What is already known on this topic

In most studies mortality from unexpected cardiac arrest in hospital exceeds 50%

Such events are usually preceded by signs of clinical deterioration in the hours before cardiac arrest

What this study adds

Early intervention by a medical emergency team significantly reduced the incidence of and mortality from unexpected cardiac arrest in hospital

vention based on well defined criteria of clinical instability, together with a system of support, ongoing education, and performance feedback to the primary caregivers, can significantly reduce the incidence of and mortality from cardiac arrest in hospital.

We thank Mary Draper from the Department of Human Services, Victoria, for the department's financial support and her enthusiasm for the project. We also thank the staff of Dandenong Hospital, who have made the commitment to better quality care for all our patients.

Contributors: See bmj.com.

Funding: Department of Human Services.

Competing interests: None declared.

1 Peatfield RC, Sillett RW, Taylor D, McNicol MW. Survival after cardiac arrest in hospital. *Lancet* 1977;i:1223-5.
2 Bedell SE, Delbanco TL, Cook EF, Epstein FH. Survival after cardiopulmonary resuscitation in the hospital. *N Engl J Med* 1983;309:569-76.
3 Schein RM, Hazday N, Pena M, Rubens BH, Sprung CL. Clinical antecedents to in-hospital-cardiopulmonary arrest. *Chest* 1990;98:1388-92.
4 Franklin C, Mathew J. Developing strategies to prevent inhospital cardiac arrest: analyzing responses of physicians and nurses in the hours before the event. *Crit Care Med* 1994;22:244-7.
5 Buist MD, Jarmolowski E, Burton PR, Bernard SA, Waxman BP, Anderson J. Recognising clinical instability in hospital patients before cardiac arrest or unplanned admission to intensive care. A pilot study in a tertiary-care hospital. *Med J Aust* 1999;171:22-5.
6 Hourihan F, Bishop G, Hillman KM, Daffurn K, Lee A. The medial emergency team: a new strategy to identify and intervene in high risk patients. *Clin Intensive Care* 1995;6:269-72.
7 Lee A, Bishop G, Hillman KM, Daffurn K. The medical emergency team. *Anaesth Intensive Care* 1995;23:183-6.
8 Campbell JP, Maxey VA, Watson WA. The Hawthorne effect: implications for pre hospital research. *Ann Emerg Med* 1995;26:590-4.

(Accepted 20 September 2001)

ELPS

The full version of this article appears on bmj.com

Risk adjustment for hospital use using social security data: cross sectional small area analysis

Roy A Carr-Hill, James Q Jamison, Dermot O'Reilly, Michael R Stevenson, James Reid, Barry Merriman

Centre for Health Economics, University of York, York YO10 5DD
Roy A Carr-Hill *professor*

Health and Social Care Research Unit, Queen's University Belfast, Institute of Clinical Science, Belfast BT12 6BJ
James Q Jamison *director*
Dermot O'Reilly *deputy director*
Michael R Stevenson *statistician*
Barry Merriman *research associate*

Northern Ireland Cancer Registry, Queen's University Belfast
James Reid *epidemiologist*

Correspondence to: J Q Jamison, Centre for Social Research, Queen's University Belfast, Belfast BT7 1NN
j.jamison@qub.ac.uk

BMJ 2002;324:390–2

Abstract

Objectives To identify demographic and socioeconomic determinants of need for acute hospital treatment at small area level. To establish whether there is a relation between poverty and use of inpatient services. To devise a risk adjustment formula for distributing public funds for hospital services using, as far as possible, variables that can be updated between censuses.

Design Cross sectional analysis. Spatial interactive modelling was used to quantify the proximity of the population to health service facilities. Two stage weighted least squares regression was used to model use against supply of hospital and community services and a wide range of potential needs drivers including health, socioeconomic census variables, uptake of income support and family credit, and religious denomination.

Setting Northern Ireland.

Main outcome measure Intensity of use of inpatient services.

Results After endogeneity of supply and use was taken into account, a statistical model was produced that predicted use based on five variables: income support, family credit, elderly people living alone, all ages standardised mortality ratio, and low birth weight. The main effect of the formula produced is to move resources from urban to rural areas.

Conclusions This work has produced a population risk adjustment formula for acute hospital treatment in which four of the five variables can be updated annually rather than relying on census derived data. Inclusion of the social security data makes a substantial difference to the model and to the results produced by the formula.

Introduction

The 1990s saw an increase in managed care in the United States and western Europe.[1 2] This change was partly in response to growing awareness of the inescapable scarcity of healthcare resources in almost all countries in the Organisation for Economic Cooperation and Development.[3] Various market style approaches to reforming health care have also been tried to help contain costs.[4 5] At the same time many countries have been trying to improve funding mechanisms so that the whole population has equal access to care—for example, Canada,[6 7] Germany,[8] the Netherlands,[9] the United Kingdom,[10] and the United States.[11]

Methods for adjusting funding according to need (risk adjustment) have probably been most carefully studied in the United Kingdom. Equity of funding has been a recurring preoccupation of NHS policymakers and analysts for at least 20 years. There has been periodic and sometimes acrimonious debate[12] about how best to use available morbidity and socioeconomic data

to reflect healthcare needs once demographic differences have been accounted for.

The original English Resource Allocation Working Party report in 1974 recommended using standardised mortality ratio as a default proxy for morbidity and ultimately need for health care.[13] During the 1980s it became increasingly recognised that any risk adjustment formula should include measures of social deprivation as well as health and that the effects of supply of facilities needed to be disentangled from their use so that the relative effects of social deprivation and morbidity could properly be estimated.

Availability of data across the United Kingdom has improved greatly in recent years, and methods to adjust for the confounding of need and supply have been developed.[14 15] However, previous methods have relied on census data, which are often out of date and include only proxy measures of household income such as car ownership. We describe a study of the determinants of use of inpatient services undertaken as part of a review of the expenditure needs of the four health and social services boards in Northern Ireland. As part of this study we investigated the potential contribution of social security data as direct measures of poverty.

Methods

We assembled large quantities of data on broad population healthcare needs (both health and socioeconomic); use of inpatient services; and supply of hospital and community services. We aggregated data on needs and use to electoral ward level (average population 3200) and attached grid references to the supply variables for use in the spatial interactive modelling (see below). When electoral wards were small, we amalgamated neighbouring electoral wards to ensure a minimum population size of 2000.

Needs

The health variables included mortality (in the form of standardised mortality ratios), limiting long standing illness and permanent sickness (from the 1991 census), and low birth weight (<2500 g,[16] from the boards' child health systems for July 1990 to June 1996). There were 34 socioeconomic needs variables, which were mainly drawn from the census. These included religious denomination, which is recognised to be an important social indicator in Northern Ireland.[17] We also included ward data from the end of 1996 on recipients of income support and family credit. Recipients of income support were divided into two broad age groups: 18-64 years and ≥ 65.

Use of services

We used routinely available hospital data for 1994-5 and 1995-6 to derive numbers of discharges and bed days for inpatients and day cases by specialty. Non-residents and private patients were excluded. The use and estimated specialty cost data were used to produce a measure of intensity of use at ward level (estimated cost divided by expected cost). We adjusted for the size and the age and sex distribution of the population within each ward by indirect standardisation using the overall Northern Ireland rates.[18]

Table 1 Formula for risk adjustment (model 1)

Variable	Coefficient	SE	β value
Over 75s living alone	0.108	0.024	0.161
Family credit	–2.195	0.350	–0.286
Income support (all ages)	0.079	0.016	0.251
Standardised mortality ratio (all ages)	0.271	0.032	0.297
Low birth weight	0.051	0.016	0.108

Supply of health services

We used spatial interactive modelling methods to reflect the influence of supply on usage.[19] These provide a means of reconciling the proximity of each ward to all possible facilities and the attractiveness (usually size) of each facility. We estimated travel times to hospital and used these to calibrate the acute specialty models.

Modelling methods

Because of the high degree of intercorrelation among the needs variables, we used correlation, cluster, and regression analysis to aid data reduction. In modelling hospital use, we concentrated on disentangling the feedback loop caused by simultaneous supply of, and demand for, health care (endogeneity). This arises because although the physical supply of beds at ward level is responsive to historical demand, historical supply itself may have stimulated use and could also be influenced by factors such as the characteristics of the local area and the general practitioners working within it.

We modelled use of hospital services as a function of supply and need by two stage least squares. We then excluded those needs drivers that were found to affect use only through supply, along with the supply variables themselves. The second stage of the regression was concerned with estimating coefficients for the surviving drivers, which were taken to directly affect use. This provided an adjustment for the influence of supply on use. The health and social needs variables entered into the regression models as both explanatory and instrumental variables are available on bmj.com.

Results

A model with five variables retained most of the explanatory power of the full model with both supply and needs variables (adjusted $R^2=52\%$, table 1). This risk adjustment model has been adopted for use in conjunction with an age-sex cost curve for acute hospital services in Northern Ireland to distribute funds for acute hospital services to the health and social services boards.

Table 2 shows the model obtained when the income support and family credit variables were excluded from the candidate set. This model contains seven variables, none of which is related to poverty, although many of the census based socioeconomic indicators are surrogate measures of income and material disadvantage.

Table 3 shows the results of applying the two models to a notional sum of £500m, which is roughly the amount spent on acute services in Northern Ireland annually. The allocations produced using the crude and effective (age weighted) populations are also shown for comparative purposes. Because the size of a

Table 2 Risk adjustment model without social security variables (model 2)

Variable	Coefficient	SE	β value
Over 75s living alone	0.111	0.024	0.165
Limiting long term illness <75	0.154	0.032	0.215
Limiting long term illness >75	0.065	0.026	0.087
Standardised mortality ratio (all ages)	0.309	0.032	0.338
Low birth weight	0.043	0.017	0.091
Lone parents	0.266	0.085	0.131
% Roman Catholic	–0.023	0.006	–0.150

Table 3 Distribution of £500m between health and social services boards in Northern Ireland based on crude populations, effective (age weighted) populations, and two risk adjustment models (£m)

	Northern	Southern	Eastern	Western
Crude populations	124.88	91.48	200.98	82.66
Effective populations	124.57	91.26	201.92	82.25
Model 1*	120.20	93.11	200.67	86.02
Model 2†	118.15	92.62	203.50	85.73

*See table 1 for variables. †See table 2 for variables.

population has by far the greatest influence on its need for health care size, any formula of this kind will have only a marginal (though important) effect on financial allocations. Apart from population size, the other two drivers are age structure and the needs factors used. Table 3 shows that the effect of age structure is less than 0.5% and that of the needs factors is up to 5%. The two risk adjustment models result in very different distributions of resources, particularly in the case of the largest board (Eastern). Model 1 gives that board £1.25m less than its age weighted population share, whereas model 2 gives it over £1.5m more.

Discussion

This study represents a considerable advance on previous work on risk adjustment[14 15] because we used direct measures of poverty at small area level rather than indirect census based proxies. It is widely acknowledged that understanding of the association between socioeconomic standing, health status, and the need for health services would be enhanced if data directly reflecting income levels were more readily available.[20] In addition, four of the five variables in our model (including household income) can be updated between censuses. This is clearly important for a formula used to allocate resources on an annual or three yearly basis. Our work is also an improvement on the current formula used in England in the following respects: more precise cost data were available; there was accurate and current measurement of access to private beds in health service hospitals; and the effect of distance from acute beds was empirically estimated by specialty.

The previous British government's decision to damp down the effect of the "York formula" on allocations in the English NHS caused some controversy.[21] This decision limited the extent of transfer of resources from the shire counties to metropolitan districts. It is notable, therefore, that the main effect of our formula that included social security benefits was to move resources from the board centred on Belfast to those serving primarily rural parts of Northern Ireland.

What is already known on this topic

Use of hospital services at small area level is related to supply and census derived proxy measures of socioeconomic status as well as morbidity

Changes to census data can be determined only every 10 years

What this study adds

Social security data directly reflecting household income predicts use of inpatient services

Use of social security data allowed development of a risk adjustment model in which four of the five variables can be updated annually

The main effect of the resulting formula is to move resources from urban to rural areas

We thank Stephanie Harcourt, Karen Campbell, David Marshall, Stephen Donnelly, and Sandy Fitzpatrick for providing the data and helpful advice.

Contributors: See bmj.com

Funding: Northern Ireland Department of Health and Social Services.

Competing interests: JQJ has received research funds for a member of staff from the Northern Health and Social Services Board. RC-H is self financing and carrying out the study meant that there were sufficient funds to pay his salary.

1 Marquis MS, Long SH. Trends in managed care and managed competition, 1993-1997. *Health Aff (Millwood)* 1999;18(6):75-88.
2 Elola J. Health care system reforms in western European countries: the relevance of health care organization. *Int J Health Serv* 1996;26:239-51.
3 Organisation for Economic Cooperation and Development. *Health care systems in transition*. Paris: OECD, 1990. (Social policy studies No 7.)
4 World Health Organization. *European health care reforms: analysis of current strategies*. Copenhagen: WHO Regional Office for Europe, 1996.
5 Organisation for Economic Cooperation and Development. *Health care reform: the will to change*. Paris: OECD,1996.
6 Eyles J, Birch S, Chambers S, Hurley J, Hutchison B. A needs-based methodology for allocating health care resources in Ontario, Canada: development and an application. *Soc Sci Med* 1991;33:489-500.
7 Pampalon R, Saucier A, Berthiaume N, Ferland P, Couture R, Caris P, et al. The selection of needs indicators for regional resource allocation in the fields of health and social services in Quebec. *Soc Sci Med* 1996;42:909-22.
8 Wysong JA, Abel T. Risk equalization, competition and choice: a preliminary assessment of the 1993 German health reforms. *Sozial-und-Präventivmedizin* 1996;41:212-23.
9 Van de Ven WPM, Van Vliet RCJA, Van Barneveld EM, Lamers LM. Risk-adjusted capitation: recent experiences in the Netherlands, *Health Affairs* 1994;13(5):120-36.
10 Mays N. NHS resource allocation after the 1989 white paper: a critique of the research for the RAWP review. *Community Med* 1989;11:173-86.
11 Taylor T. The natural life of policy indices: geographical problem areas in the US and UK. *Soc Sci Med* 1998;47:713-25.
12 Mays N, Judge K. A new approach to weighted capitation. *BMJ* 1994;309:1031-2.
13 Department of Health and Social Security. *Sharing resources for health in England: report of the Resource Allocation Working Party*. London: HMSO, 1976.
14 Carr-Hill RA, Sheldon TA, Smith P, Martin S, Peacock S, Hardman G. Allocating resources to health authorities: development of method for small area analysis of use of inpatient services. *BMJ* 1994;309:1046-9.
15 Smith P, Sheldon TA, Carr-Hill RA, Martin S, Peacock S, Hardman G. Allocating resources to health authorities: results and policy implications of small area analysis of use of inpatient services. *BMJ* 1994;309:1050-4.
16 World Health Organization. *International classification of diseases. Ninth revision*. Geneva: WHO, 1978.
17 Standing Advisory Commission on Human Rights. *Religious and political discrimination and equality of opportunity in Northern Ireland: second report*. London: HMSO, 1990.
18 Armitage P. *Statistical methods in medical research*. Oxford: Blackwell, 1971.
19 Batty M. *Urban modelling: algorithms, calibrations, predictions*. Cambridge: Cambridge University Press, 1976.
20 Carstairs V. Deprivation indices: their interpretation and use in relation to health. *J Epidemiol Community Health* 1995;49(suppl 2):S3-8.
21 Brennan M., Carr-Hill R. *No need to weight community health programmes for resource allocation?* York: Centre for Health Economics, 1996.

(Accepted 26 September 2001)