research on this issue carried out since then (that published up to 1990 being reviewed by Davey Smith *et al*).⁸

So, those who would seek to criticise or ignore research on socioeconomic deprivation and health using ecological correlation studies in which appropriate indices of deprivation have been used cannot legitimately seek support from the ecological fallacy.

- 1 McCarron PP, Davey Smith G, Womersley JJ. Deprivation and mortality in Glasgow: increasing differentials from 1980 to 1992. *BMJ* 1994;309:000-000.
- 2 McLeone P, Boddy FA. Deprivation and mortality in Scotland, 1981 and 1991. *BMJ* 1994;309:000-000.
- 3 Selvin HC. Durkheim's suicide and problems of empirical research. *American Journal of Sociology* 1958;63:607-19.
- 4 Robinson WS. Ecological correlations and the behavior of individuals. *American Sociological Review* 1950;15:351-7.
- 5 Morgenstern H. Uses of ecologic analysis in epidemiological research. *Am J Public Health* 1982;72:1336-44.
- 6 Sloggett A, Joshi H. Higher mortality in deprived areas: community or personal disadvantage? *BMJ* 1994;309:000-000.
- 7 Department of Health and Social Security. *Inequalities in health: report of a research working group*. London: DHSS, 1980.
- 8 Davey Smith G, Bartley M, Blane D. The Black report on socioeconomic inequalities in health 10 years on. *BMJ* 1990;301:373-7.

Appropriateness of deprivation indices must be ensured

Mel Bartley, David Blane

Nuffield College, Oxford
OX1 1NF
Mel Bartley, research officer
in public health policy

Academic Department of
Psychiatry, Charing Cross
and Westminster Medical
School, London W6 8RP
David Blane, lecturer in
medical sociology

Correspondence to:
Dr Bartley.

Since 1971, census information has been used to identify localities where a high proportion of households are living under adverse social and economic conditions. The initial intention was that such areas should be provided with extra resources to improve the quality of life of individual people and their families.

Underlying this exercise was the assumption that improving local facilities (by upgrading housing estates or setting up educational priority areas) could improve residents' opportunity and quality of life without changing individual circumstances such as low wages or unemployment.¹ The items from the 1971 census used for the original Department of Environment deprivation index therefore included measures of housing quality and proxy measures of income such as employment status. Other variables such as the numbers of children aged up to 14 years would not in themselves constitute "disadvantage", but they were included as a measure of the need for services. In general, area deprivation index scores measure the proportion of households within a defined small geographical unit with a combination of circumstances indicating low living standards or a high need for services, or both.

Several deprivation indices have been developed

since the original 1971 Department of Environment measure. The underprivileged area index developed by Jarman was intended as an indicator of the demand for primary medical care. Accordingly, it included items thought to indicate the likelihood of high demand such as the proportion of elderly people living alone and the number of children under 5. Two other well known measures developed by Carstairs and colleagues and by Townsend and colleagues were guided by an interest in the effects of living standards on health. They contain items that might be regarded as good indicators of the amount and stability of household income: housing tenure, car ownership, unemployment, and social class.

Deprivation indices therefore need to be understood and evaluated in terms of (a) the purpose for which they are being used and (b) the validity of the assumptions about social and economic life that they embody. This is true of the decisions to include or exclude different items. It is also true of the different types of statistical procedures used to combine items together into a summary score. Items are often converted into a standardised Z score, which expresses each one in terms of its mean value in the population and its standard error. If this were not done then items with longer scales would have more weight than those with shorter scales in the overall score. For example, the number of children in a household could vary from, say, 0 to 10, while the number of cars available would lie between 0 and 3. Simply adding these together would give children more weight than cars. Standardisation is intended to avoid this problem, though this is easier for some items than for others. On the other hand, some components may deliberately be weighted more heavily if they are thought to be more important—for example, in the Jarman index "pensioners living alone" is weighted highest, whereas in the Department of the Environment's 1981 index unemployment has double the weight of other variables.

Information on the relation between mortality and deprivation in individual people can be obtained by linking death certificates to census information. This is what the longitudinal study of the Office of Population Censuses and Surveys makes possible—though only for 1% of the population. As a growing number of people find themselves without a single stable occupation, social class is becoming less satisfactory as a measure of living standards and lifestyle. The use of additional measures of disadvantage, both in the form of linked individual data and in the form of small area statistics, will therefore become increasingly valuable in estimating social variations in health.

1 Holtermann S. Areas of urban deprivation in Great Britain: an analysis of 1971 Census data. *Social Trends* 1975;6:33-47.

Relation between rates of leg amputation and distal arterial reconstructive surgery

J A Michaels, P Rutter, J Collin, F M Legg,
R B Galland for the Oxford Regional Vascular
Audit Group

A recent audit of vascular surgical practice in the Oxford region showed distinct variation between districts in the rate and level of leg amputations for occlusive arterial disease.¹ There were also considerable differences between districts in the volume and nature of reconstructive arterial surgery. Arterial

bypass grafting of the calf or foot, operations largely reserved for limb salvage, were undertaken in only two hospitals in the region.

We carried out a six month prospective audit to study in greater detail the relation between distal reconstructive arterial surgery and leg amputation.

Subjects, methods, and results

The Oxford region has a total population of 2.5 million, with eight districts serving populations of 150 000 to 550 000. On the basis of the previous audit we divided districts into three high volume and five low volume districts, depending on whether they were carrying out above or below the average rate of arterial reconstructions for the region.¹

Vascular surgeons in each district were invited to participate in a prospective audit of all leg amputations

Nuffield Department of
Surgery, Oxford
University, John Radcliffe
Hospital, Oxford
J A Michaels, clinical lecturer
P Rutter, consultant surgeon
J Collin, reader in surgery
F M Legg, clinical audit
assistant
R B Galland, consultant
surgeon

Correspondence to:
Mr J A Michaels, Northern
General Hospital NHS
Trust, Sheffield S5 7AU.

BMJ 1994;309:1479-80

Details of reconstructive surgery and amputations carried out in districts with below (low volume) and above (high volume) the average rate of arterial reconstructions in the Oxford region. Values are numbers or proportions (percentages)

	High volume	Low volume	Statistics		
			χ^2	df	P value
Referrals from outside the district	10/67 (15)	2/46 (4.3)	2.197	1	0.138
Balloon angioplasty before reconstructive surgery	23/67 (34)	3/41 (7.3)	8.729	1	0.0031
Types of infrainguinal graft:					
Femorotibial graft	17 (25)	4 (11)	23.943	2	0.0001
Femoropopliteal:					
Vein	31 (46)	4 (11)			
Prosthesis	19 (28)	27 (77)			
Amputation rate per 100 000 population per year (95% confidence interval)	6.1 (4.0 to 8.2)	10.3 (7.4 to 13.2)	5.365	1	0.021
Ratio of below knee to above knee amputations	2.6:1	1.1:1	2.37	1	0.124
Angiography before amputation	36/44 (82)	19/36 (53)	3.565	1	0.059
Surgical reconstruction before amputation	27/44 (61)	6/36 (17)	14.53	1	0.0001

and vascular reconstructions distal to the inguinal ligament over six months. Amputations for trauma or malignancy were excluded. A single datasheet was completed giving details of each procedure carried out, the indication, the patient's district of residence, where the operation was performed, and details of previous investigations or treatment.

At the end of six months all theatre records in participating districts were checked by one of the participants or an audit assistant. Additional forms were completed from the notes of those patients who had been omitted.

Completed forms for all patients identified by a subsequent check of theatre records were received from five districts, covering a total population of 1.9 million, two of these districts being high volume and three low volume, as defined above. Differences between centres in high and low volume districts were analysed by using a χ^2 test with correction for continuity.

Overall, data were collected for 137 reconstructions and 93 amputations, 79 of which were the first major amputation of that leg. These represent rates of 11.7, 9.6, and 8.2 procedures per 100 000 of the population respectively.

In the high volume districts more patients had been referred from outside the district, more reconstructive procedures were preceded by balloon angioplasty, and more reconstructive procedures entailed arterial bypass grafting to the calf or foot and use of autologous vein. These districts had a lower rate of amputation, a higher proportion of below knee amputations, and a higher proportion of patients who had undergone previous angiography or surgical treatment (table).

Comment

Access to vascular surgery is variable and depends on district of residence.¹ Our findings show that districts with high rates of distal arterial reconstructions do fewer amputations and that amputations are carried out more distally and are more likely to be preceded by investigations or surgical attempts to save the leg.

We conclude that an expansion in specialist vascular surgical services in the Oxford region and more widespread use of distal arterial reconstructive surgery would result in substantial reductions in the number of leg amputations with consequent savings in both disability and cost.² These findings are supported by studies elsewhere³ and shed further light on the debate about the provision of specialist vascular surgical services.⁴

This work was presented orally at the annual scientific meeting of the Association of Surgeons of Great Britain and Northern Ireland in Harrogate in April 1994.

We thank all the surgeons in the Oxford region who participated in this study.

1 Michaels JA, Browse DJ, McWhinnie DL, Galland RB, Morris PJ. The provision of vascular surgical services in the Oxford region. *Br J Surg* 1994;81:377-81.

2 Cheshire NJ, Wolfe JH, Noone MA, Davies L, Drummond M. The economics of femorocrural reconstruction for critical leg ischemia with and without autologous vein. *J Vasc Med Biol* 1992;15:167-74.

3 Lindholt JS, Bevilacqua S, Fasting H, Henneberg EW. Vascular surgery reduces the frequency of lower limb major amputations. *Eur J Vasc Med Biol* 1994;8:31-5.

4 Michaels JA, Galland RB, Morris PJ. Organisation of vascular surgical services: evolution or revolution? [Commentary by R Greenhalgh.] *BMJ* 1994;309:387-8.

(Accepted 23 August 1994)

Confounding and Simpson's paradox

Steven A Julious, Mark A Mullee

Medical Statistics and Computing, University of Southampton, Southampton General Hospital, Southampton SO16 6YD

Steven A Julious, statistician
Mark A Mullee, senior statistical programmer

Correspondence to:
Mr Julious.

BMJ 1994;309:1480-1

A common problem when analysing clinical data is that of confounding. This occurs when the association between an exposure and an outcome is investigated but the exposure and outcome are strongly associated with a third variable. An extreme example of this is Simpson's paradox, in which this third factor reverses the effect first observed.¹ This phenomenon has long been recognised as a theoretical possibility but few real examples have been presented.

Examples

Charig *et al* undertook a historical comparison of success rates in removing kidney stones.² Open surgery (1972-80) had a success rate of 78% (273/350) while percutaneous nephrolithotomy (1980-5) had a success rate of 83% (289/350), an improvement over the use of open surgery. However, the success rates looked rather different when stone diameter was taken into account. This showed that, for stones of <2 cm, 93% (81/87) of cases of open surgery were successful compared with just 83% (234/270) of cases of percutaneous nephro-

lithotomy. Likewise, for stones of ≥ 2 cm, success rates of 73% (192/263) and 69% (55/80) were observed for open surgery and percutaneous nephrolithotomy respectively.

The main reason why the success rate reversed is because the probability of having open surgery or percutaneous nephrolithotomy varied according to the diameter of the stones. In observational (non-randomised) studies comparing treatments it is likely that the initial choice of treatment would have been influenced by patients' characteristics such as age or severity of condition; so any difference between treatments could be accounted for by these original factors. Such a situation may arise when a new treatment is being phased in over time. Randomised trials are therefore necessary to demonstrate any treatment effect.

In another example Hand reported that the proportion of male patients in a psychiatric hospital seemed to fall slightly over time, from 46.4% (343/739) in 1970 to 46.2% (238/515) in 1975.³ When the results were broken down according to patients' age, however, it was observed that the proportion of male patients had increased; from 59.4% (255/429) to 60.5% (156/258) among those aged <65 and from 28.4% (88/310) to 31.9% (82/257) among those aged ≥ 65 .

The table shows another example, a study of mortality and diabetes (data from the Poole diabetic cohort⁴). In the study only 29% of the patients with