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Measures of performance in Scottish maternity hospitals

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Abstract

Objective—To develop measures of hospital performance over time with particular reference to maternal and neonatal care by controlling for case mix.

Design—Analysis of computerised records of births.

Setting—Scotland, 1980-7.

Subjects—Over half a million singleton live births and stillbirths.

Main outcome measures—Numbers of perinatal deaths and caesarean sections.

Results—Scottish maternity hospitals perform more or less equally with regard to perinatal mortality. When caesarean sections are considered, there is evidence that hospitals differ in their treatment of different groups of women; in two examples one hospital had an increased rate among women of parity 2 or more and another had a reduced rate of repeat caesarean section.

Conclusions—Developing measures of performance over time by controlling for case mix is a valid system for monitoring hospital outcomes and activity, and allows comparison either between hospitals or with data for all Scottish maternity hospitals. Hospital profiles permit identification of differences for particular patient groups after allowance is made for other case mix variables.

Introduction

In the pursuit of improved efficiency, management policies in the NHS have focused increasingly on the use of performance indicators. Most such measures are concerned with crude indicators of resource use^{1,2} and few make allowance for the ways in which the characteristics of the patients treated in a hospital (or health authority) may influence either the use of resources or the outcomes that are achieved. It should be self evident that performance indicators are, at best, difficult to interpret if they do not take account of variation in the case mix of hospitals and thus the work they undertake.

This general point is illustrated by the example of Scottish maternity hospitals in 1980-7. For this period the perinatal mortality rate in Scotland was 9.7/1000 births; individual rates for the 46 hospitals delivering more than 800 babies ranged from less than one to more than 13 deaths per 1000 births. In the same period, the rates of caesarean section for the 30 hospitals employing this mode of delivery varied between 5% and 18% compared with a rate in all Scotland of 13%. Taken at face value, these differences suggest either variations in clinical practice and in the quality of obstetric care or—the more likely explanation—that hospitals differ in the types of cases they manage. If this second interpretation is correct then it has obvious implications for interpreting resource related descriptors of hospital activity. Some of these

factors are considered by Lynch in an econometric study of the variation in cost per case among 35 of the hospitals we analysed.³

A major difficulty in devising and applying performance indicators is that they depend on information that is routinely available (usually for other primary purposes) and thus on the post hoc ability of this information to reflect "performance" in more complex ways than, for example, the number of patients processed in a given time interval. Most NHS information systems fail to provide sufficient detail about patients' characteristics or the content of clinical care to allow proceeding much beyond the general comparisons included in published lists of performance indicators. The system of Scottish morbidity records used for maternity and neonatal care (forms SMR2 and SMR11⁴) is an exception for two reasons: firstly, the forms include data about the circumstances of the pregnancy and its outcome, and, secondly, they are completed for nearly all births occurring in Scottish maternity hospitals. It is thus possible to compare hospitals in terms of differences in their case mix and to make allowance for these differences when interpreting the outcomes the hospitals achieve or the activities they undertake.

Methods

The analysis used data for singleton births from routinely completed maternal and neonatal discharge records (forms SMR2 and SMR11) for births in Scotland during 1980-7. The forms provide information about the mother (demographic and obstetric characteristics) as well as details of the recorded pregnancy. The records included 98% of all pregnancies in Scotland; 514 193 records from 96 hospitals were included in the analysis. The reporting of deaths was slightly less complete, consisting of 98% of stillbirths, 97% of early neonatal deaths, and 93% of late neonatal deaths (S K Cole, personal communication). In all 8.8% of all live births were transferred from the hospital of birth to another hospital; these accounted for 12.6% of all deaths in the first week. All such transfers were ascribed to the birth unit. No systematic bias was found in either the reporting of deaths or the distinction between deaths in the first week and early neonatal deaths between hospitals or hospital types.

The data were formed into a multidimensional contingency table and a logistic regression^{5,6} was performed for each outcome measure by using GLIM 3.77⁷ with each of the 14 variables listed in the table regarded as a factor with two to eight levels. These variables were chosen as classic explanatory variables from previous studies⁸⁻¹⁰ under the constraint of the availability of the data. The purpose of this initial model fitting was to define a statistical model for selected outcomes (numbers of perinatal deaths and caesarean sections) that would account for variations in the data for all years included in the study. Only

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variables shown to have a significant effect ($p < 0.0001$) on the outcome after other significant effects had been controlled for were included in each model. Including interactions in the models meant that effects of

potential variables were not confounded by others.⁶

Because some outcomes are rare and so yield few events (as an example, between 1980 and 1987, 2487 stillbirths were recorded in over half a million births—a frequency of just 0.5%) the influence of a variable may vary from one year to the next. To provide more robust estimates of how a particular variable affects the outcome in a given year we used a new application of the EM algorithm,^{11,12} details of which may be found in the appendix.

For each category of patients we were able to obtain outcome probabilities (that is, the chance of an outcome for a given obstetric and demographic history) based on data for the entire Scottish population. Aggregating these probabilities for the cases managed by individual hospitals provided a measure of the outcome that could be expected for each hospital, taking account of variations in the case mix between hospitals. These expected outcomes could then be compared with those observed for the hospitals. The difference between the observed outcome for a hospital and that expected on the basis of data for all Scotland (for a given hospital population) is called the residual. This difference cannot be explained by the model and so it can be regarded as an estimate of other effects, including a hospital's care—in other words, it can be regarded as a measure of performance. To make allowance for hospital size and case mix the residuals were expressed as signed X^2 values.

In this paper we describe outcomes for four models: the results for stillbirths and deaths in the first week were combined as perinatal deaths, and caesarean sections with and without breech presentations were combined in one category. The table gives the variables significantly associated with the different outcomes and included in each of the models.

Results

Figure 1 plots the number of perinatal deaths observed against the number predicted by the model for the 46 maternity hospitals that delivered an average of more than 100 babies a year during 1984-7. If the observed and expected numbers coincided then a hospital would appear on the diagonal line; the broken lines indicate the simultaneous 95% confidence intervals for this diagonal.¹³ (The use of simultaneous confidence intervals is designed to ensure that there is a 5% chance that a hospital lies outside the intervals as opposed to 5% of the hospitals lying outside, as would be the case with a conventional 95% confidence interval.) The distance of a hospital above or below the diagonal line can be regarded as a measure of its performance for the outcome of perinatal mortality. None of the hospitals fell above the confidence interval of the diagonal (that is, none had significantly more deaths than expected); only one fell below. For perinatal death rate Scottish maternity hospitals perform more or less equally.

The vertical distance of a hospital from the diagonal line indicates the overall performance of that hospital for this outcome. The method also permits comparisons of a hospital's performance with all Scottish hospitals with respect to particular case attributes. Risks for individual hospitals were calculated by running the models for the case mix of each hospital and then calculating the risk associated with that variable for a particular hospital. These were then compared with the estimated risks obtained for the whole of Scotland.

For ease of illustration, four hospitals are described graphically (see fig 2 and fig 4). The vertical line represents the risk associated with a particular variable for the whole of Scotland, and the shaded area the 95% simultaneous confidence intervals of the difference

Variables used for calculating four outcomes

Variable	Category	Outcome			
		Stillbirth	Death in first week	Caesarean section with breech presentation	Caesarean section for other reasons
Parity	0/1/2+	X	X	X	X
Maternal age	Age <20/20 to <35/≥35	X		X	X
Marital status	Once married/never married	X	X		X
Maternal height	≥155 cm/<155 cm			X	X
Antenatal care	Yes/no	X	X	X	X
Complications in pregnancy*	Yes/no	X		X	X
Length of antenatal stay	≤13 days/>13 days	X		X	X
Previous therapeutic abortion	0/1+				
Previous spontaneous abortion	0/1+		X	X	X
Previous perinatal death	0/1+	X	X	X	X
Previous caesarean section	0/1+			X	X
Hospital admission this pregnancy	Yes/no	X			X
Length of gestation (or estimate)	≥37 weeks/33 to <37 weeks/<33 weeks	X	X	X	X
Social class:†					
Men	1,2/3/4,5/Armed forces				
Women	1,2/3/4,5/Other				

*Placenta praevia, pre-eclampsia, or eclampsia and hypertension.

†Mother's occupation used if father's was missing.

FIG 1—Perinatal mortality in 46 Scottish hospitals that delivered an average of >100 babies/year during 1984-7. Shaded area shows simultaneous 95% confidence intervals. Hospitals marked A and B are profiled in figure 2

FIG 2—Case characteristics associated with differences in rates of death in first week of two Scottish hospitals compared with all hospitals in Scotland, 1984-7

FIG 3—Number of caesarean sections during 1984-7 in 30 hospitals where such deliveries occurred. Shaded area shows simultaneous 95% confidence intervals. Hospitals C and D are profiled in figure 4

FIG 4—Case characteristics associated with differences in caesarean section rates of two Scottish hospitals compared with all hospitals in Scotland, 1984-7

between that hospital and all of the hospitals in Scotland for each of the patient attributes included. Each variable was standardised for all the others and the percentage of a hospital's cases with that attribute is also given. The bars at the top of the figure indicate the risk for that hospital compared with the Scottish mean for cases without the variables listed in the figure. The lower part of the figure is then based on an estimate of the added risk associated with a particular case attribute, again comparing the hospital with Scotland.

In these two figures the risks are represented by points and so each column provides a "profile" of the way that a hospital's performance may differ from the Scottish norm; a point to the right of the central line indicates a higher than expected risk associated with that variable and one to the left that the risk is lower than expected (the method is detailed in the appendix). This graphical presentation thus provides a simple way of identifying those groups of patients for whom a hospital's practices or outcomes deviate from the Scottish "standard."

Figure 2 gives profiles for deaths in the first week for the two hospitals marked A and B in figure 1. A direct comparison between the two is not intended; each is compared with the Scottish mean and so the two may only be contrasted indirectly. The distribution of case mix variables in these two hospitals was very similar but hospital A had 17 (23%) more deaths than predicted by the model and hospital B had 18 (48%) fewer deaths than predicted. Despite this apparent discrepancy neither hospital differed significantly from the Scottish mean for cases either with or without the variables shown.

Figure 3 compares the number of observed and expected deliveries by caesarean section in the 30 hospitals where such deliveries occurred during 1984-7. The scatter of hospitals was somewhat greater than that for perinatal mortality but the overall pattern was again one in which the observed number of deliveries by caesarean section is close to that predicted by the model. Figure 4 illustrates the profile of delivery by caesarean section other than breech presentation for hospitals C and D identified in figure 3. Overall, the number predicted by the model was about equal, but in practice the hospitals differed by a total of 594 operations over four years.

Hospital C performed 12% more operations than the model predicted. This excess can be linked to an increased rate of this mode of delivery in women of parity 2 or more; conversely, there were fewer operations than expected in women who had had one or more perinatal deaths before this pregnancy. Hospital D performed 21% fewer caesarean sections than predicted, with a below average rate for women who had had a previous caesarean section and an above average rate for women who had had previous perinatal death. These differences show how discrepancies between observed and expected outcomes (the measure of "performance") may come about. The overall performance of a hospital is a combination of two factors: the proportion of its case mix possessing a particular attribute and also the risk of a given outcome associated with that attribute in that hospital when compared with a reference standard (in this case, for Scotland).

The overall rate of caesarean section in hospital C was greater than expected because of an increased rate among women of parity 2 or more, who made up 21% of all cases. The effect of a lower than expected rate in women with previous perinatal deaths was small because only 3% of cases had this feature. In hospital D the overall rate was lower than expected because of the lower rate in women with a previous caesarean section (14%); the higher than expected rate in women with previous perinatal deaths (7%) had a smaller influence on the overall rate.

One of the criteria for a performance indicator is that it should permit comparison of the performance of a hospital within the larger pattern of service provision. The residuals of the models provide such a measure. Figure 5 plots the residuals for caesarean sections for three teaching hospitals over eight years against the median for Scotland: the 10th and 90th centiles are for all hospitals in the analysis calculated for each year. Statistically, four hospitals must lie above the 90th centile in each year and four below the 10th centile. What is of interest is whether or not hospitals are consistent in their deviance from the median. In this example all three hospitals fall within the guidelines of the centiles, although the year on year instability of each line is a striking feature.

The correlation between the residuals for perinatal mortality and those for caesarean section is important as a test of the model's validity but is also a relevant measure of hospital performance. Because the indicators for the two outcomes are largely the same (that

FIG 5—Standardised residuals for caesarean sections: annual residuals of three Scottish teaching hospitals, 1980-7

is, the same variables are used in the model for each) a large positive correlation (more—or fewer—perinatal deaths than expected corresponding to more—or fewer—caesarean sections than expected) would suggest that the model is inadequate and is not standardising for case mix. A strong negative association between the two sets of residuals (more—or fewer—perinatal deaths than expected corresponding to fewer—or more—caesarean sections than expected) would suggest that an above average perinatal mortality rate might be reduced by increasing the rate of caesarean section. In the event the correlation was found to be practically zero ($r=0.03$).

Discussion

Performance indicators are of use to both clinicians and the managers of services. The crude rates currently used provide some information but little or no indication of what, if any, action is appropriate to improve health care. Performance indicators determined by the method described in this paper improve the quality of information. This method identifies and separates the variation that is due to factors beyond the scope of immediate hospital intervention and, where problems are identified, makes it possible to pinpoint particular groups of patients on whom attention could most effectively be directed.

A major criticism of performance indicators has been that they merely identify differences; they do not explain why differences occur. In particular, they fail to distinguish between other risks inherent in the case mix of the hospital and the hospital's performance. The method we describe is an extension and refinement of more general approaches including that of Knox *et al*¹⁴ and the American work on risk adjusted monitors of outcome (RAMOs),¹⁵⁻¹⁷ which require that comparisons of either outcomes or activities take account of those variables, in addition to medical care, that may influence the results that are achieved.

If it were possible to take account of all aspects of the case mix, then the residuals would provide a precise measure of performance. The closer we come to identifying and measuring all risks to individual patients the more accurate our measures of performance will be. Thus estimation of risks at the individual level comes nearer to the ideal than earlier methods in which the unit of analysis is the hospital.¹⁸

An important limitation of the approach is that the model is only as good as the data it uses in terms of both their scope and quality. One deficiency in the SMR2 data, for example, is that morbidity during pregnancy is identified but there is no estimate of its severity. Even so, figures 1 and 3 provide a picture of the overall performance of Scottish maternity hospitals in regard to their perinatal mortality and caesarean section rates and thus (as shown in figures 2 and 4) a basis for more detailed insights into the seemingly different rates of

individual hospitals. In this sense it comprises an audit of obstetric care in Scotland.

The method can be applied to other aspects of obstetric care, such as rates of antenatal admission or the use of neonatal special care facilities. Similarly, it provides a basis for exploring geographical differences in outcomes or for other subsets of the obstetric population. One interesting observation about the development of the models is that social class was originally included as a variable in the expectation that it would influence rates of both perinatal mortality and caesarean section. In the event, it did not seem to do so, possibly for two reasons. Firstly, social class data are poorly collected on the SMR2 forms and, secondly, it may be that social class differences noted in crude mortality rates from the SMR2 data are explained by variations in the prevalence of other adverse factors included in the models. This is a possibility that requires further exploration. A second variable that did not contribute to the models was a history of therapeutic abortion.

The results we report illustrate another feature of the interpretation of findings from these methods. Despite definitional problems¹⁹ perinatal mortality is a definitive outcome for which an excess of observed over expected outcomes would clearly be a matter for concern. On the other hand, caesarean section rates arise from a combination of opinion about good practice and large numbers of individual clinical judgments at the time of delivery. The general point is that the approximation between observed and expected events will vary from one performance measure to another depending on the judgments that underlie it. Figure 3 suggests that there is a fairly high degree of agreement among Scottish obstetricians about the indications for caesarean section even though the crude rates for their hospitals vary by a factor of 3-5.

This analysis has been possible because of the availability of adequate data; there is no theoretical reason why these methods should not be used in other contexts, provided that data describing relevant patient characteristics and the activities undertaken in their management are available both for individual hospitals and for an appropriate reference population. The number of patients managed by each hospital is the constraining factor and so information about every case is necessary. Figure 5 illustrates the further need to take account of year on year variation and to make allowance for time trends within the data.

These conditions are not only necessary for the technical method we describe but are central to the problem of adjusting for variation in case mix when comparing the activities or performance of one hospital (or region) with another. The Scottish system of maternity and neonatal records happens to satisfy the requirements of risk adjusted monitoring; wide applications of the approach will require substantial improvements in NHS information systems.

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Appendix

Robust estimation of model parameters over time using the EM algorithm

The vectors of parameter estimates $\mathbf{b}_t$ are observed for year

i , as are their covariance matrices V_i . Taking the V_i as fixed, we assume the distribution of the b_i to be

$$\beta_i \sim N(\beta_i, V_i)$$

where

$$\beta_i \sim N(\mu + \alpha_i, \Sigma)$$

that is, the distribution of the β_i depends on the year i by way of the parameter α_i . Assuming a linear trend in the parameter estimates we constrain α_i such that

$$\alpha_i = ix$$

Estimation and maximisation now proceed according to the computational details given by Dempster *et al*² with the exception of α , an estimate of which may be achieved by maximum likelihood.

Calculation of the profile

All variable differences are standardised to a normal $N(0,1)$ distribution using the parameter estimates from Scotland and from the hospital alone, together with the two standard errors of these estimates. Using figure 2 as an example, the parameter estimate (SE) for the variable associated with no antenatal care obtained from the Scottish model for death in the first week (1984-7) was 2.101 (0.386), while for hospital A these figures were 2.534 (1.048). The z score for the difference in the parameter estimates (hospital A - Scotland) is then

$$z = (2.534 - 2.101) / \sqrt{(0.386^2 + 1.048^2)} \\ = 0.388$$

Because the comparison is being made across eight variables, the confidence intervals are placed at ± 2.734 , so that there is a probability of 0.025/8 in each tail. The point by this variable in figure 2 is therefore positioned 14% of the distance between the central vertical line (the mean for Scottish, representing zero difference) and the right hand edge of the shaded area (95% simultaneous confidence interval).

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Randomised controlled trial comparing oral and intravenous rehydration therapy in children with diarrhoea

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Abstract

Objective—To determine the effectiveness of oral rehydration in children with moderate dehydration caused by gastroenteritis, and to compare the complications of oral and intravenous treatment.

Design—Randomised controlled trial.

Setting—Emergency department and infectious diseases ward in a large urban teaching hospital.

Patients—111 children aged 3-36 months who had been previously healthy, had had diarrhoea for seven days or less, had clinical signs of dehydration, and were not in shock. Six children were withdrawn because the diagnosis was incorrect (four in oral group, two in intravenous group) and one (oral group) was withdrawn at her parents' request.

Interventions—Oral rehydration fluid was given by mouth or nasogastric tube, or both to 52 children. The remaining 52 received intravenous rehydration fluids but were allowed to drink.

Main outcome measures—Success or failure of rehydration. Number of times child vomited or passed stool after starting treatment. Time taken to rehydrate.

Results—Oral treatment failed in two children (failure rate 3.8%, upper 95% confidence limit 11.6%) and intravenous treatment in none. Vomiting was more common in the oral group ($p < 0.01$): 26 of 50 children (52%) in the oral group and 11 of 50 (22%) in the intravenous group vomited during rehydration. There was no significant difference between the two

treatment groups in the number of stools passed during rehydration ($p = 0.09$). None of the children had serious complications of treatment.

Conclusion—Rehydration by mouth or nasogastric tube is a safe and effective treatment for moderately dehydrated children with gastroenteritis.

Introduction

Oral rehydration is underused in developed countries, usually being given only for maintenance or to correct mild dehydration. Two factors contribute to the overuse of intravenous fluid: firstly, the degree of dehydration is consistently overestimated in children in developed countries¹ and, secondly, it is widely believed that children with anything more than mild dehydration should be rehydrated with intravenous fluid² despite much evidence from developing countries that oral rehydration is safe and effective treatment even for severe dehydration (provided that the patient is not in shock).³

Few controlled trials have been performed in developed countries to test whether oral rehydration is as successful as the more expensive and complicated intravenous therapy.^{4,7} In addition many doctors believe that oral rehydration is more labour intensive.⁸ These two factors have contributed to the reluctance of doctors in developed countries to use oral rehydration.

To assess the effectiveness of oral rehydration and to compare the complications of oral and intravenous

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