*For Debate . . .*

# Economics of coronary artery bypass grafting

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## Abstract

**To decide whether the number of operations for coronary artery bypass grafting should be increased, maintained at the present levels, or decreased we need to know how cost effective they are relative to other claimants on the resources of the National Health Service. For this purpose effectiveness is taken to be the effect on life expectancy adjusted for the quality of life. In an assessment of the cost per quality adjusted life year gained coronary artery bypass grafting rates well for cases of severe angina and extensive coronary artery disease. The cost, however, rises sharply for less severe cases. Bypass grafting seems to compare favourably with valve replacement for aortic stenosis and implantation of pacemakers for heart block; it is distinctly better than heart transplantation and the treatment of end stage renal failure but is probably less cost effective than hip replacement. If the number of operations for coronary artery bypass grafting were to increase it would be a fairly strong claimant only if restricted to the most severe cases.**

**The data on which these judgments are based are crude and in need of refinement. The methodology is powerful, far reaching, and open to comment.**


## Introduction

The report of a consensus development conference on coronary artery bypass surgery recommended a large increase in the number of such operations in the United Kingdom, to 300 for every million of the population, "if this represents provision for high benefit patients."[1] The report acknowledged, however, that such a development would require considerable funds and that "the problem of assessment of priorities remains. This in turn should take account of estimations of the relative cost effectiveness of other procedures competing for resources."

The report went on to say "We were impressed by one method of measurement combining quality and duration of life. Further development of this approach is recommended so that it can be of help not only in comparison between coronary artery bypass surgery and other priorities but also between the various subgroups of patients whom it is proposed should be treated by coronary artery bypass surgery. Such techniques would also help to identify health service estimates which are being continued despite low benefit."

This paper presents the economic analysis given to the panel at the consensus development conference in the hope that this will lead to a better understanding of the methodology and enable better data to be collected and deployed than the rather crude data used here.

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## The problem

The objective of economic appraisal is to ensure that as much benefit as possible is obtained from the resources devoted to health care. In principle the benefit is measured in terms of the effect on life expectancy adjusted for the quality of life. The resources for health care should include not only costs to the service but also costs borne by patients and their families. Given the amount of unemployment, which is expected to persist in the near future, increases in production that might be associated with employment gains have been disregarded. Procedures should be ranked so that activities that generate more gains to health for every £ of resources take priority over those that generate less; thus the general standard of health in the community would be correspondingly higher.

Coronary artery bypass grafting is one of many contenders for additional resources. Ideally, all such contenders should be compared each time a decision on allocation of resources is made to test which should be cut back and which should be expanded. The central issue before the conference was whether the number of operations for coronary artery bypass grafting should be increased, decreased, or maintained at its present level. To address this problem three factors need to be considered: firstly, which groups of patients stand to gain the most and the least from such operations; secondly, whether any of these groups of patients gain more for every £ of resources than patients awaiting other types of cardiac surgery—for example, transplantation, replacement of valves, insertion of pacemakers, and percutaneous transluminal coronary angioplasty; and, thirdly, whether other specialties have procedures that are more important than any of these—for example, kidney transplantation, renal dialysis, and hip replacement. In an ideal world a better standard of care for the elderly, mentally ill, and mentally handicapped, diagnostic methods such as computed tomography and nuclear magnetic resonance, and preventive measures should also be considered. I shall restrict attention here to the more costly therapeutic technologies.

## Measuring benefits

Generally, clinical trials compare rates of survival at various arbitrarily selected times after treatment has started. For our purposes we need to translate these comparative rates of survival into information on the change in life expectancy, which must then be adjusted for the effects on quality of life: some patients are willing to sacrifice a measure of life expectancy for a better quality of life. This feature is particularly important with respect to coronary artery bypass grafting as the procedure seems to offer a considerable improvement in the quality of life even for patients whose life expectancy has not changed or has even worsened.

To what extent will patients generally exchange duration of life for quality of life? The two principal (crude) components of quality of life in this context are physical mobility and freedom from pain (in other contexts the capacity to perform the activities of daily living and to engage in normal social interaction may be relevant).

Kind *et al* based their work on these two factors, and it is their work on the valuation of the state of health that is used here to establish profiles of quality of life for the various procedures under investigation.[2] Their classification of the state of disability is as follows: I, no disability; II, slight social disability; III, severe social disability or slight impairment of performance at work, or both, able to do all housework except heavy tasks; IV, choice of work or performance at work severely limited, housewives and old people able to do only light housework but able to go out shopping; V, unable to undertake any paid employment, unable to continue any education, old people confined to home except for escorted outings and short walks and unable to shop, housewives able to perform only a few single tasks; VI, confined to

chair or wheelchair or able to move only with support; VII, confined to bed; and VIII, unconscious. Their classification for distress is as follows: A, none; B, mild; C, moderate; and D, severe. They do not claim that these measures exhaust all the features that might be incorporated in a measurement of quality of life.

Table I shows the actual (median) valuations elicited by Kind *et al* for each state of health from 70 respondents. Some severe states were regarded as worse than death—that is, had negative valuations—and it was only for those states given a value of below 0·9 (below the line) that the respondents regarded the degree of disability and distress as warranting less than 90% of the score assigned to being fit and well. The 70 respondents included 10 doctors, all of whom appeared to have a much greater aversion to disability and distress than the population at large; they would therefore overvalue reductions in disability and distress compared with the rest of the population.

TABLE I—*Valuation matrix for 70 respondents.*[2] *(1=healthy, 0=dead)*

| Disability rating | Distress rating | | | |
|---|---|---|---|---|
| | A | B | C | D |
| I | 1·000 | 0·995 | 0·990 | 0·967 |
| II | 0·990 | 0·986 | 0·973 | 0·932 |
| III | 0·980 | 0·972 | 0·956 | 0·912 |
| IV | 0·964 | 0·956 | 0·942 | 0·870 |
| V | 0·946 | 0·935 | 0·900 | 0·700 |
| VI | 0·875 | 0·845 | 0·680 | 0 |
| VII | 0·677 | 0·564 | 0 | −1·486 |
| VIII | −1·028 | * | * | * |

*Not applicable.

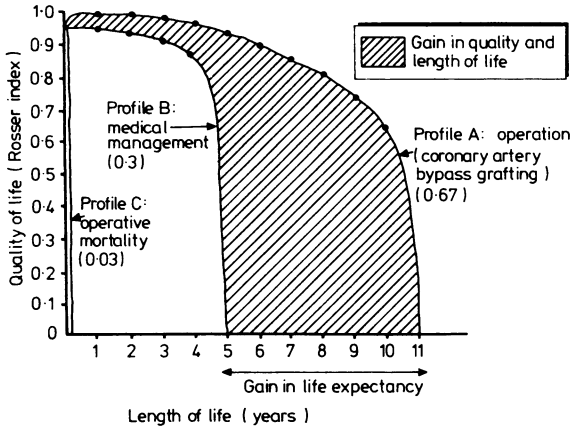


FIG 1—Expected value of quality and length of life gained for patients with severe angina and left main vessel disease.

Life expectancy and quality of life can then be joined into a single unit of benefit, the quality adjusted life year. Unfortunately, few clinical studies have attempted a systematic measurement of changes in quality of life in these terms. I therefore asked three well informed cardiologists to give me their judgments on the comparative profiles of health of various patients with angina who had or had not undergone coronary artery bypass grafting. The cardiologists were asked to distinguish cases of severe, moderate, and mild angina and within each of these three subgroups to distinguish cases with left main vessel, triple vessel, double vessel, and one vessel disease. Figures 1 and 2 show the expected quality of life profiles obtained from these data. In 67% of patients with disease of the left main vessel and severe angina there would be considerable gains from coronary artery bypass grafting. For 30% the operation would provide no better prognosis than medical management, and for an unfortunate 3% the operation would prove fatal (fig 1). Thus the expected value of coronary artery bypass grafting in this case would be 0·67 of the shaded area minus 0·03 of the unshaded area (representing the quality of life that would have been enjoyed had the operation not been undertaken).

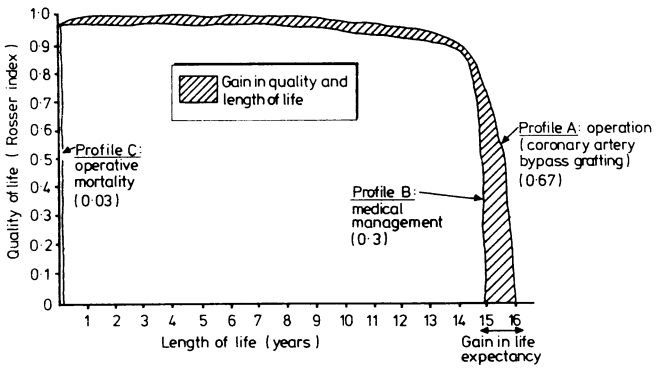


FIG 2—Expected value of quality and length of life gained for patients with severe angina and one vessel disease.

In patients with disease of one vessel and severe angina (fig 2) the probabilities would be the same but the outcomes different as coronary artery bypass grafting offers little potential benefit over medical management, and if the operation proves fatal the patients will have lost the adjusted life expectancy that medical management offers.[3]

The three cardiologists complained about the difficulty of establishing these profiles with any confidence, which seems to be a serious indictment of the nature of the evaluative work currently carried out, with measurements of the quality of life playing a minor part, so that they were having to rely heavily on their clinical experience. All three cardiologists offered prognoses for the cases of severe angina, but one was unable to offer any estimates for the cases of moderate and mild angina. The prognoses for replacement of valves for aortic stenosis were also based on only two respondents, and the prognoses for percutaneous coronary angioplasty and pacemakers were from only one respondent. Table II, based on these responses, gives a schedule of the effect on life expectancy adjusted for quality of life.

TABLE II—*Expected value of quality adjusted life years gained from operation compared with medical management**

| Coronary anatomy | Degree of angina | | |
|---|---|---|---|
| | Severe | Moderate | Mild |
| Left main vessel disease | 3·5 | 3 | 1·5 |
| Triple vessel disease | 3 | 1·5 | 1 |
| Double vessel disease | 2 | 1 | 1 |
| One vessel disease (coronary artery bypass grafting) | 0·5 | 0·5 | |
| One vessel disease (percutaneous transluminal coronary angioplasty) | 1 | 1 | 0·5 |

*Values are for a "standard" patient: a 55 year old man with good left ventricular function and no important concurrent conditions. For other classes of patient gains are probably less—for example, for women, older patients, and those with poor left ventricular function, or other important diseases. Gains have been discounted at 5% per annum to maintain comparability with data on cost.

## Measuring costs

The resources devoted to diagnosis and treatment include costs to the service and those falling on patients and their families. As there are few procedures for which much information about private costs is available these have been ignored here. The possibility that some of the rankings might be changed had private costs been included cannot be ruled out.

Several estimates of the service costs of coronary artery bypass grafting have been made in the United Kingdom and the United States of America. A detailed study conducted by the Department of Health and Social Security and the National Health Service in three NHS hospitals in 1980 suggested that the average recurrent cost of bypass surgery, including angiography, was about £3580 at 1983-4 prices, with an allowance of £725 for capital. Outpatient costs were not included. Three other British studies with apparently similar coverage of use of resources, but excluding capital, suggested that costs ranged from £2500 to £4500.[4-6] Most studies have assumed that the cost of coronary artery bypass grafting is roughly the same regardless of the number of bypasses performed. American studies have suggested higher costs for bypass grafting ($17 500).[7] Much of the difference is probably explained by the fact that doctors' remuneration and the costs of acute inpatient care are fairly high in the United States of America.

The alternative to bypass surgery is medical treatment. Some studies assume that this costs about the same with and without bypass surgery. Others suggest that medical treatment is considerably reduced after coronary artery bypass grafting[7 8]: the incidence of myocardial infarction may be reduced after grafting, resulting in further savings in medical costs.

The incidence of repeat operations after coronary artery bypass grafting and late operations after medical management may be similar. Weinstein and Stason suggested that, after working out the difference in the costs of medical care with and without operation, and the difference in the cost of treatment of myocardial infarction, the net cost of coronary artery bypass grafting is about 80% of the surgical cost in cases of severe angina and about 90% in cases of mild angina.[7] When these ratios are applied to the DHSS's estimates of surgical costs of bypass surgery the excess of surgical over medical costs in the United Kingdom is about £2860 for cases of severe angina and £3170 for cases of mild angina. This would suggest a cost of about £3015 for moderate angina. The implication of this British and American hybrid estimate is that the cost of medical management without operation lies between £150 and £70 annually, depending on the severity of angina. The cost of medical care after operation would be about £75 annually.

A report from the Mayo Clinic by Reeder *et al* indicates that, owing to the high rate of restenosis, percutaneous transluminal coronary angioplasty is only about 15% cheaper than coronary artery bypass grafting.[9] If this is so in the United Kingdom it would mean excess costs over medical management of between £2400 and £2680.

## Cost effectiveness

Table III shows, not surprisingly, that coronary artery bypass grafting offers better value for money in cases of severe angina and left main vessel disease or triple vessel disease and in cases of moderate angina and left main vessel disease than in any other circumstances.

TABLE III—*Coronary artery bypass grafting and percutaneous coronary angioplasty*

| Degree of angina | Coronary anatomy | Treatment | Present value of extra service costs (£000) | Discounted quality adjusted life years gained | Present value of extra cost per quality adjusted life year gained (£000) |
|---|---|---|---|---|---|
| | | *Severe angina* | | | |
| Severe | Left main vessel disease | Coronary artery bypass grafting | 2·85 | 2·75 | 1·04 |
| | Triple vessel disease | | | 2·25 | 1·27 |
| | Double vessel disease | | | 1·25 | 2·28 |
| | One vessel disease | | | 0·25 | 11·40 |
| | One vessel disease | Percutaneous transluminal coronary angioplasty | 2·4 | 1 | 2·40 |
| | | *Moderate angina* | | | |
| Moderate | Left main vessel disease | Coronary artery bypass grafting | 3·0 | 2·25 | 1·33 |
| | Triple vessel disease | | | 1·25 | 2·40 |
| | Double vessel disease | | | 0·75 | 4·00 |
| | One vessel disease | | | 0·25 | 12·00 |
| | One vessel disease | Percutaneous transluminal coronary angioplasty | 2·55 | 0·75 | 3·40 |
| | | *Mild angina* | | | |
| Mild | Left main vessel disease | Coronary artery bypass grafting | 3·15 | 1·25 | 2·52 |
| | Triple vessel disease | | | 0·5 | 6·30 |
| | Double vessel disease | | | 0·25 | 12·60 |
| | One vessel disease | | | | |
| | One vessel disease | Percutaneous transluminal coronary angioplasty | 2·68 | 0·25 | 10·72 |

To assess the relative value of coronary artery bypass grafting we need to make comparisons with other forms of expensive treatment such as replacement of valves, implantation of pacemakers, and heart transplantation. Thick *et al* estimated the cost of inserting a prosthetic valve (Bjork-Shiley) as being £2000,[10] which would be £4540 at 1983-4 prices. This includes the cost of the operation, the valve, and subsequent inpatient care (intensive and general care) but does not include the cost of long term anticoagulant treatment or repeat operations. An estimate of the costs of inserting cardiac pacemakers was made by Barber, which included the costs of implanting, reimplanting, and associated check ups based on the experience at two hospitals in the West Midlands.[11] These were revalued to accommodate 1983-4 prices. Initial implantation implies a commitment to future expenditure if the patient survives as replacement pacemakers are required every five years (less often if batteries powered by lithium are used). For heart transplantation Jennett quoted a figure of £15 000 (November 1982 prices) for initial costs[12]; additional costs for subsequent drugs, etc, need to be included, which I have taken to be slightly higher than those required for kidney transplantation, amounting to an annual figure of about £2000.

For the quality of life I obtained estimates for patients with replaced valves and pacemakers by the same method as for those who had undergone coronary artery bypass grafting, but for heart transplantation I used Hellinger's review of American (mainly from Stanford) experience, which indicated gains in life expectancy of between about two and six years.[13] As techniques have probably improved I took a figure of 5·5, which I assume to be good quality of life, which, with discounting, gave a score of 4·5. Table IV summarises these data and shows that insertion of pacemakers (for heart block) and replacement of valves (for aortic stenosis) are better value for money than coronary artery bypass grafting, though insertion of a pacemaker for the sick sinus syndrome and replacement of valves for mitral problems compare less favourably. Heart transplantation does not seem to be a serious contender. Table V shows the costs and relative gains in adjusted quality of life for the treatment of end stage renal failure and hip replacement. Interestingly, of all treatments examined so far, hip replacement comes near the top of the league whereas renal dialysis fares less well than heart transplantation.

TABLE IV—*Summary of costs and benefits of three cardiac procedures*

| Procedure | Present value of extra service costs (£000) | Discounted quality adjusted life years gained | Present value of extra service costs per quality adjusted life year gained (£000) |
|---|---|---|---|
| Valve replacement for aortic stenosis | 4·5 | 5 | 0·9 |
| Pacemaker implantation for atrioventricular heart block | 3·5 | 5 | 0·7 |
| Heart transplantation | 23 | 4·5 | 5 |

TABLE V—*Summary of costs[14] and benefits[15 16] of some selected non-cardiovascular treatments**

| Treatment | Present value of extra service costs (£000) | Discounted quality adjusted life year gained | Present value of extra service costs per quality adjusted life year gained (£000) |
|---|---|---|---|
| Kidney transplantations (cadaver) | 15 | 5 | 3 |
| Haemodialysis in hospital | 70 | 5 | 14 |
| Haemodialysis at home | 66 | 6 | 11 |
| Hip replacement† | 3 | 4 | 0·75 |

*All costs at 1983-4 prices, including an estimate of annual capital costs. Complications are included in costs of end stage renal failure. For hip replacement a 2% rate of failure and replacement each year is assumed.
†Estimate from DHSS Economic Advisor's Office, November 1984.

## Discussion

Before a well informed judgment can be made of whether it is in the public interest to increase, decrease, or keep constant the number of operations for coronary artery bypass grafting reliable comparisons must be made with other potential users of resources.

Such information is not readily available, and the assumptions that I have made are not entirely satisfactory. Clearly, further research is needed and should be focused much more on measurement of the quality of life and on costs (both public and private). Far too much attention has been paid to the rate of survival, which, in the case of coronary artery bypass grafting and many other therapeutic procedures in which the main benefit is improved quality of life, is potentially misleading.

Resources need to be redeployed at the margin to procedures for which the benefits to patients are high in relation to the costs, such as the insertion of pacemakers for heart block, hip replacement, replacement of valves for aortic stenosis, and coronary artery bypass grafting for severe angina with left main disease and triple vessel disease and moderate angina with left main disease. These treatments should take priority over additional facilities for patients needing kidney transplants and coronary artery bypass grafting for mild angina with left main disease, moderate angina with triple vessel disease or one vessel disease, and severe angina with one vessel disease, for which the costs per quality adjusted life year gained are higher.

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# *From the CDSC*

# Reye's syndrome surveillance scheme: third annual summary report

The third year of the Reye's Syndrome Surveillance Scheme ended in July 1984 and the findings are summarised below. During the first[1] and second years of the surveillance scheme, which covered the period 1 August 1981 to 31 July 1983, 30 and 52 case reports respectively were received.

In the surveillance year 1983-4 (1 August-31 July) 90 reports of patients meeting the case definition were received, though the diagnosis was subsequently revised in eight of them. Sixty (67%) of the cases were first reported by paediatricians. The sources of the other 30 were: pathologists (five), death certificates (12), the National Reye's Syndrome Foundation for the United Kingdom (eight), laboratory reports (three), and one each from a parent directly and a general practitioner. Questionnaires or case summaries were obtained for 79 of the 82 cases. In the analysis below the eight patients with revised diagnoses have been excluded.

The distribution of the 80 cases for whom this information was provided was widespread throughout the British Isles, although, as in previous years, the number reported from Northern Ireland was disproportionately large. The incidence in children under 16 years old in the British Isles overall was 0·7 per 100 000, whereas that in the province of Northern Ireland was 4 per 100 000.

As in the previous two years' surveillance there was no clear seasonal trend. The highest number reported in any one month was 10.

**Case definition*—"Acute non-inflammatory encephalopathy of uncertain cause with microvesicular fatty infiltration of the liver confirmed by biopsy (histology or ultrastructure, or both) or necropsy (macroscopically large pale and fatty liver and histological or ultrastructural confirmation); or suggested by a serum aspartate transaminase or alanine transaminase concentration or blood ammonia concentration greater than three times the upper limit of normal for the laboratory."

For the analysis, a case was considered "definite" Reye's syndrome if there was histological confirmation of the clinical diagnosis; it was "possible" if there was encephalopathy with raised transaminase concentrations with either (*a*) no histological examination, or (*b*) some unusual clinical, biochemical, or histological feature but no more reasonable explanation for the encephalopathy.

The ages of the patients ranged from 8 days to 13 years with a median of 15 months, compared with 14 months in previous years (fig 1). Forty five (55%) of the 81 patients for whom the information was reported were boys compared with a more nearly equal sex distribution in previous years. Twenty three (60%) of the 38 cases below the age of 1 year were boys.

Of the 74 patients whose ethnic group was reported, 69 (93%) were white Caucasians, two were Asians from the Indian subcontinent, two were of mixed race, and one was Caribbean.

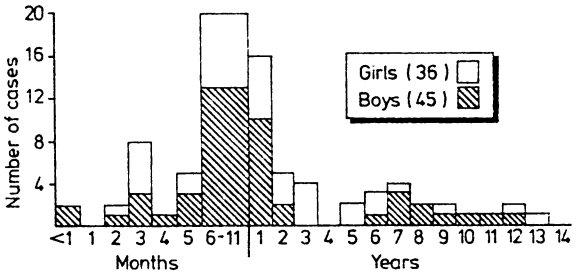


FIG 1—Age and sex of 81 patients with Reye's syndrome.

## Outcome

Information on outcome was available for 79 patients. Thirty five (43%) survived without any apparent sequelae; 34 (41%) died, and 10 (12%) survived with neurological damage. The proportion of normal survivors has shown a steady increase over the three years of surveillance from 20% in 1981-2 to 43% in 1983-4 (fig 2).

All 37 cases (45%) examined histologically were reported to show