Cost-effectiveness
Particle Therapy

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Content

- cost PT and reimbursement
- efficacy PT
- health economics: some basics
- different approaches
- cost-effectiveness PT: current results
- future needs
Costs radiotherapy

- Relatively cheap: 5% of costs of global oncology budget (about 3000 euros for standard treatment)
- Increasing complexity will translate in higher costs
  - Charged Particles
  - About 2.4 (Goitein & Jermann, 2003) of highly sophisticated photon beam treatments (IMRT)
  - Between 11,000-35,000 euros, average 25,000 euros
Costs

- Construction (capital)
  - project management, equipment, building, treatment infrastructure (CT, TPS etc.)

- Operation costs
  - personnel, utilities, maintenance, business cost

- Unit cost of treatment/cost per fraction
  - depending on construction/operation costs and reimbursement system (agreements government/health insurances: can be highly variable between countries/regions)
- 60% of the centers: 1 system (36% budget, 5% case payment, 15% FFS)
- 40%: mix of different systems
- prospective reimbursement: large and university centers
What are the total cost for each protocol ... for the hospital point of view*?

→ to discuss the reimbursement

Per patient? Per session?
Specific for preparation & irradiation phases?
Reimbursement per “protocol”? ..../..

* Costs for transportation, hospitalisation, associated therapies... excluded
<table>
<thead>
<tr>
<th>Scenarios</th>
<th>« Ref»</th>
<th>Boost</th>
<th>Exclusive</th>
<th>hypofraction</th>
<th>Reduced session duration</th>
<th>1 beam/session</th>
<th>1 shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient (€)</td>
<td>21,000</td>
<td>19,805</td>
<td>26,122</td>
<td>17,287</td>
<td>17,033</td>
<td>13,114</td>
<td>33,194</td>
</tr>
<tr>
<td>Session (€)</td>
<td>1600</td>
<td>1650</td>
<td>1462</td>
<td>2055</td>
<td>1287</td>
<td>1018</td>
<td>2534</td>
</tr>
</tbody>
</table>

**Scenarios for the simulation:**
- « boost » vs. « exclusive » C ion therapy
- 13 vs. 10 mean # of sessions per patient
- mean session time duration: 30 vs. 20 min
- Mean # of beam per session: 2.3 vs 1
higher costs worthwhile?

Systematic literature review: no firm conclusions about clinical or cost-effectiveness protons of C-ions could be drawn \(^1,2\)


where do we expect a gain?

- less side effects
- less relapses: cost-sparing palliative treatment
- reduction late morbidity
- improvement in QoL
- less secundairy cancer inductions
- ...

Health Technology Assessment (HTA)

Why??

- To provide evidence-based information about aspects and consequences of the (new) medical technology
- Calculating healthcare costs
- Cost control/management and efficiency
- Strategic decision for budget allocation
main problems with HTA

- often difficult to interpret by non HTA-researchers (like clinicians, physicists, policy-makers, etc)
- often performed with inadequate methodology
- no uniform terminology (e.g. often incorrect use of term cost-effectiveness analysis)
- problems with transferability (often only applicable to specific country/region)
Economics: some basics

How societies meet their wants from limited resources

Three key questions:

- **What** should we produce?  
  VALUE

- **How** should we produce what is to be produced?  
  EFFICIENCY

- How to **distribute** what is to be produced between individual citizens?  
  FAIRNESS
What is efficiency?

1. Technical efficiency
   - do not waste resources

2. Allocative efficiency
   - produce products which people value most

3. Cost–effectiveness
   - produce each product at least cost
### Tool to assess efficiency: economic evaluation

Are both costs (input) and effects (output) examined?

<table>
<thead>
<tr>
<th>Is there a comparison of two alternatives?</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>No effects</strong></td>
<td><strong>Only costs</strong></td>
</tr>
<tr>
<td></td>
<td>Outcome description</td>
<td>Cost description</td>
</tr>
<tr>
<td></td>
<td>Efficacy or effectiveness</td>
<td>Cost analysis</td>
</tr>
</tbody>
</table>

|                                           | **Yes** |
|                                           | Cost outcome description | Full economic evaluation* |
# Types of full economic evaluation

<table>
<thead>
<tr>
<th>Method</th>
<th>Costs</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-minimisation analysis (CMA)</td>
<td>Monetary units (€)</td>
<td>No difference in effects</td>
</tr>
<tr>
<td>Cost-effectiveness analysis (CEA)</td>
<td>Monetary units (€)</td>
<td>Natural units (life years gained, point blood pressure, etc)</td>
</tr>
<tr>
<td>Cost-utility analysis (CUA)</td>
<td>Monetary units (€)</td>
<td>Utilities and Quality Adjusted Life Years (QALYs)</td>
</tr>
<tr>
<td>Cost–benefit analysis (CBA)</td>
<td>Monetary units (€)</td>
<td>Monetary units (€)</td>
</tr>
</tbody>
</table>
Quality Adjusted Life Year

Utility

4 * 0.9 = 3.6
3 * 0.7 = 2.1
4 * 0.2 = 0.8
Total QALY: 6.5
(area under the curve)
Full economic evaluation: Relevant costs and effects for each alternative (using the same methodology)

Incremental cost-effectiveness ratio: 

\[
\frac{(\text{Costs}_A - \text{Costs}_B)}{(\text{Effects}_A - \text{Effects}_B)}
\]

Choice

Programme A

Cost A

Programme B

Cost B

Effects A

Effects B

Difference in costs? 

\[(\text{Costs}_A - \text{Costs}_B)\]

Difference in effects? 

\[(\text{Effects}_A - \text{Effects}_B)\]
Incremental analysis

Difference in costs

Difference in effects

Inferior

Dominant

$50000/10 = 5000

$42000/12 = 3500

$56000/8 = 7000

$42000/12 = 3500

$50000/10 = 5000

$56000/8 = 7000
Cost-effective or not?

€5000/ QALY or LYG acceptable?
YES!!

Depending on benchmarked (varies between countries between 20,000-100,000 euros)

ceiling-ratio of €50,000 is often used
Study design: two approaches

- Trial based economic evaluation
  - Use economic data collected alongside a single trial
  - Only right approach if the trial truly reflects the decision context

- Model based economic evaluation
  - Use a model as an analytical framework to synthesize evidence relevant to the decision problem from different sources
A model is a ‘simple’ reflection of former, current or future reality
Current reality ??
Current reality
Future reality
Models in health care: support decision for future course of action
Mathematical models

\[(X_a - X_c) \pm 1.96 \sqrt{\frac{\text{s.d.}_a^2}{n_a} + \frac{\text{s.d.}_c^2}{n_c}}\]
Different approaches

- Decision tree
- Markov model
- Discrete event simulation
Decision tree

decision problem regarding a patient population

at least two strategies to choose from

expected costs and outcomes

path probabilities

C & E

events

C & E

C & E

probabilities

C & E

etc

C & E

probabilities

C & E

etc

C & E

probabilities

C & E

expected

costs

and

outcomes

path

probabilities

live child birth

no life child birth

life child birth

no life child birth

life child birth

no life child birth
Markov model

HEALTH STATES

T0
- Full health
- Illness
- Death

T1
- Full health
- Illness
- Death

T2
- Full health
- Illness
- Death

TRANSITIONS

CYCLETIME
Simulation models

Discrete event simulation:
How much time does it take for an event to happen?
Comparison

- Decision tree
  - What is the probability of A?

- Markov model
  - What is the transition probability of A to B within one cycle?

- Discrete Event Simulation model
  - How long does it take for B to happen, given A?

Courtesy to Aukje van Gestel, dept. Ophthalmology, university hospital Maastricht
The current literature on "cost-effectiveness"

- so far, only 14 papers on economic evaluation of PT were identified ²
- only 4 reported on cost-effectiveness ³-⁶

some results

- CUA based on Markov model for breast, prostate, H&N and medulloblastoma $^5$:
  average cost QALY $\approx € 10.130$

- CEA skull base chordoma $^6$:
  € 7692 per LYG (life year gained)

both studies high level of uncertainty: many assumptions, non-optimal methodology
future perspective in effectiveness of PT

- more hospital based facilities
- improvement in equipment
- number of treated patients will be increase
- possibilities to perform high quality international multicentric research (RCT’s ??)
- likely to expect clinical evidence on efficacy in future
What do we need NOW to prove EVB effectiveness?

- model based economic evaluations
- with an adequate methodology
- multidisciplinary project team
- as much real data to decrease uncertainty
- long term effects from broad health care perspective