PAPERS

Measures of early postoperative mortality: beyond hospital fatality rates

Valerie Seagroatt, Michael Goldacre

Abstract

Objective—**To quantify the short term risk of postoperative mortality in ways which take account of deaths after discharge and the background risks of death in patients who come to operation.**

Design—**Analysis of linked abstracts of hospital admission records and death certificates for common operations.**

Setting—**Six health districts in the Oxford region.**

Subjects—**Records of 223 529 operations performed in 1980-6.**

Main outcome measures—**In hospital fatality rates, case fatality rates, and standardised mortality ratios at selected time periods during the year after operation and the ratio of early (< 30 days) to late (90-364 days after operation) fatality rates.**

Results—**Fatality rates throughout the year after operations performed after emergency admissions were generally higher than those for similar operations performed after elective admissions and higher than expected from population rates. Examples were prostatectomy, hip arthroplasty, inguinal herniorrhaphy, and cholecystectomy. Common elective operations such as inguinal herniorrhaphy and cataract operations showed no early peak in mortality, but others did. These included transurethral prostatectomy (ratio of early to late mortality 2·0; 95% confidence interval 1·3 to 2·6), hysterectomy (3·2; 1·5 to 6·6), hip arthroplasty (3·8; 2·5 to 5·4), and cholecystectomy (6·9; 4·3 to 11·1).**

Conclusions—**Temporal profiles of death rates in the year after operation show which operations have early peaks in mortality and which do not. Emergency and elective operations have very different profiles and should be analysed separately. For elective operations for conditions which pose no immediate threat to life the ratio of early to later fatality rates provides a measure of increase in mortality after operation while allowing for the background risk of death in the patient groups.**

Introduction

The use of routine statistics to analyse death rates as outcomes of hospital care has been advocated for at least 150 years.[1-3] The most readily available measure of postoperative mortality is the in hospital fatality rate. This is influenced by length of stay in hospital and can be hard to interpret.[4-6] Postoperative mortality is sometimes defined as deaths which occur within 30 days of operation.[7] These case fatality rates are often difficult to obtain because routine methods do not generally identify deaths which occur after transfer or discharge from the hospital of initial treatment. The rates are not dependent on length of stay but their interpretation is limited, as some deaths which occur shortly after operation may be unrelated to the operation or indications for it. This is a particular problem in interpreting case fatality rates after operations in elderly people. Fatality rates after particular operations are sometimes compared with fatality rates in the general population by calculating standardised mortality ratios. These may complement case fatality rates but they too have their limitations. This is because patients who undergo surgery may not be typical of the general population (of the same age) in their background risk of dying—that is, the risk of death which is independent of the operation or indications for it.

We wished to quantify the short term risk of postoperative mortality in ways which take account of deaths after discharge and allow for the background risk of death. Most deaths related to operations are likely to be concentrated in a definable period shortly after operation. We therefore examined the time course of fatality rates in consecutive periods in the first year after common operations to aid in interpretation of fatality rates and standardised mortality ratios. For elective operations for conditions which are not life threatening at the time of operation we reasoned that fatality rates, if raised postoperatively, would decline to the background rate characteristic of the patient groups who had each operation. Thus a comparison of the early fatality rate with the fatality rate in the later part of the year would identify any early excess deaths associated with the operation. We illustrate our methods with examples in this paper.

Unit of Health Care Epidemiology, Department of Public Health and Primary Care, University of Oxford, Oxford OX3 7LF
Valerie Seagroatt, *statistician*
Michael Goldacre, *director*

Correspondence to: Ms Seagroatt.

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Materials and methods

The Oxford record linkage study[8] includes anonymised abstracts of records of inpatient and day case admissions to National Health Service hospitals and deaths in six health districts (population 2 million). Death certificates were available for all deaths of residents regardless of where death occurred, but not for patients who migrate permanently out of the study area (an estimated 2% of the population yearly). We analysed data on patients who were resident in these districts and had operations in 1980-6 with linkage to death certificates up to December 1987.

Standard operation codes were used.[9] For individual operations we selected the first recorded admission with the operation recorded in the main position and excluded admissions of patients with a diagnosis of cancer on the admission record. By searching the computer files for 1979 we excluded patients who had had the same operation in the preceding 12 months. Admissions were grouped into elective (waiting list, booked admission, or booked readmission) and emergency.

MEASURES OF POSTOPERATIVE MORTALITY

Case fatality rates were calculated as the number of deaths (from any cause) within specified time periods per 1000 people who had each operation. Standardised mortality ratios were calculated by using the total resident population of the study area as the standard. The expected number of deaths after each operation was calculated by applying the sex and age specific death rates (in 10 year age groups) in the standard population to the population of patients at risk at the beginning of each period.[10] Standardised mortality ratios were calculated for deaths in each of 12 consecutive periods in the first postoperative year (eleven 30 day periods and a final 35 day period) and for broader periods.

For some operations fatality rates were fairly stable during the later part of the first postoperative year (defined by us after scrutinising the data as 90-364 days after operation). We took the fatality rate in this period as an estimate of background mortality in the patient population who had the operation. We calculated the ratio of early (within 30 days) to later (90-364 days) standardised mortality ratios as a measure of postoperative mortality and termed this measure the relative mortality ratio.[11,12] (The ratio of standardised mortality ratios incorporates changes in mortality expected from changes in the age distribution between the two periods.) The validity of the ratio of standardised mortality ratios as a measure of short term postoperative mortality assumes that the postoperative and background mortality are multiplicative effects. This is considered in the appendix.

Confidence intervals for standardised mortality ratios and relative mortality ratios were calculated as described.[13]

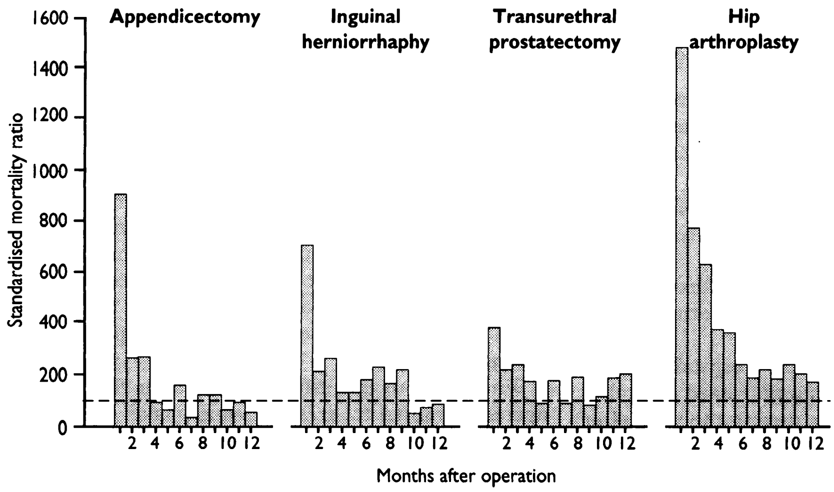

FIG 1—*Standardised mortality ratios in successive months in first year after emergency operations*

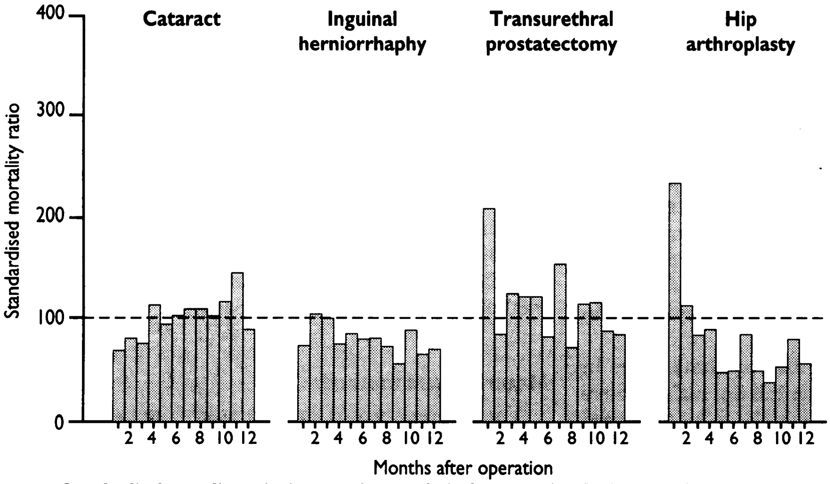

FIG 2—*Standardised mortality ratios in successive months in first year after elective operations*

Results

There were no deaths in hospital or within the first 30 days after operations on squint, varicose veins, or tonsils and adenoids, or after laminectomy, myringotomy, submucous resection of the nasal septum, vasectomy, female sterilisation, meniscectomy, or termination of pregnancy (a total of 90 571 operations). In hospital fatality rates, case fatality rates, and standardised mortality ratios after other operations are given in table I. In hospital fatality rates were similar to case fatality rates for deaths within 30 days after emergency admissions. By contrast, in hospital fatality rates after elective admissions were, on average, about half those occurring within 30 days. Operations after emergency admission and those in older patients had higher fatality rates than others.

emergency admissions—Temporal profiles of standardised mortality ratios after appendicectomy, inguinal herniorrhaphy, transurethral prostatectomy, and hip arthroplasty are shown in figure 1. These profiles showed early peaks and then declines in death rates. Apart from appendicectomy, the standardised mortality ratios after the initial peak were, on average, higher than 100 for the remainder of the year.

Elective admissions—Examples of temporal profiles of standardised mortality ratios after elective operations are shown in figure 2. Cataract operations and inguinal herniorrhaphy showed no early peaks in mortality but transurethral prostatectomy and hip arthroplasty did. After 90 days the standardised mortality ratios became fairly stable and, in contrast with those after emergency admissions, averaged values close to, or less than, 100. The relative mortality ratios for elective dental operations and haemorrhoidectomy

TABLE I—*In-hospital fatality rates, case fatality rates, and standardised mortality ratios for deaths within 30 days and one year of operation (listed in ascending order of standardised mortality ratios at 0-29 days)*

Operation (code)†	No of patients	Fatality rate/1000 operations (No of deaths)			Standardised mortality ratio (95% confidence interval)	
		Hospital	0-29 days	0-364 days	0-29 days	0-364 days
Emergency admissions:						
Prostatectomy (633)	1 870	14·4 (27)	19·8 (37)	105·9 (198)	384 (270 to 529)	183 (158 to 210)
Inguinal hernia (411)	1 668	16·8 (28)	21·0 (35)	67·1 (112)	711 (495 to 988)	209 (172 to 252)
Appendicectomy (441-4)	16 046	1·7 (28)	2·0 (32)	4·7 (76)	906 (619 to 1278)	188 (148 to 235)
Cholecystectomy (522)	1 425	30·9 (44)	33·0 (47)	74·4 (106)	1430 (1051 to 1901)	291 (238 to 352)
Hip arthroplasty (810-1)	3 486	91·2 (318)	92·1 (321)	274·0 (955)	1480 (1323 to 1651)	461 (432 to 491)
Elective admissions:						
Cataract (170-9)	9 590	0·5 (5)	3·0 (29)	51·6 (496)	69 (46 to 99)	100 (92 to 110)
Inguinal hernia (411)	15 731	0·5 (8)	1·1 (18)	14·5 (228)	76 (45 to 119)	81 (70 to 92)
Dilatation and curettage (703-4)	24 544	0	0·2 (6)	3·6 (89)	83 (31 to 181)	103 (83 to 127)
Hysterectomy (690-6)	16 341	0·4 (7)	0·7 (11)	2·8 (46)	183 (92 to 328)	64 (47 to 85)
Haemorrhoids (490-5)	3 020	0·7 (2)	1·7 (5)	8·3 (25)	184 (60 to 429)	77 (50 to 114)
Thyroidectomy (71-2)	2 038	0·5 (1)	1·0 (2)	6·4 (13)	202 (24 to 731)	110 (58 to 187)
Prostatectomy (633)	5 157	5·0 (26)	8·1 (42)	52·7 (272)	210 (152 to 284)	116 (103 to 131)
Hip arthroplasty (810-1)	6 287	4·9 (31)	6·2 (39)	26·1 (164)	235 (167 to 321)	83 (71 to 97)
Dental operations (251-2)	18 174	0·1 (1)	0·3 (6)	2·9 (53)	273 (100 to 594)	203 (152 to 265)
Cholecystectomy (522)	7 581	3·6 (27)	4·5 (34)	12·0 (91)	467 (324 to 653)	105 (85 to 129)

†Operation codes as used by Office of Population Censuses and Surveys.[9]

TABLE II—*Standardised mortality ratios and 95% confidence intervals for periods specified in days after elective operation, and the relative mortality ratios and 95% confidence intervals*

Operation	Days from operation	Standardised mortality ratio (No of deaths)	95% Confidence interval	Relative mortality ratio (95% confidence interval)
Cataract	0-29	69 (29)	47 to 99	0·6 (0·4 to 0·9)
	30-89	79 (66)	61 to 100	
	90-364	110 (401)	98 to 121	
Dilatation and curettage	0-29	83 (6)	31 to 181	0·8 (0·3 to 1·8)
	30-89	90 (13)	48 to 155	
	90-364	108 (70)	84 to 136	
Inguinal hernia	0-29	76 (18)	45 to 119	1·0 (0·5 to 1·5)
	30-89	104 (49)	77 to 137	
	90-364	76 (161)	65 to 89	
Dental operations	0-29	273 (6)	100 to 594	1·3 (0·5 to 3·2)
	30-89	160 (7)	64 to 330	
	90-364	205 (40)	146 to 279	
Thyroidectomy	0-29	202 (2)	24 to 731	1·8 (0·2 to 8·4)
	30-89	51 (1)	1 to 282	
	90-364	112 (10)	54 to 207	
Haemorrhoids	0-29	184 (5)	60 to 429	2·6 (0·8 to 7·4)
	30-89	55 (3)	11 to 162	
	90-364	70 (17)	41 to 112	
Transurethral prostatectomy	0-29	210 (42)	152 to 284	2·0 (1·3 to 2·6)
	30-89	107 (42)	77 to 144	
	90-364	108 (188)	93 to 124	
Hysterectomy	0-29	183 (11)	92 to 328	3·2 (2·5 to 5·4)
	30-89	33 (4)	9 to 86	
	90-364	57 (31)	39 to 81	
Hip arthroplasty	0·29	235 (39)	167 to 321	3·8 (1·5 to 6·6)
	30-89	100 (33)	69 to 141	
	90-364	62 (92)	50 to 76	
Cholecystectomy	0-29	467 (34)	324 to 653	6·9 (4·3 to 11·1)
	30-89	90 (13)	48 to 154	
	90-364	68 (44)	49 to 91	

were higher than one but not significantly so (table II). Relative mortality ratios for prostatectomy, hysterectomy, hip arthroplasty, and cholecystectomy were all significantly higher than one ($\chi^2=15$, 11, 54, and 93 respectively; df=1; $P<0·01$).

Discussion

The health and underlying risk of death of surgical patients are likely to differ from those of the general population and between operations. We found, like others,[7] that fatality rates were higher after emergency admissions than after similar operations undertaken electively. Fatality rates in the first year after emergency operations were also higher than in the general population. These higher rates no doubt reflected, at least in part, the clinical condition of the patients at the time of operation, though these patients may also have been at higher risk of death more generally than this.

By contrast, patients who are selected for elective surgery to restore function may be healthier than average. For example, the standardised mortality ratio in the 90-364 days after elective hip arthroplasty was 62. This suggests that though the operation was followed by some postoperative deaths, in general the patients may have been healthier than "average." Cataract operations were associated with a low standardised mortality ratio initially (69), but thereafter these ratios were closer to 100. This was consistent with a small short term selection effect, possibly attributable to postponing operation for elderly patients with acute illness such as respiratory infections. Standardised mortality ratios during the year after dental operations were almost twice those expected from rates in the general population. One possible explanation is that some patients may be selected for inpatient rather than outpatient dental treatment when they are deemed to be at risk of postoperative complications and that the raised standardised mortality ratio indicates the effect of selecting patients who are less healthy than average.

Some investigators have attempted to adjust postoperative death rates for selection effects by obtaining information on comorbidity from the medical records of individual patients. This adjustment is problematical: data are often unavailable or biased.[14] Other investigators have taken death rates in the general population as an approximation of background mortality. We suggest that in some circumstances the 90-364 day fatality rate in the specific patient group is a better approximation of background mortality and that any short term rise in mortality can be quantified as the ratio of early (say within 30 days) to later fatality rates.

This approximation assumes that the background risk of death for patients surviving 90 days is not much different from that for all patients at the time of their operation. This is unlikely to be true for emergency conditions but is likely to be valid for patients having elective operations for conditions which are generally not life threatening at the time. Among these cases not all deaths within 90 days would be in the more severely ill patients: some might occur because of rare but avoidable mishaps during or after surgery or the anaesthetic.[7] Though proportionately more of the deaths might occur among elderly patients, we adjusted for this in our calculations. Furthermore, comparatively few patients died in the first 90 days. Therefore, the numerical values of background fatality rates of all patients and the 90 day survivors would not be appreciably different. Modelling the postoperative and background mortality as multiplicative rather than additive effects was supported by finding that the ratios of age specific fatality rates varied less between age groups than did the differences (appendix).

The relative mortality ratio is not applicable to operations for which fatality rates do not stabilise over time. It could, however, be used to analyse deaths from specific causes, such as thromboembolic disease, which are likely to be attributable to the operation and would stabilise over time. It underestimates any short term rise in mortality when the operation or underlying disease process is associated with a delayed increase in longer term mortality. It will also be an underestimate —as would the case fatality rate and standardised mortality rate—when a short term selection effect produces a low short term background death rate.

Temporal profiles of fatality rates in the postoperative year showed different patterns between operations and between elective and emergency admissions. For instance, fatality rates after elective admissions for inguinal herniorrhaphy showed no early peak whereas those after emergency admissions did. The life threatening event may, of course, be the strangulated hernia rather than the operation or anaesthetic.

The use of temporal profiles and relative mortality ratios when appropriate allows operations to be grouped into those with little or no mortality associated with the operation or clinical condition necessitating the operation and those with significant short term increase in mortality. The former included cataract and elective inguinal herniorrhaphy and the latter prostatectomy, hysterectomy, hip arthroplasty, and cholecystectomy. Other workers have also found postoperative fatality rates much higher than expected from population rates after prostatectomy,[15] total hip replacement,[15] cholecystectomy,[15] and hysterectomy.[16] When short term clustering of deaths is found after operations its likely causes are the fatal potential of the disease necessitating operation (for example, strangulated hernia) or rare but possibly avoidable mishaps during or after surgery and anaesthesia. We cannot judge "avoidability" of the deaths in our study but suggest that our methods may usefully complement the methods of individual medical audit and confidential inquiry.

METHODS OF EVALUATION

Randomised controlled trials are now generally accepted as the best way to evaluate new or controversial treatments. There are, however, important circumstances when information on clinical outcomes is generally available only from observational data. These include monitoring outcomes of well established methods of treatment in routine clinical practice (a treatment may have been evaluated in clinical trials but its benefits may not be as high or risks as low in routine use); circumstances when surgical techniques become widely used before thorough evaluation; circumstances in which clinical benefit may have been assessed in controlled trials but in which trials are too small to estimate the occurrence of rare, adverse outcomes such as death; and comparisons of the risks and benefits of treatments in different time periods, geographical areas, or hospitals.

In these circumstances the usual approach is to use summary statistics such as hospital fatality rates or relative risks. However, summary statistics are influenced by length of follow up and the background risk of death in the patient groups. The strategy we recommend for analysing postoperative mortality for individual operations and for comparing different operations, time periods, or hospitals is, firstly, to separate the data from each operation into emergency and elective and then to plot and compare age adjusted fatality rates over time by using consecutive rather than cumulative time periods. Comparison of profiles after short term postoperative mortality has reduced—say, in 90-364 days after operation—may indicate differences between groups in their case mix. In circumstances when elective operations are undertaken to restore function and their fatality rates become fairly stable after some time, the relative mortality ratio can be used to quantify any short term rise in mortality after operation. Relative mortality ratios of different groups of patients can then be compared.

In hospital fatality rates, case fatality rates, and standardised mortality ratios for deaths within defined periods after operation (say, within 30 days) are used as measures of postoperative mortality, but all have limitations. The in hospital fatality rate is readily available but is dependent on length of hospital stay. The case fatality rate measures what happened to groups of patients. It shows, for example, that 5% of patients who had cataract operations were dead within a year. However, it does not take into account background mortality. The standardised mortality ratio shows how postoperative mortality differs from mortality in the general population but does not allow for selection of patients for surgery. Careful interpretation of results from observational data is always needed, but interpretation of fatality rates after surgery is helped by examining the temporal profile of mortality after operation rather than relying simply on summarising the rates in a single value.

Clinical implications

- The risk of death after surgery is a combination of the risk associated with the operation, the illness which necessitated the operation, and the background risk of death (independently of the operation) in patients who undergo surgery
- Summary statistics such as in hospital fatality and case fatality rates do not allow for background risk of death. This may be particularly important in assessing postoperative mortality in elderly patients
- There was significant clustering of postoperative deaths after several common elective operations, such as cholecystectomy, hysterectomy, and hip arthroplasty, but not after others such as inguinal herniorrhaphy and operations on cataract
- The study of temporal profiles of death rates after operation helps identify whether particular operations are followed by increased mortality

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Appendix

CHOICE OF ADDITIVE OR MULTIPLICATIVE MODEL

Death rates may vary widely within a patient group according to factors such as age and sex. What is needed is a measure of postoperative mortality that is as stable as possible over the various subdivisions of the patient group. One possibility is that the differences between postoperative mortality and background rates are fairly constant over the various patient subgroups (additive model[17]). Another is that the ratios of postoperative rates to the background rates are fairly constant between the subgroups (multiplicative model[17]). Few elective operations have sufficient numbers of deaths to distinguish between the models (other than in large studies), and those which do tend to be performed mostly on older patients. Data for cholecystectomy, transurethral prostatectomy, and hip arthroplasty were grouped by age, and the 90-364 day fatality rates were taken as approximations for background mortality (table AI). The χ^2 statistics for goodness of fit of both models were calculated.[17] We chose the ratio rather than the difference because the multiplicative model gave satisfactory fits to all three data sets, whereas the additive model gave a satisfactory fit only to the hip arthroplasty data.

TABLE AI—*Goodness of fit for additive and multiplicative models: early and later fatality rates after elective admissions according to age, differences between early and later age specific rates, and ratios of early to later age specific rates*

Operation	Age (years)	Risk period (days)	No of patients at risk	Rate/1000 operations per 30 day period (No of deaths)	Difference between rates	χ^2 for additive model (df=1)	Rate ratios	χ^2 for multiplicative model (df=1)
Cholecystectomy	<75	0-29	7150	2·80 (20)	2·4	18·8*	6·5	0·1
		90-364	7119	0·43 (28)				
	≥75	0-29	431	33·02 (14)	28·7		7·7	
		90-364	415	4·29 (16)				
Transurethral prostatectomy	<75	0-29	3766	4·52 (17)	1·6	7·0*	1·6	1·7
		90-364	3728	2·91 (98)				
	≥75	0-29	1391	18·14 (25)	10·6		2·4	
		90-364	1345	7·55 (90)				
Hip arthroplasty	<75	0-29	4692	5·34 (25)	4·1	0·5	4·5	0·9
		90-364	4657	1·20 (51)				
	≥75	0-29	1595	8·82 (14)	5·9		3·0	
		90-364	1558	2·91 (41)				

*$P<0·05$.

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Commentary: measures of early postoperative mortality

Martin McKee, Colin Sanderson

The traditional image of the paternalistic surgeon failing to offer patients an informed choice about treatment based on knowledge of the risks and benefits is disappearing rapidly. Driven by growing consumerism and political pressure, there is an increasing volume of information to help patients make choices that are appropriate for them. Examples range from patient information leaflets, through provision of specialist advisers, to interactive video disks.[1]

If patients are to be enabled to make truly informed choices the information that they receive must be accurate. Unfortunately, much of what is published about the risk of postoperative death may be misleading. Textbooks frequently quote case series published by those working in centres of excellence and relating to patients who may be quite atypical.[2] Furthermore, published papers may be subject to considerable bias, ranging from the decision to report a series to acceptance by a journal.[3]

There are two major problems facing those who wish to measure population based postoperative death rates in the United Kingdom. The first is the absence of data on what happens to patients after they leave hospital. The second is that those who undergo elective surgery may not be typical of the general population, even after allowing for age. For example, the requirement for many procedures for the patient to be fit for anaesthesia may exclude patients with comorbidity.

Assumptions and limitations

Various solutions to the first problem have been proposed, such as the use of 30 day postoperative death rates[4] or disease specific time windows.[5] However, these do not solve the second problem. Seagroatt and Goldacre have proposed an approach in which they examine the monthly profile of death over the year after surgery.[6]

Though this approach represents a clear improvement on in hospital fatality rates, it still suffers from some limitations. The results depend on two crucial assumptions. The first is that the level of excess surgical deaths—that is, those that would not have occurred in the absence of surgery—may be indicated by the rate for an initial period of 30 days. There are two problems with this. Firstly, the results may be highly sensitive to the length of the period chosen. This will be true if, for example, the rate of surgical deaths is highest early in the first week or two of the postoperative period and then tails off. Secondly, if the period chosen is not long enough the numbers of surgical deaths on which the calculation is based will be an underestimate. The aim would be to choose the shortest period that does not exclude material numbers of surgical deaths. In this case the period was set at 30 days on the basis of an inspection of the data but there is at least a suggestion that fatality rates after some interventions continue to decline in the 90-364 day reference period. This could be validated by inspecting death certificates and, if necessary, medical records.

The second assumption is that in the absence of surgery surgical patients would have experienced the death rate observed during the 90-364 day reference period. In practice, surgery could precipitate a death within 90 days that would otherwise have occurred later in the year. If so, the reference rate will underestimate the true background rate. This would be expected when deaths due to an intervention are fairly common, as with some emergency surgery.

Value of measures

What this method can do is show where there is no excess risk. If its assumptions are valid it provides an indicator of how risky some procedures are overall compared with others. What it does not do is answer the patient's question of "to what extent is the operation likely to alter my chances of surviving the next five years?" This is partly because the mortality ratio proposed does not take the form of an indicator of relative risk. And it is partly because it is unclear how far an overall figure is relevant to people of different ages and degrees of comorbity,[7] a common problem in attempts to inform decision making.[8]

Seagroatt and Goldacre's paper provides further evidence of the difficulty of attributing mortality to a particular intervention by using routine statistics. This type of analysis can be performed only where there is a well managed, high quality record linkage scheme and coverage of a large enough population to yield stable figures. Incomplete follow up of patients can give very misleading results.[9]

The demise of regions and the lack of any clear vision about the information function in the new regional offices raise imporant questions about the extent to which this kind of work will be possible in future. Indeed, the departure of key information staff from regions because of uncertainty about the future is already making access to regional data more difficult.

Finally, this approach compares death rates from different procedures, not from different hospitals. The

Health Service Research Unit, London School of Hygiene and Tropical Medicine, London WC1E 7HT
Martin McKee, *senior lecturer*
Colin Sanderson, *senior lecturer*