappropriate days, and the other patients were distributed as follows: 1 day: 39 (8%), 2 days: 36 (7%), 3 days: 35 (7%), 4 days: 26 (5%), 5 days: 25 (5%), 6 days: 22 (4%), 7 days: 17 (3%), 8 days or more: 77 (15%) patients.

Inappropriate hospital days were concentrated among a minority of patients: 9% of patients accounted for 40% of inappropriate days, 19% of patients accumulated 64% of inappropriate days, and 29% of patients accumulated 80% of inappropriate days. The Lorenz curve of the use of inappropriate days approached the lower right corner, indicating that inappropriate

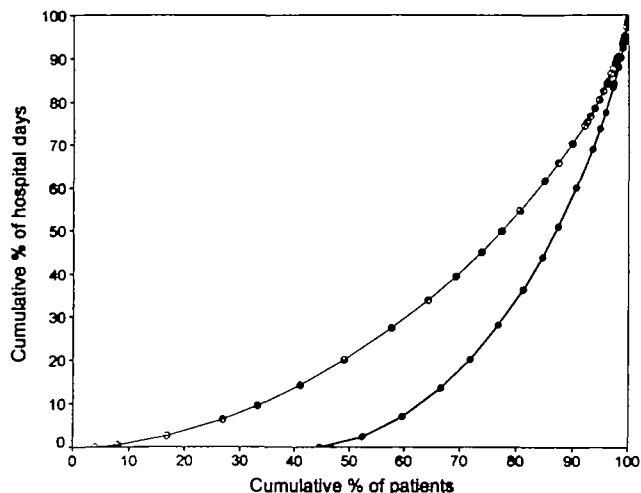


Figure 1 Disparity in distribution of appropriate hospital days (white symbols) and inappropriate hospital days (black symbols) among hospitalized patients in Geneva, Switzerland. A diagonal line would represent an even distribution among patients: the closer the line is to the lower right corner, the greater the disparity

days were unevenly distributed between patients (Figure 1). The disparity in the distribution of appropriate days was less pronounced.

Causes of appropriate days

For each hospital day, research assistants noted all relevant reasons justifying hospitalization (from a list of 32). In total, 7336 motives were assigned to 4081 appropriate hospital days (1.8 motive per day, range: 1–6). The most frequent reasons were: parenteral therapy (2360, 32%), monitoring by nurse (1735, 24%), respiratory care (615, 8%), intramuscular and/or subcutaneous injections (441, 6%), experimental therapy (439, 6%), myocardial infarction or stroke within 14 days (421, 6%), and intake and output measurement (322, 4%).

Causes of inappropriate days

Causes of inappropriate hospital days were grouped into nine main categories. A total of 1909 causes were assigned to 1584 inappropriate days (1.2 causes per day, range 1–4). The most frequent causes were related to the discharge process (939, 49%), delays in tests and investigations (440, 23%), delays in medical decisions (293, 15%), and delays in specialized consultations (209, 11%).

Patient and admission characteristics associated with inappropriateness

The proportion of days rated as inappropriate was similar in men and women, but older patients tended to have more inappropriate days than younger patients (Table 1). Patients whose hospital admission was justified had fewer inappropriate days than patients whose admission was not justified. Overall, inappropriate admissions generated 30% of inappropriate hospital days. Patients who were admitted directly to the ward generated more inappropriate days than patients who were fully evaluated at the Emergency Department. Patients who died in the hospital generated relatively fewer inappropriate days than

patients who were discharged alive. The duration of the hospital stay was only weakly associated with the average level of inappropriateness.

Day-specific predictors of inappropriateness

The frequency of inappropriate days did not differ between weekdays (Table 2). There were slightly fewer inappropriate days during the Christmas-New Year holiday, although the difference was not statistically significant. The proportion of inappropriate days increased sharply from admission to discharge: the initial days of a hospital stay were much less often inappropriate than the last days.

A relationship between day of hospitalization and inappropriateness was observed only for appropriate admissions (Figure 2, upper panel). When an admission was inappropriate, about half of subsequent hospital days were inappropriate, and this proportion was stable over time.

Following appropriate admissions, the relationship between inappropriateness and day of hospitalization depended on the length of stay: the proportion of inappropriate days increased faster for shorter than for longer stays (Figure 2, lower panel). Findings were similar when days were counted backwards, starting with the day of discharge (not shown): for any duration of stay, the last days of hospitalization were the most likely to be inappropriate.

Multivariate model

In logistic regression analyses, older patient age, an inappropriate reason for hospital admission, and a later time in the hospitalization (both when days were counted from admission and when they were counted backward from discharge), remained strongly and independently associated with an increased likelihood of inappropriateness of a hospital day (Table 3).

Discussion

This study identified several independent predictors of inappropriateness of a hospital day in internal medicine wards of a Swiss teaching hospital. Older patients, and patients whose admission was inappropriate were more likely to generate inappropriate hospital days. In addition, the likelihood of inappropriateness increased gradually during the hospital stay, regardless of its overall duration.

The overall proportion of inappropriate days was 28%, similar to previous reports.^{1–6,11–16} If the AEP provides a valid assessment of appropriateness, these figures are impressive: few sectors of the economy could afford to produce 28% of unjustified output. In addition, estimates of inappropriateness based on the AEP are probably conservative, since a day in the hospital could be rendered 'appropriate' by performing an unnecessary intervention, such as placing an intravenous line in a patient who did not need it. Questioning the appropriateness of each medical procedure might have resulted in even higher estimates of inappropriate care.⁵

Predictors of inappropriateness and implications for preventive action

Inappropriate days were four times more common among patients >80 years than in patients <50 years, after adjustment for other predictors. Such an age-gradient was seen in some¹⁴

Table 1 Frequency of inappropriate hospital days, by patient characteristics, among 500 patients admitted to a department of internal medicine, Geneva, Switzerland, 1994–95

| | Patients (%) | Total hospital days (%) | Proportion inappropriate (95% CI ^a) | | P-value ^a |
|------------------------------|--------------|-------------------------|---|-----------|----------------------|
| Total | 500 (100) | 5665 (100) | 28.0 | 25.0–30.9 | – |
| Sex | | | | | |
| Men | 282 (56) | 3149 (56) | 28.5 | 24.6–32.5 | 0.66 |
| Women | 218 (44) | 2615 (44) | 27.2 | 22.9–31.5 | |
| Age | | | | | |
| 16–49 years | 92 (18) | 987 (17) | 18.5 | 11.4–25.7 | <0.001 ^b |
| 50–59 years | 81 (16) | 762 (13) | 27.3 | 20.2–34.4 | |
| 60–69 years | 85 (17) | 979 (17) | 26.7 | 19.2–34.2 | |
| 70–79 years | 109 (22) | 1405 (25) | 26.8 | 21.3–32.4 | |
| 80–95 years | 133 (27) | 1532 (27) | 36.2 | 31.0–41.4 | |
| Appropriate admission | | | | | |
| Yes | 424 (85) | 4727 (83) | 23.3 | 20.6–26.1 | <0.001 |
| No | 76 (15) | 938 (17) | 51.3 | 41.9–60.7 | |
| Admission channel | | | | | |
| External, triage | 321 (64) | 3598 (64) | 25.0 | 21.8–28.2 | 0.002 |
| External, no triage | 121 (24) | 1328 (23) | 37.6 | 30.1–45.0 | |
| Internal transfer | 58 (12) | 739 (13) | 25.0 | 17.7–32.4 | |
| Discharge | | | | | |
| Alive, home | 314 (63) | 3140 (55) | 26.6 | 23.0–30.2 | <0.001 |
| Alive, other facility | 141 (28) | 2130 (38) | 33.2 | 28.1–38.3 | |
| Dead | 45 (9) | 395 (7) | 10.4 | 0.7–20.1 | |
| Length of stay | | | | | |
| 1–7 days | 185 (37) | 838 (15) | 22.4 | 17.3–27.5 | 0.52 ^b |
| 8–14 days | 182 (36) | 1916 (34) | 28.5 | 24.0–33.0 | |
| 15–21 days | 85 (17) | 1464 (26) | 31.9 | 26.3–37.5 | |
| ≥22 days | 48 (10) | 1447 (26) | 26.5 | 19.2–33.8 | |

^a Accounts for the lack of independence of multiple observations in the same patient.^b Test for linear trend**Table 2** Frequency of inappropriate hospital days, by characteristics of day of hospitalization, among patients admitted to a department of internal medicine, Geneva, Switzerland, 1994–95

| | Total hospital days (%) | Proportion inappropriate (95% CI ^a) | | P-value ^a |
|---|-------------------------|---|-----------|----------------------|
| Day of week | | | | |
| Monday | 831 (15) | 29.4 | 25.8–32.9 | 0.85 |
| Tuesday | 860 (15) | 28.1 | 24.9–31.3 | |
| Wednesday | 853 (15) | 28.8 | 25.6–32.1 | |
| Thursday | 828 (15) | 28.9 | 25.5–32.2 | |
| Friday | 790 (14) | 26.5 | 23.1–29.8 | |
| Saturday | 750 (13) | 26.4 | 23.0–29.8 | |
| Sunday | 753 (13) | 27.4 | 23.7–31.0 | |
| Holiday | | | | |
| Yes (24/12/94–2/1/95) | 706 (12) | 22.0 | 15.3–28.7 | 0.07 |
| No | 4959 (88) | 28.8 | 25.7–32.0 | |
| Day of hospitalization^b | | | | |
| First or second | 908 (16) | 9.5 | 7.0–11.9 | <0.001 |
| Any other | 3792 (68) | 27.3 | 23.7–30.9 | |
| Last or next to last | 908 (16) | 49.9 | 45.5–54.2 | |

^a Accounts for the lack of independence of multiple observations in the same patient.^b Based on 468 hospitalizations of 3 days or more, totalling 5608 days (test for linear trend).

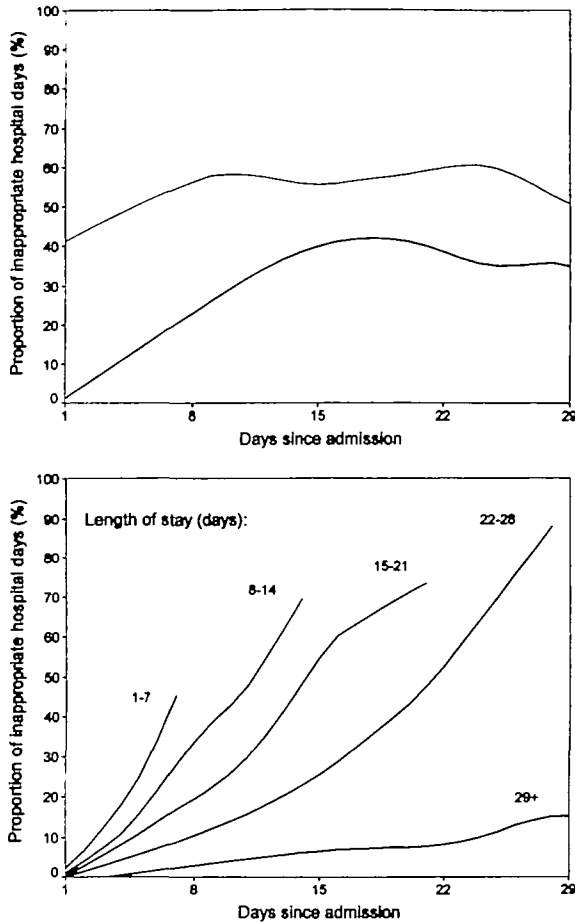


Figure 2 Proportion of days rated as inappropriate, for successive days of hospitalization, following justified (N = 426, thick line) and unjustified (N = 76, thin line) hospital admission (upper panel), and after a justified admission, according to the duration of stay (lower panel), Geneva, Switzerland, 1994–95

but not all^{15,16} other settings. This suggests that in some settings, including ours, hospitalization procedures are not well suited for the oldest patients. Some resources now devoted to acute care of the elderly may be more wisely invested in other types of health services, such as chronic care and adult day-care. However, if such resources are not available, hospitalization in an acute care hospital may still be justified for social reasons, if not for medical reasons.

Unjustified admissions caused relatively more inappropriate days than appropriate admissions, which has also been reported previously.^{6,14,16} Admission criteria at our hospital were not stringent enough: some patients were admitted for investigations that have not been planned properly, causing unnecessary waiting days, or for investigations that could have been conducted on an outpatient basis. Risk factors for inappropriate admissions included better physical functioning of the patient, lower mental health status in the patient's spouse, receipt of informal help from family or friends, and hospitalization by one's own physician; but overall, direct admission to the wards without full assessment at the Emergency/Admissions Department was the strongest predictor of inappropriate admission.¹⁷

Table 3 Patient- and day-specific characteristics associated with inappropriateness of hospital days, in 500 patients admitted to a department of internal medicine, totalling 5665 days of hospitalization, Geneva, Switzerland, 1994–95

| | Odds ratio | 95% CI ^a |
|---|------------|---------------------|
| Age group | | |
| 16–49 | 1.0 | – |
| 50–79 | 1.8 | 0.8–3.5 |
| 80–95 | 3.6 | 1.7–7.0 |
| Inappropriate admission (versus appropriate) | 5.3 | 3.1–8.4 |
| Days since admission | | |
| 1–2 | 1.0 | – |
| 3–5 | 1.9 | 1.4–2.4 |
| 6–8 | 3.7 | 2.7–5.0 |
| ≥9 | 5.8 | 4.0–8.7 |
| Days before discharge | | |
| ≥9 | 1.0 | – |
| 6–8 | 1.9 | 1.4–2.6 |
| 3–5 | 3.1 | 3.2–6.6 |
| 1–2 | 4.7 | 2.2–4.3 |

^a Obtained using 399 bootstrap samples.

Following this study, the admission process to our department was re-evaluated by a working group which included local community physicians; as a result, a dedicated telephone line was established, to allow community and hospital-based physicians to plan together elective hospitalizations.

The discharge process also generated many inappropriate days. Whether days were counted from the admission or up to discharge, the proportion of inappropriate days increased steadily as time went by, culminating on the day of discharge. Similar findings, although not stratified by length of stay, have been published previously.¹⁴ A second working group at our department reassessed selected discharge processes.

The creation of the two working groups was not only motivated by our results, but rested also on a qualitative evaluation of the hospitalization processes conducted shortly after this study. External consultants discussed possible causes of inappropriate hospital stay with physicians, nurses and social workers, reviewed in detail all processes of care that were identified in these discussions, built a flow chart for each process of care, and quantified the possible impact of each dysfunction on the overall length of stay. This evaluation also identified the admission and discharge processes as key to the reduction of inappropriate hospital stays (Calvo A *et al.*, Bossard Consultants, Barcelona, unpublished document, 1995). The similarity of conclusions from the quantitative outcome-oriented study and the qualitative process-oriented evaluation lends credibility to these shared findings.

Despite the strong positive relationship between day since hospitalization and inappropriateness, short stays did not generate significantly fewer unnecessary days than did longer stays. The potential impact on appropriateness of a global reduction in the average length of stay is therefore unclear.¹⁰ To maintain the quality of hospital care, interventions should strive to eliminate inappropriate days *regardless of length of stay*, and not

necessarily focus on avoiding long stays. Authorizing a fixed number of hospital days for a given diagnosis, as is commonly done by utilization review firms in the US, will not necessarily reduce the proportion of inappropriate hospital days.

Assessing the Appropriateness Evaluation Protocol instrument

The AEP is potentially a useful instrument for evaluating interventions aimed at reducing inappropriate hospital stays. Its inter-rater reliability was excellent ($\kappa = 0.8$). This level of agreement was higher than in several previous studies,^{1,3,6,17} perhaps because we relied on prospectively collected data, with access to real-time information, and not on medical records alone. Content validity of this instrument, although not perfect, is indirectly supported by the repeated successful use of the AEP in numerous countries over the past 15 years, with only small adjustments to local conditions. Construct validity is supported by the convergence in conclusions drawn from the use of the AEP and from a qualitative evaluation based on other sources of information.

Nevertheless, the AEP may be exceedingly lax in accepting justification of a hospital day on the basis of a possibly unjustified medical procedure. The dependence on medical procedures suggests also that appropriateness levels measured using the AEP should not be linked to financial incentives: a hospital could achieve the desired level of appropriateness simply by leaving intravenous lines in for too long, or other such stratagems.

A practical limitation of appropriateness evaluations of hospital days using the AEP is the high correlation among day-specific assessments performed in the same patient. This means that the required sample size is larger than would be necessary if day-specific assessments were mutually independent, for any level of precision, and that analysis of such data require statistical methods that take the lack of independence into account. Alternatively, one could randomly select only one day per patient for evaluation, but this can be easily accomplished only after patient discharge (once the duration of stay is known), and thus without the benefit of real-time information.

Finally, since the AEP is not perfectly reliable, some hospital days will be labelled as inappropriate by chance alone.²⁸ Thus when attempting to eliminate inappropriate hospital stays, the target should not be 0%. Eliminating all detectable unnecessary care may increase the likelihood of denial or delay of appropriate hospital care, of premature discharge, or of avoidable readmission.

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References

- ¹ Gertmann PM, Restuccia JD. The Appropriateness Evaluation Protocol: a technique for assessing unnecessary days of hospital care. *Med Care* 1981;**19**:855-71

- ² Winickoff RN, Restuccia JD, Fincke BJ. Concurrent application of the Appropriateness Evaluation Protocol to acute admissions in Department of Veterans Affairs Medical Centers. *Med Care* 1991;**29**(Suppl.): AS64-75.
- ³ Siu AL, Sonnenberg FA, Manning WG *et al.* Inappropriate use of hospitals in a randomized trial of health insurance plans. *N Engl J Med* 1986;**315**:1259-66.
- ⁴ Gloor JE, Kissoon N, Joubert GI. Appropriateness of hospitalization in a Canadian pediatric hospital. *Pediatrics* 1993;**91**:70-74.
- ⁵ Apolone G, Alfieri V, Braga A *et al.* A survey of the necessity of the hospitalization day in an Italian teaching hospital. *Qual Assur Health Care* 1991;**3**:1-9.
- ⁶ Baré ML, Prat A, Lledo L, Asenjo MA, Salleras LL. Appropriateness of admissions and hospitalisation days in an acute care teaching hospital. *Rev Epidemiol Santé Publique* 1995;**43**:328-36.
- ⁷ Rishpon S, Lubacsh S, Epstein LM. Reliability of a method of determining the necessity for hospitalization days in Israel. *Med Care* 1986;**24**:279-82.
- ⁸ Hynes M, O'Herlihy BP, Laffoy M, Hayes C. Patients 21 days or more in an acute hospital bed: appropriateness of care. *Irish J Med Sci* 1991;**160**:389-92.
- ⁹ Henley L, Smit M, Roux P, Zwarenstein M. Bed use in the medical wards of a Red Cross War Memorial Children's Hospital, Cape Town. *S Afr Med J* 1991;**80**:487-90.
- ¹⁰ Alonso J, Muñoz A, Anto JM and the Appropriateness Evaluation Protocol Group of the Hospital Unversitari del Mar. Using length of stay and inactive days in the hospital to assess appropriateness of utilisation in Barcelona, Spain. *J Epidemiol Community Health* 1996;**50**:196-201.
- ¹¹ Restuccia JD. The effect of concurrent feedback in reducing inappropriate hospital utilization. *Med Care* 1982;**20**:46-62.
- ¹² Payne SMC, Ash A, Restuccia JD. The role of feedback in reducing medically unnecessary hospital use. *Med Care* 1991;**29**(Suppl.): AS91-106.
- ¹³ Vardi A, Modan B, Blumstein Z, Lusky A, Schiff E, Barzilay Z. A controlled intervention in reduction of redundant hospital days. *Int J Epidemiol* 1996;**25**:604-08.
- ¹⁴ Restuccia JD, Payne SMC, Lenhart G, Constantine HP, Fulton JP. Assessing the appropriateness of hospital utilisation to improve efficiency and competitive position. *Health Care Manage Rev* 1987;**12**: 17-27.
- ¹⁵ Siu AL, Manning WG, Benjamin B. Patient, provider and hospital characteristics associated with inappropriate hospitalization. *Am J Public Health* 1990;**80**:1253-56.
- ¹⁶ Oterino de la Fuente D, Peiro S, Marchan C, Portella E. Inappropriate hospitalisation. Reasons and determinants. *Eur J Public Health* 1996;**6**:126-32.
- ¹⁷ Perneger TV, Chopard P, Sarasin FP *et al.* Risk factors for a medically inappropriate admission to a department of internal medicine. *Arch Intern Med* 1997;**157**:1495-500.
- ¹⁸ Strumwasser I, Paranjpe NV, Ronis DL, Share D, Sell LJ. Reliability and validity of utilization review criteria. *Med Care* 1990;**28**:95-109.
- ¹⁹ Selker HP, Beshansky JR, Pauker SG, Kassirer JP. The epidemiology of delays in a teaching hospital: the development and use of a tool that detects unnecessary hospital days. *Med Care* 1989;**27**:112-19.
- ²⁰ Klein JD, Beshansky JR, Selker HP. Using the delay tool to attribute causes for unnecessary pediatric hospital days. *Med Care* 1990;**28**: 982-89.
- ²¹ Levy LS, Lemeshow S. *Sampling of Populations*. 2nd edition. New York, NY: John Wiley & Sons, Inc., 1991.
- ²² Dean AG, Dean JA, Coulombier D *et al.* *Epi Info, Version 6 A Word Processing, Database, and Statistics Program for Epidemiology on Microcomputers*. Atlanta, GA.: Centers for Disease Control and Prevention, 1994.

- ²³ Eatwell J, Milgate M, Newman P, eds *The New Palgrave: A Dictionary of Economics*. London: The Macmillan Press Ltd., 1987.
- ²⁴ Lee WC. Characterizing exposure-disease association in human populations using the Lorenz curve and Gini index. *Stat Med* 1997;**16**:729-39
- ²⁵ Cleveland WS. Robust locally weighted regression and smoothing scatterplots. *J Am Stat Assoc* 1979;**74**:829-36.
- ²⁶ Hosmer DW, Lemeshow S. *Applied Logistic Regression*. New York, NY: John Wiley & Sons, Inc., 1989.
- ²⁷ Efron B, Tibshirani RJ. *An Introduction to the Bootstrap*. New York: Chapman & Hall, 1993.
- ²⁸ Phelps CE. The methodologic foundations of studies of the appropriateness of medical care. *N Engl J Med* 1993;**329**:1241-45.