It is becoming widely accepted that research which considers only the outcome and not the costs associated with new technologies in health care, is of limited value in making decisions about the use of scarce resources. Economic evaluation is becoming a standard feature of clinical research but many published economic evaluations fall short of best practice in their methodology. We have described the essential features of economic evaluation, using published studies in orthopaedics, in order to try to improve the ability of orthopaedic surgeons to read, understand and appraise such studies critically, and to encourage them to consider including economic evaluation in future investigations.

What is economic evaluation?

Economic evaluation is concerned with efficiency. Its purpose is to help to select those interventions which maximise the benefit to health from given resources. It compares the costs and outcomes of each available option. If the aim is to find whether a new treatment for back pain is preferable to one which is currently in common practice, the ‘comparator’, four situations may arise when comparing the costs and effects of these treatments. These are represented graphically by the quadrants of the cost-effectiveness plane as shown in Figure 1. In this diagram the horizontal axis represents the difference in effect between the new procedure and the relevant comparator and the vertical axis the difference in costs. In quadrant II of the plane the new treatment ‘dominates’ the comparator since it is less costly and more effective. The opposite happens in quadrant IV in which the comparator dominates. The dominant therapy should always be preferred.

The decision is not as straightforward in quadrant I, however, in which the new treatment is more effective and more costly, or in quadrant III, in which it is less effective and less costly. There is then a trade-off between costs and effects, and a decision on which treatment to use will depend on how much we are prepared to pay for a gain in effectiveness. This means placing a ceiling on the acceptable cost per unit of effect, as shown graphically in Figure 1 by the dotted line which passes through the origin.

Outcome measures

Depending on the outcome measure used, economic evaluation can be classified into three main groups, namely analysis of cost-effectiveness, cost-utility and cost-benefit. In analysis of cost-effectiveness a single outcome is meas-
ured in terms of physical or natural units, such as the number of complications avoided in surgical operations, the mobility score or the number of life years saved as a result of treatment. If the effectiveness of the treatments considered is equal, or almost equal, the objective is to find that which minimises costs. This is described as cost-minimisation analysis. Studies reporting costs and multiple outcomes separately, leaving the reader to decide what weight to attach to each, are sometimes referred to as cost-consequence analyses. It may be desirable to measure several dimensions of the outcome of an intervention such as the quality of life and survival. These composite measurements of health are referred to by health economists as utility states, since they reflect the valuation which an individual places on a particular state of health and the well-being derived from it. Utility may be measured on an index with a scale from 0 to 1 (or 100) in which 0 relates to the worst and 1 (100) to the best imaginable state of health. A year in a particular state of health can then be termed a Quality Adjusted Life Year (QALY). The instruments and methods available for evaluating health states are discussed elsewhere. Because quality of life is important and this type of analysis facilitates broad comparisons between health-care interventions, such cost-utility analyses are used increasingly in orthopaedics. Cost-benefit analysis attempts to report all costs and effects associated with an intervention in monetary terms, for example, by estimating a value of life. Various approaches can be used to convert health effects into monetary terms. Traditionally, in the human capital approach, average earnings were attached to working time gained as a result of an intervention and the total value was then measured as the present value of all future earnings. There are examples of cost-benefit studies in orthopaedics using the human capital approach, but it has severe disadvantages in that it places very low valuation on those not in paid employment. There are alternative methods, but all present difficulties; consequently, cost-benefit analyses are not commonly used at present.

It is important to choose the outcome and design of the study which will best assess the materials. In general, analysis of cost-effectiveness is more appropriate when the effect of the treatments considered can be captured by a single measure. If quality of life and survival are important outcomes, analysis of cost-utility is preferable. Utility measures (preferably QALY) should be always included in the analysis.

The perspective

A health intervention may affect patients and their families, the health-care sector, other fields and society as a whole. In theory, economic evaluation should consider all the effects and resource consequences of the treatments assessed. In practice, however, these often depend on the purpose of the evaluation, which may be undertaken from the perspective of particular agencies, the hospital sector or society in general. The results may affect these various agents quite differently and therefore the perspective adopted should be clearly defined. For example, a study comparing surgery with conservative treatment for the management of a herniated
lumbar intervertebral disc\textsuperscript{21} found no significant differences in cost or effect and thus neither treatment was preferable to the other. Table I shows that the total cost comprised that of the treatment together with the compensation related to absenteeism. Since the outcome was the same, the hospital would consider rehabilitation to be more cost-effective, whereas the insurance scheme, which pays the compensation, would prefer surgery.

To date, most economic evaluations have measured only costs occurring within the health sector, and often include only those of the hospital. Many interventions have much broader implications, however, and such narrow perspectives do not give the full picture. In determining policy, generally measurement of the overall effect on society is to be preferred, so that the observations can be arranged into multiple viewpoints depending on the use of the study.\textsuperscript{19}

**Costing**

Costing involves measuring the quantities of resources consumed to obtain a cost per patient. Collecting full details of all resources used in an intervention can be time-consuming, but information such as the length of stay, numbers of consultations or time in the operating theatre can be obtained from the clinical notes or from hospital information systems. Costings based on microdata are likely to be more accurate and reliable than the average costs or prices often quoted in national statistics or hospital reports.

Theoretically, the correct price for a resource is its opportunity cost, namely the value of the opportunities forgone by not using the resources in the best way, but in practice market prices are often used instead. Usually, these are easily obtainable, but there are difficulties in measuring the value of resources such as volunteer, family, or leisure time.\textsuperscript{31} It is also not easy to assess the costs of capital outlay in buildings and equipment, and the overhead costs of resources such as administration, which are not directly related to the treatment. Alternative ways of treating such costs have been discussed.\textsuperscript{10,12,31}

Most evaluations in orthopaedics have been confined only to costs strictly related to the hospital treatment provided. Very few studies have attempted to measure costs incurred outside the hospital. A treatment, however, may transfer costs from the hospital sector to the patients and their families, and to other organisations, and these effects should also be considered. Most published studies focus on the methods used to derive estimates of effectiveness, and fail to give detailed information as to the estimation of the overall costs of the treatments considered. Costing should be done cautiously, the data should be as precise as possible and the methods used to derive the estimates should be explained thoroughly.

**Analytical horizon and discounting**

The study should be long enough to capture all the major resource implications and health effects associated with the treatments assessed and the cut-off points should be clearly defined. To show how the time assessed matters, consider again a study on the management of a herniated lumbar intervertebral disc.\textsuperscript{21} The length of this study was five years, and the total costs per year are given in Table II. The initial costs of surgery were higher, but subsequent expense was substantially lower. Hence a study with a limited period of follow-up may reach a misleading conclusion. Unfortunately, it is not always easy to determine the appropriate cut-off point in advance, as witnessed by studies of similar conditions adopting different periods of follow-up.\textsuperscript{8,13,20}

**Table I.** Cost (US$1989) of surgery v conservative treatment for the management of a herniated lumbar intervertebral disc (adopted from Shvartzman et al\textsuperscript{17})

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of treatment</th>
<th>Compensation cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>26,643</td>
<td>29,411</td>
<td>56,054</td>
</tr>
<tr>
<td>Conservative</td>
<td>16,572</td>
<td>37,066</td>
<td>53,638</td>
</tr>
</tbody>
</table>
In orthopaedics interventions are often associated with costs and effects which occur in the long term, and hence assessment may extend far beyond the period for which primary information is available. In such cases mathematical models may be used to extrapolate from the intermediate to the final endpoints. Extrapolation beyond the period observed in a clinical study is not always straightforward and the assumptions used should be justified and thoroughly tested. Moreover, since comparisons are made in the present, measurements have to be adjusted for timing. This is because individuals have a positive rate of time preference. They prefer the desirable consequences of health improvements to occur earlier and the undesirable features, such as costs, later. Future effects and costs have therefore to be discounted to the present. At present the consensus among UK economists is that both costs and outcomes should be discounted at the rate recommended by the Treasury of 6% per annum. By contrast, in the USA the rate is 3%. Thus, for comparative purposes analyses using a range of rates should be performed.

Treatment comparator and incremental analysis

Economic evaluation is based on comparisons between different courses of action. The cost-effectiveness of a treatment should always be established relative to an appropriate comparator, which may be standard practice, the least costly or more effective alternative or simply doing nothing. There are many examples of orthopaedic studies using the above comparators.

Economic evaluations should always report incremental results, that is the additional costs which a treatment imposes relative to a comparator over the additional benefits it delivers. There are many examples in the literature of average cost-effectiveness ratios, but they can be misleading. Table III gives the costs and effects associated with treatments for hip replacement in the case of undisplaced subcapital fracture. The incremental analysis indicates that quality-adjusted life gains come at much higher cost than those indicated by the average analysis. This is because the option to do nothing still yields some QALYs and therefore attributing all the health outcome to the intervention overstates its effect.

Modelling

When the costs and effects of an intervention take many years to occur, modelling can be used to extrapolate the findings. It is also useful when diseases are characterised by multiple stages, when data and results need to be moved from one setting to another, or when research needs to compare two treatments which have previously been individually assessed against a common option, such as a placebo. Modelling can be used early in a study to investigate whether it is worth proceeding with the evaluation, to identify the key variables which should attract attention and to estimate the sample sizes needed to detect significant differences in cost-effectiveness. Some commentators therefore argue that the use of models will become unavoidable in economic evaluation. There are very few studies in orthopaedics in which modelling has been used. This is likely to change, but it should be kept in mind that models also have shortcomings. Those who develop and use them should pay particular attention to sources of information, underlying assumptions, and their overall validity.

Uncertainty

Economic evaluations are often based on data from various sources which may be imprecise, subject to variation, or involve guesses and assumptions. The samples used may also be very small, increasing the uncertainty concerning any results obtained. A simple way of testing the robustness of the results is a one-way sensitivity analysis in which each component is varied over a certain range to assess the impact on the results. More sophisticated investigation
includes changing two or more variables simultaneously. Uncertainty may be countered by employing statistical methods to calculate confidence intervals around costs, effects and the estimated incremental ratio of cost-effectiveness. This is illustrated in Figure 2 in which the horizontal and vertical ‘I’ bars show the 95% confidence intervals around the effect difference and cost difference, respectively. The line which connects the intersection of the two ‘I’ bars with the origin of the plane has a slope equal to the estimated cost-effectiveness ratio, and the spherical area gives an approximate idea of the variance around this. There are methods available which measure the confidence interval around the cost-effectiveness ratio more precisely. Orthopaedic studies have commonly used one-way sensitivity analysis but have failed to deal with uncertainty in a more rigorous manner, but this is a general problem with economic evaluations. A good example of how simple but useful sensitivity analysis can be is a study on neonatal screening for dislocation of the hip. As shown in Figure 3, the authors calculated the net benefit per 1000 infants screened for a range of false-negative rates used in different studies in order to demonstrate the conditions under which a screening programme would be cost-effective.
Conclusions

Economic evaluations of interventions in health care are becoming common and unavoidable. Orthopaedics has seen only a limited number so far, but this will change in the future. It is important that these studies should be standardised and comply with certain underlying principles which are reflected in a number of guidelines recently published on how to perform, report and referee economic valuations. The US Panel on Cost-Effectiveness has proposed a set of guidelines which are of assistance both to those wishing to appraise existing studies critically and those planning further investigations. An adapted summary of this checklist is given in Table IV.

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