Cost-Effectiveness in Interventional Radiology

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18.1 Introduction

Cost-effectiveness is a term most radiologists did not know some years ago and some of them still do not, although cost-effectiveness analyses of imaging procedures are performed for more than 20 years (Otero et al. 2008)! However, it will become more and more important in the future, and physicians can no longer afford to leave this field to economists and controllers only! In most other areas of life, it is accepted that resources are limited, and therefore, a lot of effort is made to use it optimally, to "produce" at minimal costs. Only in medicine where the well-being (and sometimes indeed the life) of patients is at stake does this seem to be unethical while in fact it is unethical to waste resources thoughtlessly which are missing to treat another patient who much needs them.

Before we proceed, let me quickly explain what you can and cannot expect in this short chapter. Certainly, you will be disappointed if you just want to know whether, for example, radiofrequency ablation of the liver is cost-effective. The answer to this complex question depends on so many variables (such as: What other procedure do you compare it with? What are the local costs and outcomes of both procedures? What time horizon do you chose? At what rate do you discount future costs and health benefits? What view do you take if you compare costs: the view of the hospital, the sickness fund, or society) that it just cannot be answered globally. On the other hand you will learn:

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- What the difference is between efficacy, effectiveness, and cost-effectiveness.
- What the definition of cost-effectiveness is.
- An easy graphic model of cost-effectiveness.
- What kind of resource allocations have to be identified, collected, and valued.
- How the systematic cost calculation is done annually in the German DRG system.
- How important the point of view (society as a whole, sickness fund, hospital, private practice, patient) as well as the time horizon chosen is for the result of a cost-effectiveness analysis.
- Why we have to discount future costs.
- Why models can help you in assessing cost-effectiveness.
- How to ask the right questions.

18.2 Hurdles on the Way to the Market

Here are the three consecutive steps every pharmaceutical drug or interventional procedure normally has to go through:

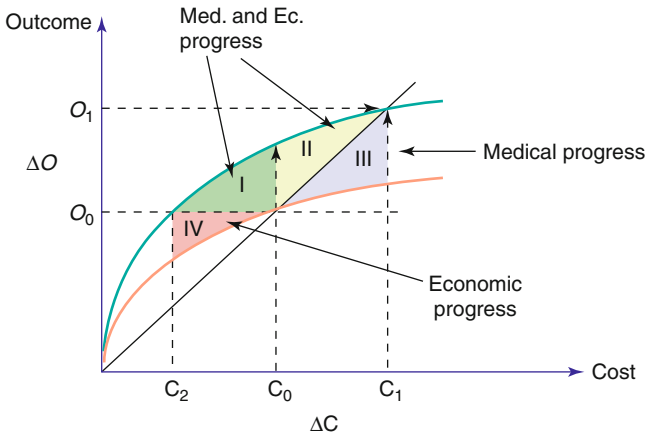
1. The evaluation of a new procedure (or drug) starts with clinical studies to prove its *efficacy*. The patient group in those clinical studies on purpose is made very homogenous by strict inclusion and exclusion criteria. The question which can be answered after this step is: "Does it work?" Only if the answer to this question is a clear "yes," it will be approved and put on the market.
2. The evaluation typically continues with registries or all-comer studies to prove its *effectiveness*. This step is important in order to come closer to real world conditions. The patient population in this stage has to be as inhomogeneous as the patients a doctor sees every day. At the end it is clear, whether the intervention is effective, that is, whether it works in regular patients under regular conditions (which among others also means "in the hands of average physician") and therefore has an advantage for them.
3. Only after these first two steps have been successful the question of *cost-effectiveness* (or efficiency) comes up. Now the question to be answered is: "How much effect do we get at what cost?" Unfortunately, for most interventions, valid data on cost-effectiveness in real-world patients are still lacking, but much needed.

It is the constant price pressure of every national health-care system (due to various factors such as an aging population, costly innovations, less revenue of the sickness funds due to unemployment in countries where their revenue is defined as a percentage of wage) that puts cost-effectiveness on the forefront of health-political discussions with organizations like NICE (National Institute for Health and Clinical Excellence) in the UK or IQWiG (Institut für Qualität und Wirtschaftlichkeit im Gesundheitswesen) in Germany. For them, cost-effectiveness is a means of ensuring that the least-cost interventions are utilized given the allocated budget. An economic evaluation informs what additional costs society has to spend for an additional improvement in medical benefits (Aidelsburger et al. 2007).

Clearly, policy makers cannot and should not scrutinize every minor change in medical practice. In the United States, the Centers for Medicare and Medicaid Services (CMS), for example, reserves its national coverage determinations for types of technologies that (Hollingworth and Jarvik 2006):

1. Affect a large number of beneficiaries
2. Represent a significant medical advantage
3. Have a potential for rapid diffusion or overuse
4. Are subject to substantial controversy
5. Local carriers have inconsistent coverage policies for

It is generally accepted that minimally invasive procedures such as they are performed in interventional radiology do have many advantages in comparison to, for example, open surgery. This is true for the patient (less trauma, shorter stay in hospital, quicker recovery), the sickness fund and society as a whole (shorter stay in hospital, sooner back to work), and the hospital/doctor if adequately reimbursed (good image, high patient satisfaction). Therefore, their number is growing in virtually all medical fields. However, according to evidence-based medicine,



I	II	III	IV
Medical and economic progress	Medical and economic progress	Only medical progress	Only economic progress
$O_1 > O_0$	$O_1 > O_0$	$\Delta O > 0$	$\Delta O_1 > O_0$
$C_2 < C_0$	$C_1 > C_0$	$\Delta C > 0$	$\Delta C_1 > C_0$
$\Delta O > \Delta C$	$\Delta O > \Delta C$	$\Delta O > \Delta C$	$-\Delta O > -\Delta O$

Fig. 18.1 Model of cost-effectiveness: the two production functions (*upper one*: with the innovation; *lower one*: conventional procedure for comparison) show the relationship between the different inputs (i.e., costs, *C*) and the outcomes (*O*) of the intervention. *I* "ideal situation," *II* typical "cost-effective" innovation, *III* typical "costly" innovation, *IV* only economic progress (modified according to (Bundesverband Medizintechnologie e.V 2003))

their superiority needs to be shown in well-made cost-effectiveness studies.

18.3 Definition of Cost-Effectiveness

Since there are various similar terms, let us start by defining what cost-effectiveness is. Cost-effectiveness analysis (CEA) is a form of economic analysis that compares the relative expenditure (costs) and outcomes (effects) of two or more courses of action. It is important which procedure is chosen as the comparator: this can be the most frequently performed procedure, the most effective, or the most cost-effective procedure. Sometimes it is also essential to compare a new procedure to doing nothing ("watchful waiting" as, e.g., in the case of prostate cancer).

The difference between the effects (*E*) of an intervention (I) and an alternative intervention (A) in relation to the difference of cost (*C*) results in the incremental cost-effectiveness ratio (ICER) (Drummond et al. 1997; Gold et al. 1996):

$$\text{ICER} = (C_1 - C_A) / (E_1 - E_A) \qquad (18.1)$$

The four general results which a cost-effectiveness analysis can potentially have are illustrated in Fig. 18.1. The two production functions show the relationship between the different inputs (i.e., costs, *C*) and the outcomes (*O*) of the intervention.

I – "*Ideal situation*" *which probably is rare in the real world.* The new procedure (blue curve) is a medical progress since its outcome (O_1) is higher (better) than the outcome of the compared procedure (O_0). At the same time, it is also an economic progress since its costs (C_2) are lower than the costs of the compared procedure (C_0).

II – *Typical* "*cost-effective*" *innovation.* Again, it is a medical progress since its outcome (O_1) is higher (better) than the outcome of the compared procedure (O_0). However, this time there is a price to pay for this progress, its costs (C_1) are somewhat higher than the costs of the compared procedure (C_0). Please note that additional outcome is greater (*above* the 45°

line) than the additional costs ($\Delta O > \Delta C$). Such a procedure should be acceptable to most health economists.

III – Typical "costly" innovation. Here we have almost the same situation as in case No. II: a higher outcome ($\Delta O > 0$) at higher costs ($\Delta C > 0$). The minor, however, important difference is that the additional outcome is smaller (*below* the 45° line) than the additional costs ($\Delta O < \Delta C$). Such a procedure will be looked at very intensely by health economists who will ask: Should we pay this higher price for this amount of better outcome or should be better spend this money in other fields where we can get more additional outcome for it?

IV – Only economic progress. Here is a result not many physicians and patients will like: The outcome is worse ($\Delta O < 0$)! Why then is it still considered to be an economic progress? Simply because costs are more reduced than outcome ($-\Delta C > -\Delta O$). In cases of very scarce resources, one therefore might decide to go for a procedure which "only" brings economic progress.

18.4 What Kind of Resource Allocations Have to Be Identified, Collected, and Valued?

If we look at the costs of an intervention, the challenge is to identify, measure, and value all resources which are needed for a certain intervention. Obviously there are various groups of costs as far as the time is concerned: costs incurred before the intervention (e.g., before hospital), in hospital, and after hospital. The same applies to the various benefits. The general difficulty of collecting cost/benefit data is partly due to that fact. If a country (like Germany) has two totally separated sectors, hospitals (inpatient), and private practices (outpatient), the task of collecting cost data becomes almost impossible.

Costs and benefits may be separated in direct and indirect costs which can be divided in tangible and intangible. Figure 18.2 summarizes some (by far not exhaustive) examples of what costs and benefits we could think of.

On the other hand, there are various cost categories which you will have to look at when calculating the cost of a procedure:

- Material costs (such as implants, catheters, contrast medium, etc.)
- Drugs
- Costs of labor (time of physicians, assistant medical technicians, nurses, etc.)
- (Virtual) renting costs of, for example, a computed tomography (CT) or magnetic resonance (MR) scanner
- Overhead costs (e.g., for the hospital administration)

If you do not restrict your view to the time in hospital, you might also have the following costs:

- Future medical costs that are a consequence of the intervention (such as medication the patient has to take after an intervention or adjuvant medical devices such as crutches or a wheelchair).
- Rehabilitation.
- Medical treatment in private practice.
- Lack of work due to sick certificate (indirect cost).
- Home care by professionals or family members (indirect cost).
- Invalidity pension (indirect cost).
- Time losses from activities which might not receive a wage, but which may be valued by society or the individual none the less (intangible cost).

There is one more outcome parameter which needs to be measured (by questionnaires which have proven their effectiveness such as the SF-36): quality of life (QoL) (Ware and Sherbourne 1992). It is obvious that one of the main advantages of (minimally invasive) interventional radiology is that QoL in most cases should be better than in the case of open (and more invasive) surgery.

But how can one measure and compare the lifetime gained by different procedures if the QoL is different because of the different procedures (e.g., bypass vs. percutaneous coronary intervention). The answer is quality-adjusted life years, or QALYs, a way of measuring both the quality and the quantity of life lived, as a means of quantifying the benefit of a medical intervention. They are based on the number of years of life that would be added by the intervention. Each year in perfect

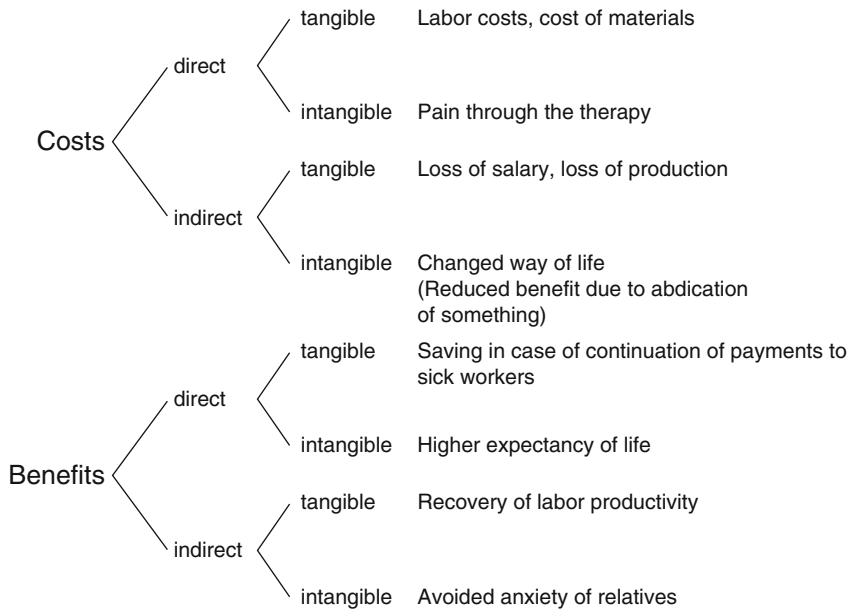


Fig. 18.2 Various costs and benefits (Ujlaky 2005)

health is assigned the value of 1.0 down to a value of 0 for death. If the extra years would not be lived in full health, for example, if the patient would lose a limb or be blind or be confined to a wheelchair, then the extra life years are given a value between 0 and 1 to account for this (e.g., major stroke ~ 0.35, post-MI ~ 0.683). The calculation of QALY therefore depends on the health state (QoL score) and time spent in that state.

Example:

- 1 year in perfect health = 1 QALY
- 1 year after major stroke = 0.35 QALY
- 0.5 year in perfect health + 0.5 year dead = 0.5 QALY

QALYs are used in cost-utility analyses to calculate the ratio of cost to QALYs gained for a particular health care intervention. This information is used to allocate health-care resources, with an intervention with a lower cost to QALY-saved ratio being preferred over an intervention with a higher ratio. This method is controversial because it means that some people will not receive treatment as it is calculated that cost of the intervention is not warranted by the benefit to their quality of life. However, its supporters argue that, since health-care resources are inevitably limited, this method enables them to be allocated in the way that is most beneficial to society.

The meaning and usefulness of QALY is debated for some other reason too. Perfect health is hard, if not impossible, to define. (The WHO has tried to do so and came up with "Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity"; but its definition is of no practical use) (WHO 1948) Some argue that there are health states worse than death and that therefore there should be negative values possible on the health spectrum (indeed, some health economists have incorporated negative values into calculations). Determining the level of health depends on measures that some argue places disproportionate importance on physical pain or disability over mental health. The effects of a patient's health on the quality of life of others – caregivers, family, etc. – also do not figure in these calculations.

18.5 Systematic Cost Calculation in the German DRG System: An Example

The various kinds of costs become much more practical if we look for an example at the German DRG (diagnosis related groups) system where costs are calculated every year anew.

Although relatively new and "imported" from Australia, the German DRG system which is mandatory for all German acute care hospitals is already rather refined and (in contrast to, for example, the USA and Italy) updated every year. The basis for cost calculations is about 250 hospitals which collect their full-year cost data (according to the specifications of a detailed calculation handbook) and give it to the German DRG institute (called InEK). InEK makes a quality check, annually calculates the roughly 1,200 various DRGs, and publishes the aggregated data afterward (InEK 2007).

Let us demonstrate this point with radiofrequency ablation of the liver. In 2010 this leads to the DRG H41A (Table 18.1) if the patient has so many side diagnoses that he has a PCCL (patient clinical complexity level, i.e., the total weight of all his side diagnoses) of 4.

The different columns show the different cost categories:

1. Doctors
2. Nurses
3. Assistant medical technicians
4. Drugs
5. Implants
6. Other medical equipment
7. Medical infrastructure
8. Nonmedical infrastructure

Cost categories 1–3 obviously are labor costs, 4–6 are material costs, 7 and 8 are a mixture of both.

The different lines outline the various *cost centers*:

1. Regular ward
2. Intensive care unit
3. Operating room
4. Anesthesia
5. Cardiology diagnosis and therapy
6. Endoscopic diagnosis and therapy
7. Radiology
8. Laboratory
9. Other diagnosis and therapy
10. Basic cost center

Total costs of the DRG add up to €5301.80 with €301.80 of this being in radiology.

Despite the fact that this DRG (called "complex therapeutic ERCP with extremely severe clinical complexity or photodynamic therapy") contains many more patients than just those who received a radiofrequency ablation of the liver, these costs are considered more and more as norm costs. The consequence is that many heads of radiology departments in Germany are confronted with the norm costs of their department given all the various DRGs of a hospital. This figure is then compared with the actual costs of the radiology department in order to assess its overall "cost-effectiveness."

A rough calculation of all DRGs (weighting the costs of each DRG with its number in the calculation data) shows this picture (own data on file): the cost of radiology (cost center No. 9) in 2007 was €206,000,000,00 representing 3.8 % of a total of €5,400,000,000,00 since this percentage is constantly rising from 3.5 % in 2006 to 5.3 % in 2010.

18.6 The Importance of the Point of View and the Time Horizon of a Cost-Effectiveness Analysis

Although it is useful in cost-effectiveness analyses to take the perspective of the society in evaluating alternative allocations of health resources (i.e., by measuring aggregate health cost and aggregate health benefits across all members of society), it is also important that the particular objectives of the actual decision maker are considered. For example, total costs might be of concern to a sickness fund or health maintenance organization, whereas only in-hospital costs might concern a hospital administrator receiving a certain DRG reimbursement. Society as a whole bears all the costs, whether through insurance premiums or out-of-pocket payments, but the organizations and individuals who actually make resource-allocation decisions usually have varying objectives that should be recognized in a realistic cost-effectiveness analysis (Weinstein and Stason 1977).

It is also vital to choose the right time horizon for the study. As all effects and costs related to an intervention should be included into the economic evaluation, a long-term time horizon for the evaluation might become necessary. In these

Table 18.1 Model of cost-effectiveness

	Personnel expenditure			Non-personnel costs					Personnel and non-personnel costs		
	Doctors	Nurses	Assistant medical technicians	Drugs		Implants	Other medical equipment		Medical infrastructure	Non-medical infrastructure	
	1	2	3	4a	4b	5	6a	6b	7	8	Sum
Regular ward	464.5	990.0	54.3	152.0	65.5	0.0	89.3	9.6	252.2	901.1	2978.3
Intensive care unit	62.6	136.8	2.3	20.7	8.7	0.0	22.9	0.6	23.8	69.3	347.7
Operating room	26.9	0.0	23.1	1.1	0.7	6.3	18.4	6.3	11.6	18.6	113.0
Anesthesia	27.5	0.0	18.8	2.4	0.1	0.0	6.6	0.1	3.5	7.6	66.7
Cardiology diagnosis and therapy	1.6	0.0	1.9	0.1	0.0	1.5	1.1	3.0	1.1	1.6	11.8
Endoscopic diagnosis and therapy	185.2	0.0	197.4	9.7	1.6	66.9	120.3	56.9	93.6	151.4	882.9
Radiology	59.8	0.0	77.2	1.0	0.8	6.1	24.9	42.9	31.9	57.2	301.8
Laboratory	24.1	0.0	118.3	3.4	54.0	0.0	90.8	39.0	14.1	60.3	404.0
Other diagnosis and therapy	55.1	1.8	68.2	2.6	0.0	0.0	10.3	1.4	12.5	44.1	195.8
Sum	907.2	1128.5	561.5	193.1	131.4	80.8	384.4	159.8	444.2	1311.0	5301.8

cases the usage of data from randomized clinical trials (RCT) are not sufficient (even if they should contain cost data) as they usually do not cover this long-term time horizon for cost containment reasons. Mathematical models which utilize data from different sources can be applied to overcome this limitation.

The importance of the time horizon chosen can be easily illustrated by the following example. If you compare the cost-effectiveness of an arrhythmic drug with the cost-effectiveness of a pacemaker or internal defibrillator, no doubt the drug will be superior in a short time frame. However, if you set the end point of the study at 7–8 years, the result might be the opposite (Aidelsburger et al. 2007).

A totally different question to cost-effectiveness is whether the costs of an intervention (the total stay of a patient in hospital) are adequately reimbursed.

Literature about the cost-effectiveness of certain interventions is not easily found; the number of patients included is generally too low (e.g., 7 and 6, respectively, in a study comparing the cost of MR-guided laser ablation and surgery in the treatment of osteoid osteoma), and its quality is not satisfactory (Ronkainen et al. 2006). Blackmore and Smith (1998) have evaluated the methodological quality of economic analyses of radiological procedures published in the non-radiology medical literature during the years 1990–1995. Of the 56 articles, only 8 (14 %) conformed to all ten methodological criteria:

1. Comparative options stated
2. Perspective of analysis defined
3. Outcome measure identified
4. Cost data included
5. Source of cost data stated
6. Long-term costs included
7. Discounting employed
8. Summary measure provided
9. Incremental computation method used
10. Sensitivity analysis used

One of the peculiarities in comparison to clinical studies is that cost-effectiveness studies should be national (since the health-care systems and their incurred costs vary so much across different countries) and recent (since prices vary considerably over time).

This can be demonstrated by a recent cardiologic cost-effectiveness study (Brunner-La Rocca et al. 2007) from Switzerland which was intended to find out whether in percutaneous coronary interventions and stenting the use of drug-eluting stents (DES) instead of bare-metal stents (BMS) is cost-effective. They found that overall costs were higher for patients with drug-eluting stents (€11,808) than for patients with bare-metal stents (€10,450) due to higher stent costs. They calculated an incremental cost-effectiveness ratio (ICER) of €64,732 to prevent one major adverse cardiac event and stated that an unrealistic reduction of the cost of DES of about 29 % would have been required to achieve the arbitrary threshold ICER of €10,000. Sounds logical; however, what prices did they assume? Swiss list prices of 2004 are certainly much higher than, for example, present DES prices in Germany. Therefore, their findings are only valid for Switzerland in 2004 and cannot be extrapolated to all of Europe, let alone across the whole world.

18.7 Why We Have to Discount Future Costs

In finance and economics, discounting is the process of finding the present value of an amount of cash at some future date. To calculate the present value of a single cash flow, it is divided by one plus the interest rate for each period of time that will pass. If we assume a 12 % per year interest rate, the present value of €100 that will be received in 5 years time is only about €56.74. Therefore, a procedure which incurs exactly the same costs as an alternative procedure – but does it at a later point in time – is more cost-effective.

However, not only do costs have to be discounted. Benefits have to be discounted too for at least three reasons (Cairns 2001):

- Diminished marginal utility (in the temporal context).
- The risk that, whether as a result of death or some other circumstances, future consumption opportunities may not be available.
- Individuals simply have a preference for earlier consumption compared to later consumption.

18.8 Why Models Can Help You in Assessing Cost-Effectiveness

Economic evaluations (such as cost-effectiveness) depend on the evidence on cost and health effects of medical and public health interventions. This evidence can be derived from clinical studies, registries, meta-analysis, databases, administrative records (e.g., from sickness funds), and case reports. Of course the level of evidence found in these various sources is quite different.

Because the evidence required on consequences and cost of interventions is never present in a single source and the time horizon of most clinical studies is far too short, practitioners of cost-effectiveness analysis use mathematical models to synthesize data on costs and benefits of alternative clinical strategies. Economic evaluations that have been piggybacked on clinical trials often require almost as much modeling in order to extend the time horizon. If one fails to consider health and economic outcomes that may occur beyond the time frame of the observed data, there is an implicit assumption being made that all arms of the trial are equivalent.

A model makes explicit assumptions about the incidence and/or prognosis of a disease, the magnitude and duration of risks and benefits of prevention and/or treatment, the determinants of utilization of health-care resources, and health-related quality-of-life. Of particular value to clinicians and policy makers is that the models allow one to investigate how cost-effectiveness ratios might change if the values of key parameters in a model are changed (Kuntz and Weinstein 2001).

Models often used are decision trees (or probability trees), Markov models, and state-transition models (Gazelle et al. 2004). A decision tree has one decision node at the root. The branches of the initial decision node represent all interventions that are to be compared. Markov models are analytical structures that represent key elements of a disease and are commonly used in economic evaluations. They are particularly useful for diseases in which events can occur repeatedly over time such as acute myocardial infarction for patients with stable angina or cancer recurrence. For more detailed information see Sonnenberg and Beck (1993).

In both cases there is a trade-off between building a complicated model that accurately reflects all the important aspects of a disease and its treatment and building a simple model that is more transparent. At any rate, the input probabilities, utilities, and costs, as well as the key assumptions that underlie the model, should be carefully documented.

Zowall is a nice example of such a model comparing the cost-effectiveness of MR-guided focused ultrasound surgery (MRgFUS) for the treatment of uterine fibroids with uterine artery embolization, myomectomy, and hysterectomy (Zowall et al. 2008). O'Sullivan et al. present a quite different model for the same question (O'Sullivan et al. 2009). They even discuss in what ways their model differs from Zowall's considerably. The two articles seem to perfectly demonstrate the fact that models heavily depend on their assumptions. If costly equipment like MR is involved (like in MRgFUS), one of the most important assumptions is the assumed patient throughput.

Summary

Economic questions (such as cost-effectiveness of alternative procedures) become more and more important in medicine due to increasing pressure to curb health-care costs. Every radiologist is well advised to open his mind to such questions and to start finding what the costs of his clinical pathway are. In countries with a fixed payment (DRG) per patient, this is a must anyhow. Physicians need to learn how to ask the right questions when building up an interventional radiology program. These questions could be:

- What are the alternatives to my intervention (including wait and see)?
- What are the cost and the outcome of my intervention and the alternatives?
- What is the cost per QALY gained?
- What is the perspective of the patient, provider, payer, health maintenance organization, health care system, and society?

Should the radiologist initiate a clinical study? it is generally a good idea to include cost data in order to be able to answer economic questions which might arise later. As with clinical studies, the design of which has improved over the last few years, so will cost-effectiveness studies improve as more physicians become aware of the methodological standards of such studies.

Key Points

- Health economics become more and more important due to limited resources for health care.

Cost-effectiveness analyses are generally complex studies requiring a multidisciplinary team with expertise in the clinical problem, clinical epidemiology, decision analysis, economics, and statistics.

Collecting the various cost and asking the right questions is a reasonable first step.

In order to improve our knowledge about the cost-effectiveness of interventional radiological procedures, cost data (and well-made cost-effectiveness analyses) should be included in all future clinical studies.

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