Economic analyses in health care are growing in importance, and such studies are emerging in orthopaedic surgery. A valid economic cost-of-illness, cost-minimisation, cost-effectiveness, cost-utility, or cost-benefit analysis can be a powerful tool for making decisions on the allocation of resources in an environment which requires consideration of costs. Without an understanding of economic evaluation, orthopaedic surgeons may be left wondering exactly how this can be applied to clinical practice. We describe the different types of economic study and give a summary of the key components of an economic analysis including perspective, measurement of cost and outcomes, time horizon, cost discounting, sensitivity analysis, and computerised decision modelling, with an emphasis on the application of cost-utility analysis to orthopaedic surgery.

Economic evaluation: is it important to us?

Orthopaedic surgeons make decisions on the care of their patients and also on hospital and health-care policy. A knowledge of the economic analyses of surgical practices is necessary in order to advise in matters of policy. Recently, two formal reviews on the basic principles of the economics of health-care were published in the orthopaedic literature. Guidelines for the critical evaluation of health-economic studies are widely available. We have attempted to provide a foundation for understanding the different types of economic evaluation and to distinguish the strengths and weaknesses of such studies, with an emphasis on the application of cost-utility analysis to orthopaedic surgery.

What are the various types of economic evaluation?

Several categories of economic analysis are in current use, each differing in the way in which health benefits or outcomes are dealt with, and varying with the question being studied. It is important to distinguish the various types of economic analysis because each provides specific information which determines its applicability and usefulness in different types of decision-making.

Cost-of-illness analysis (COIA). This measures only the costs associated with a given disease. No consideration is given to the health consequences. The primary objective of a COIA is to calculate the cost of caring for persons with the illness compared with those who are well. For example, we carried out a one-year prospective study in elderly women with a first hip fracture and a matched control group. Overall, the costs associated with the treatment of patients with fracture of the hip were about three times greater than those resulting from the treatment of an age- and residence-matched control group without fracture. These excess costs during the one-year period after discharge from hospital represented almost 90% of the costs of the initial hospitalisation for the fracture. Two-fifths of these excess costs were spent during the first three months after discharge. A COIA may also report differential costs based on the severity of the disease or other factors, but would say nothing of the relative efficacy of the treatments being considered.

Cost-minimisation analysis (CMA). This compares the cost of procedures which yield the same clinical outcome, and identifies the cheapest. Such a study may evaluate two types of sliding hip screw with identical health outcomes in treating patients with fractures of the hip. One of the devices would be less expensive to purchase but may require more time in the operating theatre. A cost-minimisation study would determine all costs associated with each of the devices in order to determine which was the least expensive.

Even though COIA and CMA are common and important studies, they are not full economic evaluations. The latter assess the financial costs and the health outcome, and compare at least two competing procedures. There are three main types of full economic evaluation: cost-effectiveness, cost-utility, and cost-benefit analyses.
Cost-effectiveness analysis (CEA). This is the most commonly used full economic evaluation and one which we intuitively understand. It compares the outcome of decisions in terms of their monetary value per natural unit of health outcome, such as the cost per case of deep-venous thrombosis prevented, per life saved, or per year of life gained. It is the most appropriate method of analysis when the goal is to identify the most cost-effective strategy from among a set of options which produce a common health outcome. An example would be the comparison of a new prophylactic antibiotic with the standard antibiotic regime used in the prevention of post-surgical wound infection among patients undergoing total knee or hip replacement. If a treatment is more effective and less expensive, the choice is obvious, and the preferred method of treatment is called the dominant strategy. In general terms, if one surgical intervention is both more effective and less expensive, then this procedure is dominant. Conversely, if a treatment is less effective and more expensive, this procedure is dominated. Here, the decision is intuitively obvious, mainly because a physician’s main responsibility is to meet best the needs of each patient. An example was seen in the paper by Ramadier et al. in 1983 which showed that open meniscectomy was less effective, more expensive, and associated with a higher rate of complications compared with arthroscopic meniscectomy.

When dominance can be demonstrated, health-care decisions are fairly clear and the calculation of a cost-effectiveness ratio is unnecessary. Usually, however, the new treatment is both more effective and more costly. The choice is then a matter of judgement. If one treatment is more effective but more expensive, CEA helps to quantify the clinical and economic consequences of using it. Such therapies are compared on the basis of the cost-effectiveness ratio. A common error is simply to take the ratio of cost and effect of a particular surgical intervention and to compare it with that of a second intervention. Proper cost-effectiveness analysis, however, is always comparative. The average cost-effectiveness ratio is not a useful quantity since it is estimated by dividing the cost of the intervention by a measure of effectiveness without considering the alternatives. However, an incremental cost-effectiveness ratio is an estimate of the additional cost per additional unit of effectiveness of switching from one treatment to another, or the cost of using one treatment in preference to another. In estimating an incremental cost-effectiveness ratio, the numerator and denominator of the ratio both represent differences between the alternative treatments. When a comparison is made between two surgical interventions, we are interested in determining the extra health benefit which is gained from the extra unit cost. This is measured by the incremental cost-effectiveness ratio. The numerator of the incremental cost-effectiveness ratio is the difference of the mean cost of each intervention, and the denominator is the mean difference of the effectiveness. Thus, the incremental cost-effectiveness ratio is [Cost\text{Treatment A} - Cost\text{Treatment B}] / [Effect\text{Treatment A} - Effect\text{Treatment B}], and thus refers to the amount of money needed to produce an additional health benefit.

Cost-utility analysis (CUA). This is similar to CEA except that it incorporates a measure of quality of life, ‘utility’, into the outcomes of the procedures. Utility is a concept used to describe individuals’ preferences for a health status and not the quality of the health status as such. Including utility in economic evaluations allows for consideration of what is important to individuals, such as increased life expectancy or improved quality of life, or both. Certain treatments may not affect life expectancy, but may greatly improve the quality of the remaining life span. This may be particularly relevant in orthopaedics in which many diseases in their treatment do not affect life span, but may have a major influence on the quality of life. Health benefit is no longer measured as the number of deaths prevented or years of life gained, but rather as quality-adjusted life-years.
(QALYs). A QALY is computed as a year of life gained, multiplied by the utility score during that year, which is expressed on a scale of 0 to 1.15,20-23

The assessment of preferences is illustrated by the example of operations for fracture of the hip and the subsequent rehabilitation programme. Effectiveness may be measured by providing a longer life span, or improving the health-related quality of life, or both. The consideration of quality recognises that individuals have different preferences for certain states of health.2,32

In general, CUA is more complicated than CEA because it involves the actual measurement of individuals’ preferences, usually by surveys of patients or of healthy people being confronted with written descriptions of ill persons. The various techniques used to capture people’s preferences are complicated.21

**Cost-benefit analysis (CBA).** Both costs and health outcomes are expressed in monetary units.20-23 To compare treatment options CBA commonly uses two comparators, the net present value and the cost-benefit ratio. The net present value is simply the value of health benefits minus costs, and the cost-benefit ratio is the ratio between the two. CBA has the advantage of allowing direct comparisons across programmes, even outside health care, and analysis of a single programme can determine whether it is economically worthwhile in its own right. CBA remains, however, the least used technique in the economic evaluation of health care. In practice, there are major difficulties in applying CBA because of the problems in quantifying health consequences in monetary terms, and the significant number of ethical issues involved in assigning an amount of money to the value of human life, pain, and suffering.

**The use of a cost-utility analysis**

The basic differential characteristics of the three main types of full economic evaluation, CEA, CUA and CBA are listed in Table I.20-23 CBA encounters considerable problems when trying to assign a monetary value to health consequences. CUA has an advantage over CEA because it allows a direct comparison of various competing programmes, since health consequences are reported in the same units (QALYs).

There are, however, several situations in which CUA should not be used.20-23 When the treatments being compared are equally effective in all respects, a CMA will fulfil the needs. If the data show that a new intervention is both more effective and less costly, no further analyses, including CUA, are needed. The new intervention is dominant and the incorporation of utility measures would not change the conclusions. CUA should not be used when the obtaining of utility measures is too expensive or too difficult, e.g., when it is impossible to convert a surrogate or intermediate outcome (e.g., length of hospital stay, measurements of bone mineral density) into a utility.20-23

Utility and CUA should be carried out when there is no expected effect of the intervention on mortality but on the health-related quality of life.20-23 For example, treatments for degenerative arthritis, low-back pain and carpal tunnel syndrome affect pain and disability but not life expectancy. Utility and CUA may be useful when an intervention affects both morbidity and mortality, as in preventive treatment against venous thrombo-embolic disease among patients undergoing total hip or knee replacement. Most importantly, utility and CUA are used when the interventions being compared have a wide range of different outcomes. For example, a programme may wish to compare outcomes of a new technique for carpal tunnel release with those of a new drug for preventing venous thrombo-embolic events. The new technique affects pain and function; the new drug affects a range of thrombo-embolic events. Finally, a new programme can be compared with other interventions for which CUA has been done.

**What are the key components of an economic analysis, and of CUA in particular?**

**From whose perspective should the economic analysis be conducted?** The perspective may be that of the patient and the patient’s family, the hospitals, health-care professionals, the pharmaceutical industry, the paying agencies (private or public insurers), or society as a whole.5,20-23 The societal perspective takes into account that the whole population uses health care and pays for public insurance programmes. Since health interventions may cause costs or benefits in other sectors, alternative uses for the resources, such as in education or social services, should be considered. Economic analyses having a societal perspective include ethical dilemmas between individuals and society and the difficulty in assembling all the costs which are relevant to a society.

**How are costs measured in economic evaluation studies?** The perspective of the analysis determines which costs are used.9,11,20-23 This can be a potential source of bias. The key concept is to identify and to value costs. Contributors to cost must be identified before the costs can be valued. Methods to identify and value costs are described in detail by Drummond et al20 and Gold et al.21 In reporting costs, the physical quantities of resources consumed by surgical treatments should be documented separately from their prices. This is important since the price per quantity varies among different locations. By such separation, an analyst in a different country can calculate the cost for the area of practice and reach a separate conclusion regarding cost-effectiveness. Costs are more variable than other outcomes.33 The effects of treatment are sensitive to prognostic factors, but are reasonably constant in different geographical locations, and costs vary greatly even within the same city. They also depend on how health care is organised: fee for service or salary for health professionals; national or private insurance; in-patient or out-patient. Some cost studies are randomised clinical trials which carry out direct com-
parisons of the interventions being compared on both clinical and economic grounds. Parker and Pryor, for example, managed to incorporate cost data into a randomised clinical trial among patients with fracture of the hip. Conducting economic evaluations concurrently with clinical trials provides the opportunity to apply conventional tests of statistical significance to the resource quantities or costs. It is possible to set the range of estimates for sensitivity analyses based on common statistical parameters (e.g., 95% confidence intervals). Unfortunately, such direct comparisons utilising both clinical and economic grounds are rare in the field of orthopaedic surgery.

How are health outcomes measured in economic evaluation studies? A key component in cost studies is the measure of health outcome. It is in this that the differences arise among CEA, CUA and CBA. Health economists use one of three strategies: 1) the reporting of patient outcomes in natural units such as deaths prevented (CEA); 2) the weighting of patient outcomes to produce a composite index of outcome, such as QALYs (CUA); or 3) the placing of a monetary value on natural outcomes (CBA).

The reporting of patient outcomes in natural units is the most commonly used method in economic evaluation and is the most easily understood. Natural outcome units make clinical sense. In the simplest case, the outcome is a simple dichotomous or continuous measure, such as the number of deaths prevented, or the gain in life span. However, many medical or surgical treatments have more than one outcome, and have side-effects which need to be taken into account in making decisions about their net benefit and whether or not to recommend them. The beneficial and adverse consequences of many medical and surgical treatments include outcomes other than life and death. Furthermore, patients may value health states differently, and outcome analyses are increasingly concerned with the measurement of preferences and with the incorporation of health-related quality of life, as mentioned before.

To value health utility, or benefit, a variety of approaches is used, including the standard gamble (SG), time trade-off (TTO), and visual analog scales (VAS). All are based on the value individuals place on not having a particular disease. In the SG approach, respondents considering a particular health state find the balance between a chance of returning to perfect health and a risk of possibly dying in the process. In the TTO approach, respondents find the point of balance between a shorter life in perfect health versus a longer life in the health state being examined. In the VAS approach, respondents indicate the desirability of a health state on a line with well-defined end-points, usually from 0 to 1. The SG and TTO techniques are often considered the preferred approaches to estimate utility because of their roots in expected utility theory and because they confront respondents with trade-offs similar to their choices in real life. Interestingly, utility estimates obtained from VAS have been shown consistently to yield lower utility values than either SG or TTO methods. Generic and disease-specific instruments measuring health outcome may also provide an indirect means for estimating preferences; respondents complete health-status questionnaires, and prespecified preference weights from community samples are then applied. The Rosser classification of states of illness and the EuroQol Quality of Life Scale (EuroQol), for example, have been administered alongside SG exercises to relate the scores to utilities. Similarly, the Harris hip score and the Mayo hip score have been related. Most quality-of-life instruments and functional scoring systems have not undergone such testing. It is still a matter of debate whether utilities should be valued by patients, their families, health-care workers, respondents to opinion surveys, or participants in focus groups and panels who have been given detailed descriptions of the health state in question. There is evidence that patients value poor health states more highly than members of the general population who are trying to imagine the same state of health. Health-care providers may be thought to have the best understanding of the disease. However, professional experts may tend to put more weight on what they perceive as important (e.g., restoring range of movement) than the views of the patient (e.g., improving ability to perform activities of daily living). Recently, participants in focus groups have been considered as the preferred source of estimates of utility from a societal perspective. Because all people are potential patients, these community representatives would hopefully be sensitive to the needs of patients yet have a perspective on the disease relative to a normal state of health, as well as other needs within society. The difficulty lies in helping people who do not have direct experience with the disease in question to understand the health state properly. An explicit description of the disease state seems to elicit lower utility value.

Why are time horizon, cost discounting and inflation rate important issues? The time horizon, the length of time of the study of an analysis, is the time in the future beyond which all costs and health outcomes are ignored and should be consistent with the intervention being studied. For example, a one-year time horizon may be inappropriate for a cost-effectiveness study of total hip replacement for degenerative disease given the long-term potential of the prosthesis. When a cost-benefit analysis is performed, measures of health outcome are translated into monetary terms. Although there are many methods for valuing life, pain and suffering, each with certain ethical considerations, they are seldom used in the field of orthopaedics. For further discussion of problems in identifying and valuing health outcomes, the interested reader should consult Telser and Zweifel and Sugden and Williams. Related to the time horizon of the study are the issues of discounting and inflation. Discounting is a concept based on time preference. Discounting acknowledges this and recognises that money or other measures of outcome are worth more now than they will be in the future. By using a discount rate, future costs and benefits are converted to their...
present values. To retain comparability with existing analyses, it is recommended that both a discount rate of 5% and a discount rate of 3% should be used.\(^{20,21}\) Most experts recommend that costs and health benefits should be discounted at the same rate, but agreement over a suitable discount rate and whether health benefits should be discounted has yet to be achieved.\(^ {47}\)

Inflation must be considered in two ways. Cost estimates which have been collected in different years should be inflation-adjusted to a single year, and if the rates of inflation for all components of the study are not equal, component specific rates should be used.

**What is a sensitivity analysis?** When reporting the results of economic analyses, investigators start by describing the base case or reference analysis, which comprises the results that occur when a single set of assumptions are made. The investigator selects specific inputs for each variable which are believed to be the best data. Next, sensitivity analyses evaluate the stability of these conclusions. There are several types of sensitivity analysis, e.g. best case/worst case, one-way/two-way/n-way, or threshold analysis. Best case/worst case analysis compares the results if the estimates for all variables are chosen to be most favourable or least favourable for a given decision option. A one-way sensitivity analysis varies the estimates of each variable in the analysis, one at a time, while the estimates of the other variables in the analysis remain fixed. A threshold analysis is an extension of one-way sensitivity analysis. In threshold analysis, the estimate of one variable is varied until the alternative decision strategies are found to have equal outcomes, and there is no benefit of one alternative over the other in terms of estimated outcome. The threshold point is also called the ‘break-even’ point. In two-way sensitivity analysis, the expected outcome is determined for every combination of estimates of two variables, which the estimates of the other variables in the analysis remain fixed. In n-way sensitivity analysis, the expected outcome is determined for every possible combination of every reasonable estimate of every variable. Sensitivity analysis may also identify important questions for future research. For example, on the basis of the sensitivity analysis, one aspect of an economic study may appear to be the most critical. This may generate an hypothesis to be tested, perhaps resulting in a proposed clinical trial to answer the question.

**When is computer modelling of economic evaluations indicated?** The best method for comparing the health benefits of alternative surgical procedures is the randomised clinical trial and this applies equally to economic evaluation.\(^ {20,33,47}\) Economic data collected alongside a randomised clinical trial have high internal validity, and may provide excellent information about the relative costs and efficacies of the treatments under study.\(^ {48}\) A potential limitation of such a study is the generalisability of the results. This type of study will have low external validity since the subjects may not be typical of standard day-to-day clinical practice owing to the very strict inclusion criteria set for the randomised clinical trial. In surgical studies the follow-up may be too short for the purposes of economic evaluation. Decision analytical models simulate what may happen to patients during treatment programmes. Typically, the model is analysed by computer, providing a simulation of what would happen in real life. Perhaps most importantly, modelling studies can make projections of long-term outcomes from short-term data of clinical trials with inadequate follow-up.

Probabilities, costs, and health outcomes should be estimated from data in published studies, preferably from systematic reviews and meta-analyses. If no such information is available, it may be obtained from a consensus of experts in the field, such as a Delphi panel.\(^ {49}\) This technique is recognised as a systematic, literature-based, scientific method which utilises expert group judgement in the absence of adequate empirical data. In these circumstances, the Delphi approach is a widely used and validated method to make such estimates. Computerised models are much less expensive to run and can evaluate situations which are difficult to set up in real life. The models are flexible in that they can test many variations by altering the assumptions and inputs. This could not be done in real life without repeating the study. Models may be relatively simple\(^ {31}\) or extremely complex.\(^ {27,50-51}\) Readers of cost-effectiveness analyses should evaluate carefully all the assumptions which are included in decision analytical models because the results of such studies are dependent on these assumptions. In particular, the assumptions and results of sensitivity analyses should be carefully checked.

**When does a cost-utility ratio represent good value for money?** The question as to whether a given incremental cost-utility ratio represents a good monetary return, needs to be resolved. However, there is no single criterion of a cost-utility ratio below which an intervention should be adopted. European guidelines on the economic evaluation of pharmaceutical products and a recent European report\(^ {52}\) have attempted to provide guidance concerning the strength of an economic case to adopt a new medical technology, and others have been produced in Canada\(^ {53}\) and the USA.\(^ {19}\)

Another approach is to compare an intervention relative to other courses of action. League tables, named after the charts displaying the rankings of soccer teams, are a commonly used conceptual aid for deciding cost-utility.\(^ {54}\) These tables allow decision-makers to see how a particular intervention ranks in cost-utility (cost per QALY) for some widely accepted medical and surgical practices.\(^ {54,55}\) Such a league table should be interpreted with considerable caution, however, since the methodology may vary between studies. The choice of treatment, the utility instrument, the length of follow-up and the range and sources of costs included may hamper a valid comparison. If studies were carried out at different times, adjusting the cost-utility figures to a constant year requires assumptions of the constancy of relative costs, the inflation rate, exchange rates,
use of resource, the options for treatment, and the efficacy of the treatment. Analyses carried out in different countries may also not be comparable because of differences in culture, demographics, incidence of disease, patterns of clinical practice and the system of health care. Studies have found consistently that the relative prices of medication and surgical procedures tend to be higher in the USA than in other countries.

Hence, neither threshold values nor league tables should be seen as providing definite answers to difficult decisions of allocation of resource. Instead, they should be considered as a helpful aid.

Economic evaluation in orthopaedics: an ethical imperative?

Most economic papers concerning orthopaedic interventions provoke considerable interest among orthopaedic surgeons despite the multiple challenges of these analyses. Economic analyses compete with the primary ethical duty of the physician to care for the individual patient and with the community standard of care. As cost pressures grow and reimbursements continue to decline, individual providers of health care will be forced to examine their own clinical practices for the cost-effective use of resources. Furthermore, entire disciplines such as orthopaedics will be asked to demonstrate the value of allocating resources to their specialty.

The academic assessment of health economics will become an increasing part of considering how to manage patients and should be carried out without bias. Long-term assessment of health outcomes and costs is essential in order to develop a proper perspective in orthopaedic surgery, given the steadily increasing life expectancy of our population. The interpretation of such exercises is complicated by the varying approaches to obtain reproducible estimates of utility and their poor statistical properties.

Economic evaluations of orthopaedic procedures are rarely published in orthopaedic journals. Most such analyses have appeared in health-economic journals, general medical journals, government reports, books, monographs, the proceedings of conferences, or doctoral dissertations. The construction and presentation of health-economic papers is such that it is unlikely that most will be understood or appreciated by the majority of orthopaedic surgeons, who may be left wondering exactly how such research can be applied to clinical practice.

Despite these concerns and reservations, formal economic analyses may provide the means for justifying expenditures for particular diseases and can provide guidance for making decisions on treatment. If clinicians are to play a lead role in such discussions, they must develop the skills required for clinical economic analysis. These challenges need to be faced since this will help to ensure that such decision-making is in the hands of clinicians and not led by institutional or governmental policy.


