

# High cost factors for leukaemia and lymphoma patients: a new analysis of costs within these diagnosis related groups

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## Abstract

**Study objective**—To determine high cost factors to help managers and clinicians to analyse the reasons of adverse costs and provide indications for financial negotiation.

**Design**—To locate high cost or long stay patients, the analysis was designed on the basis of a mixture of Weibull distributions. In this new model, the proportion of high cost patients was expressed according to the multinomial logistic regression, permitting the determination of high cost factors.

**Setting**—The 1993 French reference database, constituted in the framework of the national study of DRG costs, conducted by the French Ministry of Health. The database of discharge abstracts recorded in 1993 in the Dijon public teaching hospital.

**Participants**—The analyses were based on 1352 abstracts from the French reference database and 368 from the Dijon database concerning patients, aged 18 and over, suffering from leukaemia and lymphoma.

**Main results**—High cost and long stay factors were the same: number of stays, death, transfer, acute leukaemia, neutropenia, septicaemia, high dose aplastic chemotherapy, central venous catheterisation, parenteral nutrition, protected or laminar airflow room, blood transfusion, and intravenous antibiotherapy.

**Conclusions**—Taking into account high cost predictive factors, as shown in the case of leukaemia and lymphoma patients, would help to reduce the adverse effects of a prospective payment system.

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(DRG) heterogeneity, is slowing down the use of DRGs and their derivatives.<sup>3,4</sup> In fact, when assessing costs generated in different centres, one is confronted with the problem of adjusting for differences in the patient mix. For example, major teaching hospitals often treat a considerably higher proportion of complicated, more severe cases than minor centres. As these patients are expected to generate more costs and stay longer in hospital, a failure to adjust for these inter-hospital differences in the distribution of different types of patients would bias the results against centres able to provide care for more complex cases.<sup>5-7</sup>

Various studies have shown that the observed heterogeneity of costs within certain DRGs requires the inclusion of a measure of severity of illness to increase the reliability of such a prospective reimbursement system.<sup>5-13</sup> Severity measures such as Computerized Severity Index (CSI),<sup>13</sup> Apache,<sup>14</sup> and Medis-groups<sup>15</sup> and Patient Management Categories and Staging<sup>16</sup> generally tend to increase economic homogeneity within DRGs but still leave a substantial portion of variation of costs within DRGs unexplained.<sup>17</sup>

Recently, Freeman<sup>18</sup> proposed a modification to the DRG classification to take into account comorbidities and complications that are associated with higher use of resources within each DRG. In this new classification, each DRG is subdivided into three or four refined DRGs according to the secondary diagnoses. In other words, for a given principal diagnosis or surgical procedure, classes of secondary diagnoses are distinguished so that the estimates of hospital costs are more precise than those based on crude DRGs. This approach was criticised for not considering the number of complications or comorbidities for each patient. It was not adopted by the French government as it would have required the hospitals to collect more accurate data. Moreover, this new classification involved a greater number of DRGs than the unrefined one, so that the number of patients in each DRG may be insufficient for statistical and economic analyses.

The purpose of this study is to demonstrate the ability of a novel statistical model to identify high cost patients, by testing the hypothesis that the observed distribution of costs represents a mixture of different distributions and estimating both the proportions and the parameters characterising each specific subgroup distribution. Finally, once the con-

sistency of the data with the existence of subgroups has been demonstrated, we propose to identify factors affecting the probability of an individual patient falling within a high cost subgroup. Estimating the burden of high cost patients borne by a given hospital will allow for justification of disproportionately high expenditures using these explanatory variables. The advantage of the proposed model over the refined DRGs is to reserve the more complex negotiation based on a multiplication of DRGs for a limited number of hospitals that have shown a significant increase of high cost patients.

This problem was evaluated in the framework of a study of two French DRGs no 589 and 590 (lymphoma and leukemia with or without complications). To illustrate the importance of accounting for heterogeneity of costs within these DRGs, data from a French database of costs per stay are used. The benefits and limitations of the proposed model are examined from both a statistical and a management point of view.

## Methods

### PATIENTS

In the first part of the study concerning costs, we used the 1993 French reference database that was constructed in the framework of the national study of DRG costs. In this database, for each hospital stay, all the expenses were gathered to compute the actual cost per DRG. The pharmaceutical and blood products were directly assigned to each patient as well as diagnosis or therapeutic procedures (biological, radiological, operating room and intensive care procedures). Prices charged for pharmaceutical and blood products to hospitals were considered. The unit of consumption used for the valorisation of the other procedures performed during the stay was specifically developed by the French Department of Health and was labelled relative cost index (RCI). For each procedure, this RCI was defined at a national level by economic and medical experts who estimated the time spent by the medical staff and the expenses involved with equipment. To value this unit of consumption at the hospital level, the global expenses of a given ward were divided by the total amount of RCI produced. For example, the valorisation of a surgical procedure consisted of multiplying the number of RCI allocated to this procedure by the value in Francs of the RCI in the corresponding surgical department. This means that hospitals participating in the study were able to record the main procedures performed for each hospital stay and to estimate the expenses of each ward. All the other expenses were allocated using a per day distribution, after having deduced the expenses corresponding to the procedures described above. The 1993 French reference database contained 449 010 discharge abstracts gathered from two public teaching hospitals, 14 public non-teaching hospitals, and six non-profit hospitals.

In the second part of the study concerning the length of stay (LOS) distribution, we considered two databases: the 1993 French

reference database and the database of 54 000 discharge abstracts recorded in 1993 in the Dijon public teaching hospital. This hospital did not participate in the national study of DRG costs, because it was not possible to systematically gather all the expenses for each patient, and only LOS were available in the Dijon database.

From these two databases we have selected only the abstracts classified into French DRG no 590, entitled "leukaemia and lymphoma without complications in patient 18–69 years old" and into French DRG no 589, entitled "leukaemia and lymphoma with complications or in patient over 69" (version 2.3 of the French classification): 1352 abstracts from the reference database and 368 from the Dijon database. All patients over 18 whose discharge abstracts had been classified into these DRGs were admitted as inpatients for the first time, and suffered from haematological malignancies like acute leukaemia, myelo or lymphoproliferative syndrome, lymphoma or Hodgkin's disease, myelodysplastic syndrome. Their hospital stay was motivated by the diagnosis and/or the management of their disease.

### VARIABLES

From the 1993 French reference database, the following variables included in the discharge abstracts could be considered: age, sex, number of stays, death, transfer to another hospital, acute leukaemia, septicaemia, neutropenia, chemotherapy, central venous catheterisation, parenteral nutrition, use of protected or laminar airflow room, and blood transfusion.

A validation of the 368 abstracts of Dijon public teaching hospital was performed, using the corresponding medical files, for 14 clinical variables chosen by the physicians for their clinical relevance and their reliability: age, sex, number of wards, death, transfer from or to another hospital, acute leukaemia, neutropenia <500 neutrophile polynuclear/mm<sup>3</sup>, septicaemia, high dose aplastic chemotherapy, low dose or non-aplastic chemotherapy, central venous catheterisation, parenteral nutrition, use of protected or laminar airflow room, blood transfusion, large spectrum intravenous antibiotherapy, and fungal diseases. These variables were clearly defined, easy to collect and check from the medical files. For all patients, the diagnosis of acute leukaemia required an immunocytochemical examination of bone marrow aspiration according to the French-American-British classification.<sup>19</sup> The neutropenia <500 neutrophile polynuclear/mm<sup>3</sup> was defined as a neutrophile polynuclear rate lower than 500/mm<sup>3</sup> on at least two blood formula counts of the patient. High dose aplastic chemotherapy consisted of some polychemotherapeutic regimen, followed by neutropenia as defined above, during at least eight days. The other chemotherapeutic regimens constituted the low dose or non-aplastic chemotherapy. The positioning of a catheter or a subcutaneous chemotherapeutic capsule in a central vein (jugular, subclavier, superior vena cava) and their maintenance care defined the central venous catheterisation variable. The intravenous sup-

ply of mixed nutrients (glucid, lipid and protid), corresponding to at least 35 kcal/day and during at least 10 days, determined the parenteral nutrition parameters. The management of the oncoheamatological malignancies, especially in case of serious neutropenia ( $<500$  neutrophile polynuclear/mm<sup>3</sup>) occurring after chemotherapy, required the use of protected or laminar airflow room to avoid the supervening of the patient's microbiological contamination and infection, particularly by the *Aspergillus sp* (a variety of a fungal agent).

Inside a protected or laminar airflow room all the aseptic measures were respected and particularly the visitors put overshoes on, used protective facial mask and cap, wore sterile overalls and washed their hands; overall the laminar airflow room permitted an air filtration. The use of protected or laminar airflow room parameter was easily collected from the medical records of each patient. The septicaemia diagnosis, the other variable used in our study, was based on the occurrence of some clinical facts, like fever and/or chills, hypotension, associated with the discovery of a pathological mycobacteriological agent in at least two microbiological blood sample examinations. The large spectrum intravenous antibiotic therapy corresponded with the association of at least two major antibiotics, injected by intravenous route, to manage all febrile episodes occurring, especially, in case of patients suffering from oncoheamatological malignancies. These associations had to be of a large spectrum, covering several bacteriological agents. The fungal disease variable reflected the pathological presence of fungal agents in tissues and/or in at least two blood samples of the patients. The presence of fungal agents in tissues had to be confirmed by the immunohistological examination of a biopsy sample; in the blood, this confirmation required a mycological analysis.

Most of these criteria can be directly encoded in the French DRGs. Thus, acute leukaemia, neutropenia, septicaemia, chemotherapy, and blood transfusion can be found in the 9th revision of the International Classification of Diseases (ICD9). For example, acute leukaemia is a principal diagnosis and could be encoded with codes 204.0, 205.0, 206.0, 207.0, 208.0 in the ICD9. The other diagnoses are secondary diagnoses and the reliability of their record depends on the hospital. Chemotherapy treatment and blood transfusion are considered, in France, as diagnoses and are respectively coded V58.1 and V58.2 in the ICD9. The French classification for therapeutic and diagnostic acts was used to record central venous catheterisation, parenteral nutrition, and protected or laminar airflow room. However, the collection of these procedures is not compulsory as they are not included in the algorithm of the French DRG classification.

In the ICD9 classification, it is not possible to distinguish aplastic chemotherapy and other chemotherapies. Moreover, the administration of an intravenous antibiotic therapy is not coded in the French classification for therapeutic and diagnostic acts. As a consequence, this

information was directly collected from medical files, to complete the 1993 Dijon public teaching hospital database.

#### STUDY DESIGN

##### Models

The proposed method examines the question of verifying the hypothesis that the observed distribution of costs/ LOS within DRGs represents a mixture. If the mixture seems consistent with empirical data, then some portion of between hospitals differences in costs/LOS may be attributed to differences in the proportions of different subgroups. In that situation it will be important to estimate such proportions and to identify their correlates.

A methodological challenge here is related to the difficulty of defining a priori criteria for determining whether a patient suffering from a given pathology will generate high costs or not. Indeed, the very concept of classifying individual patients according to expected costs may be unrealistic given the considerable variation between actual costs among patients with seemingly similar clinical profiles and the difficulty of obtaining a consensus on the correct medical procedure for certain patient characteristics. In the spirit of Fetter's method, the main objective of our study is to identify explanatory variables of high costs through an a posteriori analysis of observed costs rather than identifying predictors of high costs.

The mixed distribution model allows us to estimate the proportions of patients falling into a high cost subgroup for a given hospital and compare this to the national proportion. To adjust for patients characteristics, we introduced clinical variables to the mixed distribution model. The identification of variables that specifically explain an increase for the high cost subgroup proportion would help a hospital to justify its increase in expenditures.

Modelling of the distribution of costs was designed on the basis of a mixture of Weibull distributions. Distribution of lengths of stay has been modelled using a Weibull distribution transformed into a discrete distribution. The choice of a Weibull distribution was motivated by the distribution shape (very spread out and often asymmetrical) of costs and lengths of stay within DRGs and because it entails a small number of parameters.

Each distribution, identified as a subgroup, is characterised by three parameters (its proportion and the two parameters of the Weibull distribution), estimated by maximisation of data likelihood. The number of subgroups was determined by using the likelihood ratio test. Firstly, the fit of the mixed distribution model with two subgroups was compared with that of a single Weibull distribution model. A significant improvement in the fit was interpreted as a rejection of the hypothesis that the observed costs arise from a single homogeneous population. The likelihood ratio test was applied recursively, each time increasing the number of subgroups by one, until the first occurrence of a non-significant improvement. Each likelihood ratio statistics has, under the null hypothesis, a  $\chi^2$

Table 1 Likelihood comparison of non-mixed and mixed cost models of Weibull distributions

DRG	Number of distributions	1	2	3	4	5
589	Likelihood	-8 248.48	-8 200.27	-8 189.43	-8 183.77	-8 181.94
	LRS* (3df)	—	96.42	21.68	11.32	3.66
590	p value	—	<0.001	<0.001	<0.025	NS
	Likelihood	-6 845.30	-6 740.26	-6 731.55	-6 726.77	-6 711.69
589+590	LRS (3df)	—	210.08	17.42	9.56	30.16
	p value	—	<0.001	<0.001	<0.025	<0.001
589+590	Likelihood	-15 103.09	-14 964.21	-14 943.74	-14 936.20	-14 934.66
	LRS (3df)	—	277.76	40.94	15.08	3.08
589+590	p value	—	<0.001	<0.001	<0.010	NS

\*Likelihood ratio statistic.

Table 2 Identification of subgroups of length of stay within French DRGs

	French reference data base subgroups (n=1352)			Dijon teaching hospital data base subgroups* (n=368)		
	1st	2nd	3rd	1st	2nd	3rd
DRG 589	3.5†	11.2	25.5	47%	17%	36%
DRG 590	32%	39%	29%	48%	26%	26%
	2.5	7.5	21.8			
DRG 589+590	42%	28%	30%	52%	12%	36%
	2.7	10.1	25.3			
	44%	33%	23%			

†Mean expressed in days. \*Subgroup means were fixed to nationwide estimations.

distribution with three degrees of freedom (one for adding an additional estimate of proportion and two for the two parameters of the subgroup specific Weibull distribution). As subgroups may be too small for statistical and economic analyses to be conducted at a hospital level, we limited up to three the number of subgroups.

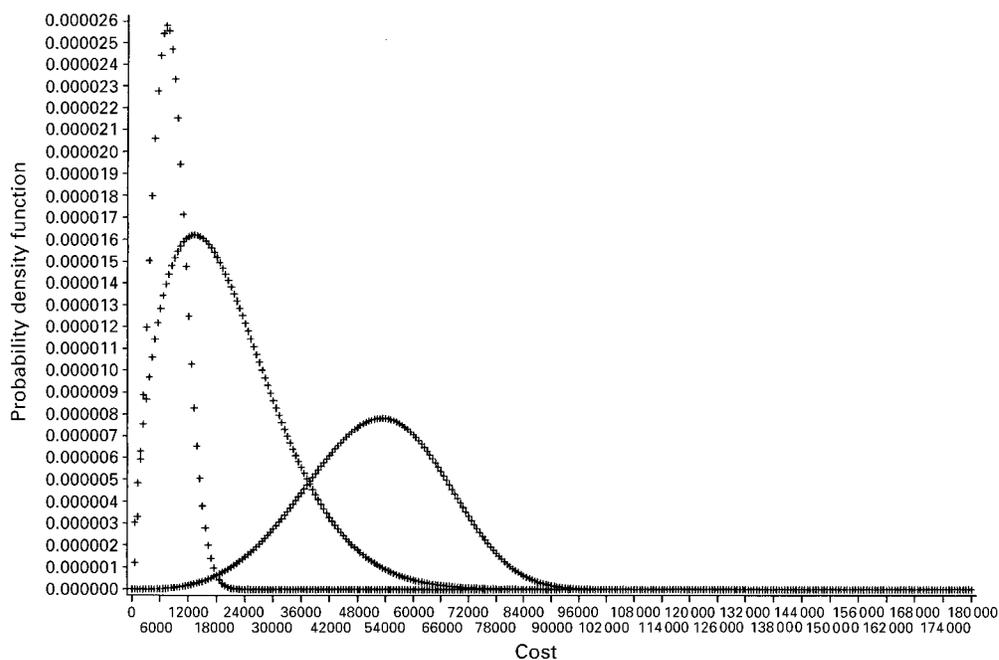


Figure 1 Actual estimates of the probability density function for each of the three subgroups identified in the data for French DRG no 589.

Table 3 Variables significantly linked with the proportion of high cost patients (multivariate analysis)

	DRG 589			DRG 590			DRG 589+590		
	OR*	95% CI†	p Value	OR	95% CI	p Value	OR	95% CI	p Value
Acute leukaemia	—	—	—	34.53	(8.37, 142.46)	<0.001	7.41	(3.25, 16.92)	<0.001
Chemotherapy	—	—	—	8.20	(2.34, 28.69)	<0.001	—	—	—
Blood transfusion	2.84	(2.43, 3.33)	<0.001	—	—	—	2.98	(1.32, 6.73)	<0.010

\*OR : odds ratio of belonging to the high cost subgroup in reference to the low cost subgroup. †CI : confidence intervals of the OR.

A clinical explanation for the distribution of subgroups in each DRG can then be studied by introducing covariates to the mixed model. The proportion of each subgroup for the mixed model can then be expressed in terms of these variables in a multivariate logistic regression as described in the appendix.

To identify explanatory factors of high costs, we performed univariate analysis followed by multivariate analysis for variables found significant in univariate analysis.

Application

This model<sup>20</sup> was applied separately to French DRG no 590, entitled “leukaemia and lymphoma without complications in patient 18–69 years old” and to French DRG no 589, entitled “leukaemia and lymphoma with complications or in patient over 69” (version 2.3 of the French classification of DRGs). These two DRGs were then pooled together to avoid bias, resulting from coding errors, in the attribution of the DRG.

Firstly, subgroups based on costs were established for these two DRGs from the 1993 French reference database on the national level only because information about costs could not be gathered in the Dijon public teaching hospital. Secondly, subgroups based on length of stays were established for these two DRGs on a national level, using the 1993 French reference

Table 4 Likelihood comparison of non-mixed and mixed LOS models of Weibull distributions

DRG	Number of distributions	1	2	3	4	5
589	Likelihood	-2536.33	-2510.22	-2500.08	-2499.55	-2499.46
	LRS* (3df)	—	52.22	20.28	1.06	0.18
	p value	—	<0.001	<0.001	NS	NS
590	Likelihood	-1878.99	-1819.32	-1800.29	-1788.14	-1785.19
	LRS (3df)	—	119.34	38.06	24.30	5.90
	p value	—	<0.001	<0.001	<0.001	NS
589+590	Likelihood	-4445.55	-4368.37	-4351.59	-4333.26	-4328.36
	LRS (3df)	—	154.36	33.56	36.66	9.80
	p value	—	<0.001	<0.001	<0.001	<0.025

\*Likelihood ratio statistic.

database, and on a local level, using the 1993 Dijon public teaching hospital database. To compare the proportions of long stay patients in the Dijon data with those estimated in the French reference database, the analysis of the Dijon data was conditional on the results of the French reference database. As a consequence, when the mixed distribution model was fitted to Dijon data, the three subgroup distributional parameters (Weibull parameters) were fixed to nationwide estimations but proportions were estimated from Dijon data. A multinomial logistic regression was then applied to search for clinical and social covariables clinically characterising either the high cost or the long stay subgroup.

## Results

### COST ANALYSIS

The modelling of costs from the 1993 French reference database allowed the locating of three subgroups (tables 1 and 2). Mixture models with two subgroups were significantly better than the non-mixture models and increasing the number of subgroups from two to three resulted in a significant improvement in likelihood. Even if the four or five subgroups models were frequently better than the three subgroup models we selected the last ones according to the rules described in the study design section. The high cost subgroup corresponded to approxi-

Table 5 Identification of cost subgroups from the 1993 French reference data base

	1st	2nd	3rd
DRG 589 (n=735)	1612*	4058	10 821
DRG 590 (n=617)	716	2305	12 562
DRG 589+590 (n=1352)	6%	67%	27%
	1595	3917	12 781
	35%	41%	24%

\*Mean is expressed in US\$.

Table 6 Variables significantly linked with the proportion of long stay patients in multivariate analysis

Database	DRG 589+590 NR			DRG 589+590 DH		
	OR*	95% CI†	p Value	OR	95% CI	p Value
Death	7.05	(3.04, 16.36)	<0.001	—	—	—
Acute leukaemia	3.01	(1.56, 5.82)	<0.010	—	—	—
Neutropenia	—	—	—	8.21	(3.04, 22.16)	<0.001
Central venous catheterisation	—	—	—	3.49	(1.37, 8.92)	<0.010
Blood transfusion	2.94	(1.22, 7.07)	<0.05	—	—	—

NR : French reference database. DH : Dijon teaching hospital database. \*OR: odds ratio of belonging to the long stay subgroup with reference to the short stay subgroup. †CI: confidence intervals of the OR.

mately one quarter of the patients with a mean cost seven times higher than that of the low cost subgroup. Similar results were obtained when the two DRGs were considered either separately or pooled. Figure 1 represents actual estimates of the probability density function for each of the three subgroups identified in the data for French DRG 589.

Explanatory factors of high costs indicated by univariate analyses were: number of stays, death, transfer, acute leukaemia, septicemia, chemotherapy, central venous catheterisation, protected or laminar airflow room, and blood transfusion. Among these factors, only acute leukaemia, chemotherapy, and blood transfusion (table 3) were selected.

### LENGTH OF STAY ANALYSIS

Modelling lengths of stay from the 1993 French reference database and the 1993 Dijon public teaching hospital database allowed us to locate three subgroups (tables 4 and 5). It can be seen that the long stay subgroup include about 30% of the patients with a mean of length of stay 10 times higher than that of the short stay subgroup.

In univariate analyses, the criteria that were found to have a significant influence on the distribution of the patients in the long stay subgroup were the same as those linked with the high cost subgroup, plus neutropenia, high dose aplastic chemotherapy, parental nutrition, and intravenous antibiotic therapy.

The multivariate analyses only selected death, acute leukaemia and blood transfusion from the 1993 French reference database on the one hand, and on the other hand neutropenia and central venous catheterisation from the 1993 Dijon public teaching hospital database, when the two DRGs were pooled (table 6).

## Discussion

The application of the mixed model to length of stay and cost emphasised the heterogeneity of the two DRGs by locating three subgroups for each DRG considered separately and for the two pooled DRGs. The consistency of the data with the existence of subgroups was demonstrated by the significantly better fit provided by the mixed model compared with a non-mixed model. The mixed approach is very different from the other studies dealing with outliers and DRG heterogeneity.<sup>21-25</sup> Most of these studies are based on linear regression and analyses of variance, which would not allow for the specific analysis of an increase in the proportion of high cost or long stay patients. Thus the mixed distribution model offers the advantage that the limit for high cost subgroups are not defined a priori. This issue is all the more important because economic decisions are to be made from the comparison of proportions for high cost subgroups.

Criteria that were significantly associated with the long stay subgroup were also associated, except for chemotherapy, with the high cost subgroup. As a consequence, these criteria could be used by hospitals that are not able to compute real costs per stay, to locate high cost patients in the framework of a budgetary nego-

tiation. However, some discrepancies were noticed between the results from length of stay obtained from the 1993 French reference database and the 1993 Dijon public teaching hospital database. For example, considering the two pooled DRGs, the influence of neutropenia and parenteral nutrition was only found to be significant in the 1993 Dijon public teaching hospital database. More accurate information available in the Dijon database might have avoided attenuation of the true association (because of the lack of precision), resulting in stronger, and thus more significant, estimated effects. Actually, all the variables recorded in the discharge abstracts of the 1993 Dijon public teaching hospital database were compared with medical files. In particular, this comparison revealed the lack of exhaustive recording of the secondary diagnosis of neutropenia, considered as a “normal” complication of leukaemia, in the case, for example, of high dose aplastic chemotherapy. The same phenomenon was observed for parenteral nutrition. The supplementary gathering of information in the 1993 Dijon public teaching hospital database allowed us to point out the influence of intravenous antibiotic therapy and high dose aplastic chemotherapy, which could not be recorded in the discharge abstracts of the French reference data base.

In this study, the application of a mixed model reveals the heterogeneity of costs within two of the most important French DRGs describing haematological ward activity, excluding bone marrow transplantation and patients receiving palliative chemotherapy. Despite this observed heterogeneity, the two main financial procedures used for hospitals—that is, budgetary allocation and tariffication—are based on a standardised estimation of hospital costs according to the DRG classifications of pathologies. In this framework, the criteria retained in this study could help hospitals to justify large discrepancies between theoretical and real budgets, in terms of budgetary allocation, or between set and real prices, in terms of tariffication.

Taking into account an increase in the proportion of high cost patients, if justified by clinical criteria, would allow the budgetary allocation to be more equitable. With regard to the strategic behaviours developed by hospitals, this method would help to reduce the intensity of adverse effects that subsist or are engendered by the pure Prospective Payment System (PPS). For example, the knowledge of the subgroup distribution per DRG would provide more specific information than that for DRGs. The allocation of compensation for outlier hospitals should restrict the cream skimming effect<sup>26</sup> corresponding to the selection of profitable cases. It would also reduce the moral hazard of under-provision for high cost cases as it diminishes the gap between the hospital cost and the fixed price.

The location of these three subgroups, well separated on an economic point of view, suggests that these results should be taken into account when considering the possibility of revising the French DRG classification. In par-

ticular, these results pointed out the advantage of the separation between acute and non-acute leukaemia, yet proposed by the third revision (1985) of the American Health Care Financial Administration DRG classification contemporaneous with the creation of the French DRG classification. In the all patients DRG classification version 10 (1993) this separation was maintained.

#### LIMITATIONS OF THE STUDY

From a clinical point of view, it would be interesting to characterise by clinical criteria, easy to collect during the hospitalisation stay, the three subgroups defined by the statistical model. It might be supposed, for example, that the first LOS subgroup could globally correspond to *de novo* non-Hodgkin's lymphoma, receiving non-aplastic induction chemotherapy, with a mean of length of stay of three days. Non-Hodgkin's lymphomas, treated by chemotherapy in accordance with a protocol, would probably be classified in the second subgroup. The third subgroup would probably gather patients suffering from leukaemia. Non-Hodgkin's lymphomas in relapse could also pertain to this subgroup, although this information would be difficult to assess as it is not systematically recorded in the discharge abstracts. But the main difficulty is that assigning each individual patient to a single subgroup would be far from obvious given the overlap between the subgroup distributions. In the mixed model, the boundaries between the subgroups are not well delimited and it is only possible to estimate the probability of a patient belonging to a subgroup.

It might be questioned why we deliberately mixed patient characteristics measured at the time of hospitalisation (that is, by definition independent of medical practice and/or quality of care during the hospital stay) with variables reflecting procedures performed during the stay (and likely to reflect conscious decisions by hospital staff). It might be supposed that the tendency to perform a costly procedure in a hospital more frequently would be either related with an unfavourable condition among patients hospitalised in that specific hospital or could be considered a result of inefficiency.

In fact, information available in the discharge abstracts could not be easily separated into patient characteristics known before the hospital stay and procedures actually performed during this stay. This problem is related to the fact that, because of the difficulty of obtaining a consensus on the correct clinical practice, Fetter proposed that profiles of clinical practice might be detected through a statistical analysis of the observed costs. The construction of clinically similar groups of patients that required similar resources are then based on an analysis of variance, where regressor variables were mainly composed of diagnoses and procedures performed during the stay. Thus, Fetter's DRG classification takes into account both variables known before hospital admission and those variables reflecting procedures performed during the hospital stay that have been found to be systematically

related to length of stay (LOS) or cost. Even the diagnoses recorded in the discharge abstracts do not systematically represent the patient characteristics before hospital admission as the principal diagnosis may not be known until the end of hospitalisation.

As we could not separate patient characteristics measured at the time of hospitalisation from variables reflecting procedures performed during the stay, it may be questioned to what extent high costs related to such procedures as blood transfusion or related to higher in-hospital mortality reflect between hospital differences in medical practices or quality of care rather than differences in case mix. However, other studies<sup>21</sup> have been confronted with the same difficulties and have shown the influence of events occurring during the stay, on the outlier status of stays according to costs, such as death, inter-hospital transfer, mechanical ventilation. These results can then be considered as useful as a “starting point” for further prospective studies specifically aimed at analysing reasons for high costs that may gather specific indicators and test them using, for example, the proposed model. Of course, a thorough validation of our results by means of prospective studies and comparisons with the results of different methods would be necessary before taking the results into account in an eventual revision of the classification.

The appropriateness of this apportionment procedure used for the constitution of the French reference database of the national study of DRG costs could be questioned. On the one hand, the apportionment procedure was not very precise as the main expenses were allocated using a per day distribution. On the other hand, we are not sure that each hospital was able to exhaustively and precisely assign all procedures performed during a hospital stay to the corresponding patient, as this assignment requires the implementation of a computerised information system in each hospital participating in the national study of costs per stay. We may also question the representativeness of the French database of costs per stay in which hospitals participated on a voluntary basis. In particular, we are not sure that the distribution of hospital types (teaching, non-teaching, and private) in this database is similar to the actual national distribution.

In conclusion, in the framework of tariffication or budgetary allocation of hospitals according to DRGs set prices, the advantage of the proposed model is to provide an analysis of the discrepancies between the real cost and the set price for a given pathology. In particular, this study shows how the determination of high cost predictive factors would point out the reasons for an increase of high cost leukaemia or lymphoma cases in a given hospital. As a consequence, this model provides a statistical tool that would help hospitals to understand more accurately how the medical practices influence their costs and to negotiate a budgetary compensation if the increase of high cost cases is justified.

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## Appendix

The proportion of each subgroup for the mixed model can be expressed in terms of variables in a multivariate logistic regression as follows:

$$f(y_i/x_i) = \sum_{j=1}^k \pi_j(x_i) f(y_i/\theta_j) \quad (2)$$

where  $f(y_i/\theta_j)$  is a Weibull density function parametrised by  $\theta_j$ , which contains only two parameters as cost is always positive and  $\pi_j$ , which is the probability of an individual patient belonging to  $j$ th sub-population, can be written

$$\pi_j(x_i) = \frac{\sum_{l=0}^p \gamma_{jl} x_{il}}{\sum_{l=1}^k \sum_{l=0}^p \gamma_{il} x_{il}} \quad (3)$$

and where

$x_i = (x_{i1}, \dots, x_{ip})$  denotes a  $p \times 1$  vector of explanatory variables associated with the  $i$ th individual,

$\gamma_j = (\gamma_{j1}, \dots, \gamma_{jp})$  denotes a corresponding vector of unknown parameters, associated with the  $j$ th distribution, for  $j=1 \dots k$ .

with the constraints,

$$\gamma_{0l} = 1 \text{ for } l = 0, \dots, p$$

The significance of each parameter associated with a covariate was tested using the Wald statistic. Odds ratio could be then calculated for each significant factor, to estimate the relative risk associated with this factor of belonging to a high cost (or long stay) subgroup.

- Fetter RB, Youngsoo S, Freeman JL, et al. Case-mix; definition by diagnosis related groups. *Med Care* 1980;18 (suppl 2):1-53.
- De Pourville G, Comar L, Bouvier V. Le paiement à la pathologie des hôpitaux : l'expérience française. *Rev Epidemiol Sante Publique* 1994;42:68-78.
- Gonella JS, Hornbrook MC, Louis DZ. Staging of disease: a case-mix group measurement. *Journal of American Statistical Association* 1984;263:241-6.
- Young W, Swinkola R, Hutton M. Assessment of the AUTOGP patient Classification System. *Med Care* 1980; 18:228-44.
- Froelich H, Jarvis WR. Economic impact of diagnosis-related groups and severity of illness on reimbursement for central nervous system infections. *J Pediatr* 1991;118:693-7.
- Kelleher C. Relationship of physician ratings of severity of illness and difficulty of clinical management of stay. *Health Serv Res* 1993;27:841-55.
- Naessens JM, Leibsom CL, Iqbal Krishan MD. Contribution of a measure of disease complexity (Complex) to prediction of outcome and charges among hospitalised patients. *Mayo Clin Proc* 1992;67:1140-9.
- Dayhoff DA, Cromwell J. Measuring differences and similarities in hospital caseloads: a conceptual and empirical analysis. *Health Serv Res* 1993;28:293-312.
- Averill RF, Mc Guire TE, Manning BE, et al. A study of relationship between severity of illness and hospital cost in New Jersey hospitals. *Health Serv Res* 1992;27:587-606.
- Horn SD, Horn RA, Sharkey PD, et al. Severity of illness within DRGs: homogeneity study. *Med Care* 1986;24:225-35.
- Horn SD, Sharkey PD, Chambers AF, et al. Severity of illness within DRGs: impact on prospective payment. *Am J Public Health* 1985;75:1195-9.
- Thomas JW, Aschcraft MLF. Measuring severity of illness: six severity systems and their ability to explain cost variations. *Inquiry* 1991;28:39-55.

- 13 Horn SD, Sharkey PD, Buckle JM, *et al.* The relationship between severity of illness and hospital length of stay and mortality. *Med Care* 1991;**29**:305–17.
- 14 Knaus WA, Draper EA, Wagner DP, *et al.* APACHE II: A severity of disease classification system. *Crit Care Med* 1985;**13**:818–29.
- 15 Iezzoni LI, Ash AS, Coffman GA, *et al.* Admission and mid-stay MedisGroups scores as predictors of hospitalization charges. *Med Care* 1991;**29**:210–20.
- 16 Calore KA, Iezzoni L. Disease staging and PMCs: Can they improve DRGs? *Med Care* 1987;**8**:724–37.
- 17 Voss G, Hasman A, Rutten F, *et al.* Explaining cost variations in DRGs “acute myocardial infarction” by severity of illness. *Health Policy* 1994;**28**:37–50.
- 18 Freeman JL, Fetter RB, Schneider KC, *et al.* Diagnosis-related group refinement with diagnosis- and procedure-specific comorbidities and complications. *Med Care*;33:806–27.
- 19 Bennett JM, Catovsky D, Daniel MT, *et al.* Proposed revised criteria for the classification of acute myeloid leukaemia. A report of the French-American-British Co-operative Group. *Ann Intern Med* 1985;**103**:620–5.
- 20 Quantin C, Entezam F, Bourdais C, *et al.* Modelization of long-stay and high cost patient distribution within broncho-pneumopathies and leukemia or lymphoma diagnosis related groups. *Rev Epidemiol Sante Publique* 1997;**45**:117–30.
- 21 Kotagal UR, Perlstein PH, Atherton HD, *et al.* Acuity scores as predictors of cost-related outcomes of neonatal intensive care. *J Pediatr* 1993;**123**:355–64.
- 22 Rosina F, Alaria P, Castelli S, *et al.* Effect of patient characteristics on hospital costs for cirrhosis : implications for the disease-related group (DRG) reimbursement system. *Ital J Gastroenterol* 1996;**28**:401–5.
- 23 Clayton MC, Solem LD, Ahrenholz DH. Pulmonary failure in geriatric patients with burns: the need for a diagnosis-related group modifier. *J Burn Care Rehabil* 1995;**16**:451–4.
- 24 Hendrie D, Rosman DL, Harris AH. Hospital inpatient costs resulting from road crashes in Western Australia. *Aust J Public Health* 1994;**18**:380–8.
- 25 Shwartz M, Iezzoni LI, Ash AS, *et al.* Do severity measures explain differences in length of hospital stay? The case of hip fracture. *Health Serv Res* 1996;**31**:365–85.
- 26 Sappington D. Incentives in principal-agent relationships. *Journal of Economic Perspective* 1991;**5**:45.