BRITISH PATIENTS' CHOICE OF CARE FOR MINOR INJURY: A CASE-STUDY OF SEPARATE SAMPLE LOGISTIC DISCRIMINATION

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Abstract

Under the British National Health Service, few types of patients are permitted a free choice between hospital care and family practice. However, the patient in need of treatment for minor injury is one of these types and this paper reports a study designed to identify factors which influence his choice.

Separate samples were drawn from patients presenting to hospital accident departments and from those consulting their family practitioner. Both samples were interviewed in their own homes as soon as possible after receiving treatment. These data have been analysed by stepwise application of separate sample logistic discrimination.

This analysis identifies only four 'objective' variables as conclusively affecting the patient's choice - his distance from his family doctor, his distance from the hospital, his diagnosis and his age. Cross-validation shows that the resulting discriminant function provides satisfactory estimates of the conditional probabilities associated with the patient's choice.

Introduction

British patients suffering from minor trauma enjoy the privilege, rare within the National Health Service (NHS), of making a free choice between two alternative systems of medical care; they are allowed to present for treatment either at a hospital Accident and Emergency Department (AED) or to their general practitioner (GP). Ever since the beginning of the NHS in 1948 (and even before that), there has been considerable debate, not only about the effects of such freedom, but also about its advisability.

In particular, the allocation of NHS resources to and within accident and emergency services, both in the hospital and in primary medical care, has been the subject of deliberation and of recommendation by a number of expert committees. The Platt Report (Central Health Services Council, 1962) recommended that the number of AEDs should be greatly reduced but that the level of staffing in the remaining units should be substantially raised. More recently, the Expenditure Committee of the House of Commons (1974) set on record its belief that the increasing use in general practice of appointment systems and deputising services had influenced patients' decisions to attend AEDs; it went on to propose a number of measures designed to counter these supposed determinants of the trend in patients' choices away from general practice and towards the AED.

The Newcastle Accident Survey was set up with a view to making an objective contribution to future decisions affecting the organisation of accident and emergency services. Specifically, it was designed to discriminate between two populations - patients in Greater Newcastle who consult general practitioners for the treatment of minor trauma and those who proceed direct to hospital.

Survey Method

As it is quite impractical to sample from the mixture of these two populations, we drew a separate sample from each. For the hospital population, it was quite easy to take a simple random sample from the register of each of the three AEDs within the survey area and then to exclude such 'foreign elements' as patients not suffering from trauma and those injured patients who were immediately admitted as inpatients and were thus, by definition, suffering from 'major' trauma.

However, there is no explicit sampling frame available for new patients consulting in general practice. Consequently, we drew a random sample, stratified by number of partners and geographical locality, of 58 GPs from the 290 doctors practising within the effective catchment area of the three AEDs. By observing each of these sampled GPs for one random week, we were able to define 'clusters' of patients, from which we excluded foreign elements much as before.

Both of these samples were interviewed in their own homes as soon as possible after receiving treatment. Unfortunately, practical constraints compelled us to handle the two samples as consecutive phases of the same study rather than concurrently. However, although the two phases had to be separated by a period of two years, we were able to carry them out over precisely the same quarter of the year. Furthermore, comparison of the numbers and characteristics of those patients in both samples who had been referred from general practice to one of the AEDs showed no significant differences.

Again, examination of routine NHS statistics and local demographic data produced no evidence of any appreciable secular trend either in the relative proportions of patients attending AEDs and general practice or in the distribution of the discriminating variables. (However, it is also worth recording that our method of analysis, yet to be described, is fairly robust to simple secular trends such as these; it requires a particularly perverse family of secular trends, those in which some discriminators become much stronger and other much weaker, to upset our analysis unduly.)

Our interviewers collected information on a wide variety of variables, of which 62 were common to both samples. However, this paper restricts attention to those variables which can be used in the future assessment of alternative policies by predicting likely responses. This requires, not only that there should be information available on the distribution of these variables in the community at large, but also that they should be objective, in two senses. We demand first that the responses should not, in all probability, have been affected by anything occurring after the patient's choice of care (and, in particular, by the treatment he received) and secondly, that the same responses would probably have been obtained using a different method of data collection. Wherever possible, data on the 27 variables fulfilling these criteria were collected not from the patients themselves but from their medical records or by means of a postal survey of their GPs (Holohan et al., 1975).

Statistical Methods

Day and Kerridge (1967) have advocated the logistic form for posterior probabilities as a basis for discrimination between two populations, H_1 and H_2. Given that the values $x_1, x_2, \ldots, x_p$ of p potentially discriminating variables are known for an individual patient, they proposed that an appropriate formula for his resulting probability of belonging to (or in this case, opting for) population H_1 is $e^z/(1 + e^z)$ where z, usually known as the 'discriminant function' (DF), is given by:

$$z = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \ldots + \alpha_p x_p$$

Replacing $\alpha_0, \alpha_1, \ldots, \alpha_p$ by their maximum likelihood estimates (MLEs) $\hat{\alpha}_0, \hat{\alpha}_1, \ldots, \hat{\alpha}_p$ leads to the discriminant rule 'Allocate to H_1 if $\hat{z}$ is positive, H_2 if $\hat{z}$ negative'. This rule is optimum in the sense that it chooses H_1 whenever $\text{Prob}(H_1/x_1, x_2, \ldots, x_p) > \text{Prob}(H_2/x_1, x_2, \ldots, x_p)$ and vice-versa.

But it was left to Anderson (1972) to consider the case, which arises here, when it is necessary, or preferable, to draw a separate sample from each population. He showed that the MLEs $\hat{\alpha}_1, \hat{\alpha}_2, \ldots, \hat{\alpha}_p$ are the same whether the sampling is carried out separately or from the mixture. However, the MLEs of the constant term, $\hat{\alpha}_0^*$ (separate samples) and $\hat{\alpha}_0$ (mixture sampling), are identical if and only if the proportion Π_1^* of H_1 in the separate samples taken together is the same as the proportion Π_1 of H_1 in the 'universe'.

In our study, we interviewed 155 patients who had opted for an AED (H_1) and 191 who had sought care in general practice (H_2); thus $\Pi_1^* = 0.448$. However, we have estimated (Russell and Holohan, 1974) that $\Pi_1 = 0.482$ with an approximate confidence interval of (0.427, 0.538). Since we are concerned more with $\alpha_1, \alpha_2, \ldots, \alpha_p$ than with α_0, we are able to take $\Pi_1^* = \Pi_1$ and $\hat{\alpha}_0^* = \hat{\alpha}_0$.

The maximum likelihood equations for $\hat{\alpha}_0, \hat{\alpha}_1, \ldots, \hat{\alpha}_p$ are solved using a Newton-Raphson procedure and starting values of zero for all parameters. However, it is not computationally feasible to force all 27 variables under investigation into the discriminant function and then to test each coefficient for significance. We therefore build up the DF in a stepwise manner; at each step we identify that variable, not yet represented in the DF, which would generate the greatest improvement in the maximised log likelihood if incorporated in the DF. We then determine whether that improvement is statistically significant by taking into account not only the asymptotic χ^2 property of the maximised log likelihood (Cox, 1970) but also the combinatorial effect of choosing as test statistic the largest of $(27-p)$ improvements in that maximised log likelihood. If this approximate test is significant, the variable is added to the DF; if not, the sequential procedure is terminated.

Findings

Our intention in applying logistic discriminant analysis to the 27 objective variables measured by the Newcastle Accident Survey is to identify that subset which *together* provide the best prediction (best, that is, in the sense that no statistically significant improvement is possible) of the patient's initial choice of care system. However, before analysing the data in this multivariate fashion, we examine the effects of certain variables *in isolation*.

TABLE 1

INITIAL CHOICE BY DISTANCE TO GP'S SURGERY

Distance from Site of Decision ('Source') to GP's Surgery	Initial Choice of Care			
	Hospital No.	%	GP No.	%
0.7 miles or less	47	30.3	112	58.6
0.8 to 1.7 miles	40	25.8	51	26.7
1.8 to 2.7 miles	34	21.9	20	10.5
2.8 miles or more	34	21.9	8	4.2
Total	155	99.9	191	100.0

Significance Test $\chi_3^2 = 44.3$ (Significant at 0.1% level)

It comes as no surprise to find in Table 1 that the farther the patient found himself from his GP, the less likely he was to consult him; similarly, the farther from the AED, the less likely he was to present there. Other attributes of the patient with effects significant at the 0.1% level are his diagnosis (fractures and wounds tend to be taken to the hospital, other conditions to the GP) and his age (patients between 15 and 44 are most likely to report to the AED, those over 65 least likely).

TABLE 2

INITIAL CHOICE BY PRACTICE APPOINTMENTS SYSTEM

Practice Use of Appointments System	Initial Choice of Care			
	Hospital No.	%	GP No.	%
Yes (All surgeries)	67	43.2	82	42.9
Yes (Some surgeries)	26	16.8	35	18.3
Yes (Not otherwise specified)	31	20.0	40	20.9
No	31	20.0	34	17.8
Total	155	100.0	191	99.9

Significance Test $\chi_3^2 = 0.38$ (Not significant)

Although variables describing the patient or the circumstances of his accident show marked univariate effects, the same is not true of those three variables which relate to the general practice with which he is registered. Indeed, the number of partners in that practice is the only one of these variables which is significant and, even then, only by testing for a linear trend in the proportion of patients choosing the hospital (a proportion which decreases with increasing partnership size). Furthermore, the two discriminators (implicitly) proposed by the Expenditure Committee of the House of Commons (1974) —whether the patient's GP makes use of an appointments system (Table 2) and of a deputising service —have no discernible one-way effects. In the case of deputising services, it is just possible that a genuine effect has been masked by the failure of GPs to respond to the postal questionnaire. However the patient's perception of whether his practitioner uses the deputising service seems to have no more effect on his actions than the objective version of that variable.

Two of the remaining 20 variables under consideration in this paper —the patient's occupational status and whether he had been treated at an AED in the preceding year —have univariate effects which are significant at the 1% level. A further five, including sex, martial status and 'external cause of injury' (International Classification of Diseases, 1967) were significant at the 5% level and the residual 13 had, in isolation, no significant effect on patients' choices.

TABLE 3

LOGISTIC DISCRIMINANT ANALYSIS:
DEFINITION OF VARIABLES
(RANKED BY ABILITY TO MAXIMISE LOG LIKELIHOOD)

Var. No. & Rank	Definition of Variables	No. of Cats.	Cat. Most Likely to Choose GP ($x_j = 0$)	Max. Log. L'hood
x_1	Distance to GPs surgery	4	≤ 0.7 miles	
x_2	Distance to hospital	4	≤ 2.8 miles	-192.90
x_3	Final diagnosis	2	All but fractures and wounds	-183.84
x_4	Age	4	≥ 65 years	-174.98
x_5	Has GP any partners?	2	Yes	-171.12

When we apply logistic discrimination to these data in the stepwise fashion already described, the two distances are the first to appear in the DF (Table 3). Since the corresponding parameter estimates, $\hat{\alpha}_1$ and $\hat{\alpha}_2$, are so similar (Table 4), it is clear that patients give equal weight to each of the two distances; all things being equal, it is the nearer of the two sources of emergency medical care which will be chosen. However, as is shown by the next two variables to enter the DF —final diagnosis and age —things are not always equal.

TABLE 4

LOGISTIC DISCRIMINANT ANALYSIS:
PARAMETER ESTIMATES AND THEIR STANDARD ERRORS

No. of Vars. in DF	Parameter Estimates (Standard Errors)				
	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\alpha}_3$	$\hat{\alpha}_4$
2	-1.971 (0.253)	0.837 (0.128)	0.799 (0.129)		
3	-2.492 (0.301)	0.865 (0.134)	0.850 (0.135)	1.106 (0.266)	
4	-3.911 (0.499)	0.830 (0.137)	0.898 (0.142)	1.180 (0.277)	0.980 (0.242)
4 (Hosp. A only)	-4.524 (0.802)	0.927 (0.197)	0.794 (0.234)	1.311 (0.422)	1.185 (0.399)
4 (Hosp. B only)	-3.121 (0.910)	0.865 (0.289)	0.854 (0.255)	1.356 (0.566)	0.656 (0.426)
4 (Hosp. C only)	-3.764 (1.071)	0.609 (0.264)	0.836 (0.328)	1.175 (0.556)	1.100 (0.473)

At this point, only one of the remaining 23 variables under consideration —the number of partners in the patient's general practice —is able to increase the maximised log likelihood by more than 1.92, the upper 5% point of $\frac{1}{2}\chi^2_1$ — the appropriate significance test in these circumstances (Cox, 1970). We deduce that none of the residual 22 variables has a significant effect on the patient's decision *over and above* that of the variables already selected —distance, age and final diagnosis. Since we have already mentioned that seven of the 22 have significant *univariate* effects however, it is helpful to consider one of these in a little more detail.

Of the patients who first sought care at an AED, 34% acknowledged that they had attended an AED at least once during the previous 12 months; the corresponding percentage among patients who reported to their GP was only 20%. That this tendency does not assist in the discrimination is explained by its positive correlation with all four variables already in the DF. In other words, of the factors which, according to our analysis, led patients to the AED on the first occasion, age is essentially immutable, and distance and diagnosis have a better than average probability of remaining unchanged.

It only remains to discuss whether partnership size should contribute to the DF. As Table 3 shows, this variable increases the maximised log likelihood by 3.86. Now although this value is approximately equal to the upper ½% point of $\frac{1}{2}\chi^2_1$, it must be remembered that 23 different variables are competing to become the fifth variable in the DF. Consequently, if all these variables were independent, the true significance level would be close to 10%. However, since our knowledge of the true correlation structure of these 23 variables is limited to this one survey, all we can say with any confidence is that the significance level to be attached to the proposition that partnership size has an intrinsic effect on the patient's initial choice of care system lies between ½% and 10%.

(Although computer simulation would enable us to be a little more precise about the size of this significance level, we doubt whether it would lead to a statement to the effect that it was less (or, for that matter, greater) than 5%.)

Thus our analysis has identified four variables which influence the patient's decision and one whose (independent) effect is is not proven. There is no evidence that the remaining 22 variables have any intrinsic effect. In particular, neither the use of an appointments system by the patient's GP nor that of a deputising service was able, at any of the five steps, to add more to the maximised log likelihood than the sixteenth (ranked by ability to maximise log likelihood) of the remaining 20 variables. However, before we can discuss the relevance of these findings for the National Health Service, we must assess how reliable they are and to what extent they may be regarded as representative of a wider population than that from which they have been derived.

Validation of Findings

Discriminant functions are traditionally appraised by examining the probabilities with which they misallocate to population H_2 patients who actually belong to (or, in this case, opt for) population H_1, and vice-versa (Hills, 1966). Although, this approach is less appropriate to logistic discrimination than it is to the classical method of linear discrimination, it provides a convenient starting point for our validation. However, there is no implied hierarchy among our populations, in the sense that misallocation from hospital to general practice is any more (or less) important than in the opposite direction. Further, both samples are of the same order of magnitude, as are the populations from which they were drawn. Consequently, there is no need for us to distinguish between the two types of misallocation.

TABLE 5

LOGISTIC DISCRIMINANT ANALYSIS:
MISALLOCATION RATES

No. of Vars. in DF	Crude Rates		Cross-Validatory	
	Within Hosps.	Overall	Random	Between Hosps.
2	0.286	0.301	0.301	0.328
3	0.251	0.272	0.275	0.282
4	0.240	0.234	0.254	0.253
5	0.231	0.234	0.237	0.231

The first two columns of Table 5 therefore present crude misallocation rates, 'crude' in the sense that they merely indicate what proportion of all 346 cases are misallocated by the discriminant functions specified in the first three rows of Table 4 and that based on all five variables included in Table 3. The second column is based on the estimation of a single DF for the entire data-set (the only case so far considered). The first column takes that analysis one stage farther by calculating a separate DF for each of the three hospitals involved; misallocation is then identified by comparing each patient's decision with that predicted by the DF appropriate to the AED in question (i.e. the one actually visited or which, according to the interview, would have been visited had the patient not elected to consult his GP).

To overcome the undesirability of testing a DF on the data which produced it, a number of authors, including Mosteller and Tukey (1968), have proposed the use of 'cross-validation', a technique in which the DF is estimated using all but one of the cases and the discarded case then used to assess that estimate. Eliminating each case in turn, thus repeating the procedure as many times as there are cases, leads to a less biased estimate of the misallocation rates.

However, even though it is an easy, if tedious, matter to carry out such an exercise, we are loath to commit ourselves to a further 346 computer runs whenever we have a DF to test. We therefore compromise by successively withdrawing each of 10 mutually exclusive and exhaustive random 10% samples. It is reassuring to find that the resulting cross-validatory estimates of the probabilities of misclassification, which appear in the third column of Table 5, are so close to the (more suspect) crude estimates in the first and second columns.

Since our 4-variable DF thus appears to be statistically valid within Greater Newcastle, we now enquire how relevant it is to other urban areas in the United Kingdom. Although a definitive answer to this question must wait for similar research to be carried out in other parts of the country, we make use of the fact that the three hospitals with which we are concerned are very different in character. Hospital A, which lies close to the centre of Newcastle, has for many years been the teaching hospital of the area; although hospital B has recently become a teaching hospital, its tradition is that of a municipal hospital serving one of the poorer parts of the city; hospital C, a smaller municipal hospital, is situated in the adjacent town of Gateshead.

This diversity suggests that, by validating across these hospitals (in much the same way as the validation across random sub-samples which we have already described), we can at least hint at what a validation across regions might eventually show. We first observe from Table 4 that the three hospital-specific 4-variable DFs show considerable similarities. Although hospital B has a non-significant age co-efficient $\hat{\alpha}_4$ (in other words, the sequential estimation procedure terminates after three steps rather than four), this is, arguably, attributable to the sample size of only 93. More important, the inter-hospital misallocation rates tabulated in the final column of Table 5 are remarkably close to the random cross-validatory rates, expecially when there are four variables in the DF.

Hence it may be suggested (and we put it no higher than that) that the logistic model which we have derived is applicable beyond the limits of Greater Newcastle. Furthermore, lest it should be thought that even this hint of wider applicability is compromised by our failure correctly to predict the decisions of as many as one-quarter of all patients who sustain minor injuries, it must be stressed that the advantage of the logistic method lies not in its power to make infallible forecasts in the face of uncertainty but in its ability accurately to estimate the probabilities inherent in that uncertainty.

TABLE 6

LOGISTIC DISCRIMINANT ANALYSIS: GOODNESS OF FIT (4-VARIABLE DF)

Estimated DF	No. of Pats.	Predicted		Observed	
		Hosp.	GP	Hosp.	GP
$\hat{z} < -2$	59	4.9	54.1	8	51
$-2 < \hat{z} < -1$	53	10.7	42.3	11	42
$-1 < \hat{z} < -\frac{1}{2}$	40	11.4	28.6	9	31
$-\frac{1}{2} < \hat{z} < 0$	52	23.0	29.0	19	33
$0 < \hat{z} < \frac{1}{2}$	32	17.8	14.2	19	13
$\frac{1}{2} < \hat{z} < 1$	52	35.6	16.4	36	16
$1 < \hat{z} < 2$	30	25.0	5.0	27	3
$\hat{z} > 2$	28	26.6	1.4	26	2
Total	346	155.0	191.0	155	191

Significance Test $\chi^2_7 = 5.50$ (Not significant)

To illustrate this point, Table 6 compares the choices predicted by our 4-variable logistic model with those actually made by the survey patients. (If only for the sake of simplicity, the table presents a 'crude' goodness-of-fit test rather than the cross-validatory test which is the logical conclusion of the argument of this section.) Although our previous emphasis on 'misallocation' has served its purpose, it is worth stressing how misleading that term is in the context of logistic discrimination by pointing out that, until now, all the boxed figures on Table 6 have been so described. In view of the evidence of that table (and its cross-validatory equivalents), the DF which we have developed may fairly be described as a probabilistic model of the decision-making behaviour of patients suffering from minor trauma.

Discussion

The Newcastle Accident Survey has derived a statistical model which predicts minor accident patients' choices between AED and general practice with some accuracy in the face of the uncertainty evident in these decisions. Furthermore, the ability of this model to cope with three very different hospitals, admittedly all situated with Greater Newcastle, has led us to suggest that it may also be relevant to other urban areas.

Although this amounts to a claim that the original objective of our study has been achieved, it is not intended to suggest that there are no other objectives which could (or even should) have been tackled. Indeed, there are two particular ways of extending our research which have always seemed to us desirable but which, like all desirable things, are not without cost.

First, our survey has been designed, implemented and analysed under the assumption that those who sustain minor accidents first decide *whether* to seek medical care and only when they have so resolved do they choose *where* to seek it. This is, of course, an over-simplification because there are, for example, some injured patients who perceive their options as being limited to general practice or self-treatment. Any comprehensive discriminatory model of accident behaviour would have to acknowledge that there are (at least) three types of care for which the sufferer can opt. However, the identification of, and collection of *comparable* data from, the self-treaters is demonstrably much more costly and arguably less relevant to NHS decision-making than the exercise we have undertaken.

Secondly, we have made no attempt to compare the costs of treating the marginal minor trauma patient at an AED with those of caring for him in general practice, nor even to identify any of those costs. Consequently, the economic conclusions to be drawn from our study are limited to statements about the ordinal values which different minor trauma patients place on the two alternative forms of NHS treatment. We know nothing either of the way those values compare with that of self-treatment, or of the values of any of these treatments to society as a whole or even to the NHS as an institution.

Implicitly, it seems, patients accord the mile travelled to the surgery the same disutility as the mile travelled to the AED. The other two major discriminators tell us that hospital care is more highly valued by those suffering from fractures or wounds and by those between the ages of 15 and 44. (It is worth stressing here that although theses attributes are correlated, the multivariate nature of the statistical analysis ensures that the findings are independent; loosely speaking, the youth with a fracture is doubly likely to report to the AED.) It seems that the AED is held to be more proficient on the technical or instrumental side while the GP is seen as more supportive in the affective or emotional aspects of the care of accidents (Holohan, 1976). Hence the hospital is preferred both by those who need a technical service such as suturing and by those of an age-group which places a higher value on technical care than on affective care.

Our analysis is equivocal on the question of whether one further variable — whether the patient's GP has any partners — has any intrinsic effect on the patient's decision over and above that of the first four variables, and thus qualifies for inclusion on the model. If so, this would mean that the treatment of injuries by single-handed practitioners is valued less highly than when undertaken by partnerships. However, it is not yet clear whether this would, if true, reflect some inherent quality of one-man practices or whether it would be attributable, for example, to the lower proportion of such practices with attached and employed nurses, as reported by Reedy et al. (1976).

Much more certain, however, is the Newcastle Accident Survey's lack of support for the view taken by the Expenditure Committee of the House of Commons (1974) that 'the use of appointments systems and deputising services can be thought to have had some influence on patients' decisions to attend AEDs'. Not only are these two variables not even remotely associated with the choice of care system, as shown by a simple cross-tabulation, but neither was able to make any contribution to our multivariate statistical analysis. Furthermore, similar negative findings with respect to deputising services have been reported by Williams et al. (1973), who analysed a year's deputising service consultations in Sheffield and Nottingham and secular trends in first attendances at AEDs.

Another argument which gets no support, either from the statistical analysis reported here or from the sociological analysis carried out by Holohan (1976), is that patients who present to AEDs for the treatment of minor injuries are either irrational or perverse, as suggested by some of the more outspoken writers in the medical press and even as hinted at by one or two of those who gave evidence to the Expenditure Committee. Indeed, the picture which emerges from our work is one of patients exercising considerable judgement in deciding which course of action is in their own better interest; so much so that their behaviour in aggregate conforms very closely to the mathematical model which we have proposed.

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