



## COMMENTARY

## Optimising patient care in medical radiation services through health economics: an introduction

Scott Jones, BAppSc (RT),<sup>1,2</sup>  Amy Brown, BAppSc (RT), MAppSc (Research),<sup>3,4</sup>   
Vanessa Barclay, BAppSc (MI),<sup>5</sup> & Oona Reardon, BSc (Applied Physics)<sup>6</sup>

<sup>1</sup>Radiation Oncology Princess Alexandra Hospital Raymond Terrace, Metro South Health Service, South Brisbane, Queensland, Australia

<sup>2</sup>Faculty of Science and Engineering, Queensland University of Technology, Brisbane, Queensland, Australia

<sup>3</sup>Townsville Cancer Centre, Townsville Hospital and Health Service, Townsville, Queensland, Australia

<sup>4</sup>College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

<sup>5</sup>Metro North Medical Imaging, Metro North Health Service, Brisbane, Queensland, Australia

<sup>6</sup>Centre for Health Economics Research and Evaluation, University of Technology Sydney, Sydney, New South Wales, Australia

### Correspondence

Scott Jones, Radiation Oncology Princess Alexandra Hospital Raymond Terrace, 31 Raymond Tce, South Brisbane, Qld 4101, Australia. Tel: +61 07 3840 3255; Fax: + 61 07 3840 3298; E-mail: scott.jones@health.qld.gov.au

Received: 5 September 2019; Accepted: 31 December 2019

*J Med Radiat Sci* **67** (2020) 87–93.

doi: 10.1002/jmrs.380

### Abstract

The role of health economics in optimising patient care in medical radiation clinical settings is of increasing importance in ensuring efficient and effective service delivery. This commentary introduces health economics to medical radiation professionals by outlining the main analysis types utilised, highlighted by examples in the literature. The purpose is to provide an over-arching framework and starting point for incorporating health economics into medical radiation research study protocols.

A mainstay of the medical radiation profession is the desire to deliver high quality work through complex technical skills and care offered to patients. Efforts to improve in both areas are often catalysed by technological changes and dynamic workloads, which leads to optimisation of healthcare at micro and macro levels. Additionally, economics factors play an important role in providing health care to a population as they guide expenditure decisions and policies. Irrespective of what the driving force is, optimisation of available resources is an important part of delivering high quality health care and leveraging the most value for the greater patient population. Further, obtaining good value for money involves the consideration of expenditure required to produce high quality health outcomes and has been described as central to health policy<sup>1</sup> as an implicit expectation of a population within any health care jurisdiction. Considering this, health economics plays an important role in identifying the different types of value a medical service may offer and cannot be overstated in this setting.

Health economics and its integration into clinical research activities has expanded in the medical radiation

profession in recent times. Now in many instances, there is an expectation to conduct some form of health economic analysis of clinical trials to provide evidence of economic benefit. Even if the expectation is not explicit, the potential benefits of a health economics analysis are too great to forego in a field of competitive funding requests. To help facilitate this work in the Australian radiation oncology setting the Assessment of New Radiation Oncology Treatment And Techniques (ANROTAT) framework was developed by the Trans-Tasman Radiation Oncology Group (TROG), which provides a systematic approach to efficiently assess health technologies and techniques.<sup>2</sup> Internationally, the European Society for Radiotherapy and Oncology (ESTRO) developed the Health Economics in Radiation Oncology (HERO) project to provide wide-scale cost-effectiveness assessments of radiation oncology departments across Europe.<sup>3</sup> Both initiatives provide excellent frameworks for assessing new and existing medical techniques across all medical radiation professions.

For many medical radiation professionals working in clinical roles however, health economics is an unfamiliar topic. As a result, the potential benefits of health economic analyses and how they apply to clinical

decisions and research are often misunderstood and underutilised. In this commentary we aim to provide some education on the basics of health economics. The authors represent a range of medical radiation professionals including two medical radiation clinicians investigating health economic applications through post-graduate research degrees, a medical radiation manager, specialist clinician and a health economics expert with a background in medical radiation physics. While this is not an exhaustive review of the health economic literature in the medical radiation sciences, we refer to previously published works that apply different health economic analyses to a variety of health services and explain the purpose of each approach.

## Evaluation Considerations

Health economics is concerned with the production, allocation, and consumption of goods and services within the health care setting. In order to understand if a medical technique is beneficial compared to other service options or current practice, robust efficacy and cost data that accurately represent patient outcomes and the true economic cost including all resources are required to make informed decisions around what represents good value. In some instances, a medical technique or service may greatly improve patient outcomes but come at a financial cost that is untenable for a health care provider with a limited budget. Alternatively, a novel medical technique may provide obvious cost savings, but impact negatively on patient outcomes. Other techniques may fall somewhere in between these two ends of the spectrum. Deciding which medical techniques or services to provide funding for subsequently becomes complex.

To further increase complexity, multiple stakeholders are involved in the decision at hand. Patients have a vested interest in accessing a medical technique or service that may improve their quality of life (QoL) or prolong their survival. Health insurers and health care providers are often interested in ensuring their limited financial resources are invested prudently and do not cause

unnecessary financial risk. While governments are accountable to the wider society and community that they represent, who themselves seek a balance of fair access to health care for all, they remain fiscally responsible with tax-payer funds. It is important then to consider upfront which perspective the economic analysis is performed from. Having a clearly defined perspective enables the appropriate stakeholders to be considered, and assumptions stated up front. Further details of perspectives can be found in Table 1. At the federal level in Australia, health economic analyses are usually conducted from a healthcare perspective (including only healthcare costs and health outcomes), though can also take on a societal perspective (including non-medical costs such as travel or the indirect impact of lost time at work to attend appointments).<sup>4</sup>

Measuring the cost of a new technique or service therefore goes beyond the initial financial outlay required for acquisition and implementation. All aspects of care provision need to be considered including patient clinical outcomes such as safety, mortality, morbidity and QoL impact; capital expenses; consumables; staff wages; facility overheads; ongoing medical resource use (MRU) and time resources.<sup>5</sup> Performing an appropriate evaluation of this information can take several forms depending on the specific question being asked. In general, there are four types of health economic evaluations that can be undertaken. These include cost-minimisation (CMA), cost-effectiveness (CEA), cost-utility (CUA) and cost-benefit analyses (CBA). In the next section we will describe the role that each approach has to play and provide a medical radiation specific example from the literature, or a hypothetical scenario to illustrate. A brief overview of these examples can be found in Table 2.

## Economic Evaluation Types

### Cost-minimisation analysis

CMA is the simplest approach and applies when the proposed medical technique is non-inferior (rather than

**Table 1.** Perspective and cost considerations.

Perspective	Costs			
	Direct Medical	Direct Non-medical (e.g. travel)	Indirect (e.g. loss of work)	Intangible (e.g. pain, QoL)
Individual (Patient and Carers)	Yes	Yes	Yes	Yes
Health systems	Yes	Maybe (if subsidies)	Maybe (if welfare)	No
Government	Yes	Maybe (if subsidies)	No	No
Societal	Yes	Yes	Yes	Yes

**Table 2.** Summary of example medical radiation based economic analyses.

Evaluation Type	Example Comparison	Costs Measured	Outcomes Measured	Result
Cost-Minimisation Analysis	Kilovoltage IGRT vs Electronic Portal Imaging IGRT <sup>9</sup>	Cost per minute of IGRT session	None	Kilovoltage imaging was quicker and therefore reduced costs
Cost-Benefit Analysis	Palpation-guided lumpectomy vs Ultrasound-guided lumpectomy <sup>11</sup>	Market value of performing both techniques	Market value of re-excision or radiotherapy boosting	Ultrasound-guided lumpectomy saved €154 on average
Cost-Effectiveness Analysis - RT	IMRT vs VMAT for prostate cancer	Time and labour costs to provide treatment	Rectal toxicity grading	Cost per reduction in rectal toxicity grading
Cost-Utility Analysis – MI	Mechanical thrombectomy for acute large-vessel ischemic stroke <sup>17</sup>	Stroke care costs	QALY	Thrombectomies were cost-effective at \$12,880/QALY

IGRT: Image Guidance Radiation Therapy; MI: Medical Imaging; RT: Radiation Therapy; IMRT: Intensity modulated radiation therapy; VMAT: Volumetric Modulated Arc Therapy; QALY: Quality Adjusted Life Years.

superior) in terms of its clinical effectiveness compared to the comparator. The aim is to compare the costs of two or more techniques to determine which is more economical. Importantly this method does not include a measure of outcome such as toxicity as it relies on absolute equivalence in outcomes between the techniques being compared.<sup>5,6</sup> While this assumption may seem to streamline the evaluation, finding comparative techniques with identical outcomes can prove very difficult. Ideally, data to prove equivalence in outcome should come from controlled trials or other high-quality research such as systematic reviews of randomized controlled trials. However, most trials or comparison studies are not aimed at proving non-inferiority results and this has been identified as a limitation of using CMA.<sup>5-7</sup> Incorporating uncertainty of the outcomes measured further reduces the likelihood of comparative outcomes being equivalent. As such, there are limited examples of CMA for medical radiation technologies in the literature. One example by Gill et al.<sup>8</sup> compared kilovoltage (kV) imaging with automated repositioning against electronic portal imaging (EPI) with manual repositioning for prostate cancer image-guided radiotherapy (IGRT). In this analysis the financial cost per minute was calculated for an IGRT session and the times between the two techniques compared. The results showed kV imaging to be quicker and cost less over time despite a larger initial outlay for equipment. This example relied on the assumption that patient outcomes were the same regardless of which type of IGRT was used. Initially this may seem like a reasonable assumption to make, however the benefits of using kV imaging extend beyond the time savings incurred in automatic repositioning and were not captured in this study. The image quality provided by kV IGRT arguably provides clearer target visualisation and

image matching in some circumstances which may influence treatment accuracy and therefore patient outcomes. This is an example of the difficulties faced when applying CMA. Further, as data collected on measures of outcome grow more specific in many contemporary studies, the chance of finding differences in outcomes increases. For these reasons, CMA are often overlooked as a robust approach for economic comparison and in some scenarios, such as clinical trials, there have been recommendations to avoid them completely.<sup>7</sup>

### Cost-effectiveness analysis

A CEA aims to compare the outcomes and relative costs of two or more medical techniques. It is used when there is a common outcome or outcomes (for example, years of life; toxicity rates; diagnostic or detection rates) for both medical techniques and may report an incremental cost-effectiveness ratio (ICER).<sup>5</sup> The ICER represents the economic value of an intervention compared to a comparator and is calculated by dividing the difference in total costs (incremental cost) between the two medical techniques by the difference in health outcomes (incremental outcomes) (Equation 1):

$$\text{ICER} = (\text{Cost}_1 - \text{Cost}_2) / (\text{Effect}_1 - \text{Effect}_2) \quad (1)$$

Equation 1, where  $\text{Cost}_1$  is the cost of the first technique being analysed, and  $\text{Cost}_2$  is the cost of the second technique being analysed;  $\text{Effect}_1$  is the effect of the first technique, and  $\text{Effect}_2$  is the effect of the second technique.

The acceptable ICER will depend on the health jurisdiction and health priorities. A lower ICER is preferable to the decision maker since it represents a

lower ratio of incremental cost compared to the incremental benefit and is therefore more likely to fall below the willingness to pay (WTP). The WTP is defined as the maximum price a consumer will pay for one unit of a product/service, where the consumer in this setting may be the government body or health service. The effect being measured requires careful consideration from the outset to ensure correct interpretation of the CEA results. Additionally, other factors such as time should be considered (i.e. is the outcome being measured at a time point where maximum effect has occurred for both techniques?).<sup>5</sup>

CEAs are utilised by health policy makers in decision making around investment and/or disinvestment of goods and services. Further evaluation is required where an action is more effective at greater cost; or conversely less effective at lower cost as demonstrated in Figure 1. Generally in health, new techniques or services often have greater effectiveness but at a greater cost, which must be considered by the relevant decision makers.<sup>9,10</sup>

### Radiation Therapy Hypothetical CEA Example

An example of CEA may be the comparison of rectal toxicity in the treatment of prostate cancer when using intensity-modulated radiation therapy (IMRT) compared to volumetric arc radiation therapy (VMAT). Rectal toxicity is the common outcome, and IMRT and VMAT are the different medical technologies analysed. A researcher might collect the time and labour costs associated with the planning, quality assurance and delivery of both treatments as well as the mean acute Common Terminology Criteria for Adverse Events (CTCAE) grading for both patient cohorts. The difference in costs and difference in outcomes would then be divided to produce the ICER.

### Medical Imaging CEA Example

The current challenge when considering cost effectiveness in the context of diagnostic imaging, is the expansion of interventional radiology services, especially advanced neuroradiology and oncology treatments such as Selective Internal Radiation Therapy (SIRTs). Medical imaging techniques, such as mechanical thrombectomy (MT) and aneurysm coiling, are often used as comparators with treatments such as intravenous tissue plasminogen activator (IV tPA) or surgical procedures. Multiple clinical trials and research studies have been initiated to validate the clinical efficacy and cost-effectiveness of such treatment options. An example of a recent publication on the cost-effectiveness of the medical imaging technique

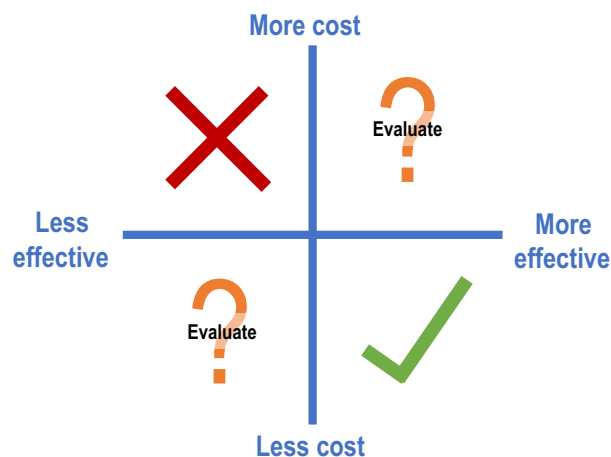


Figure 1. The cost-effectiveness evaluation plane.

MT is that from Ruggeri et al.<sup>11</sup> Initial research from 2013 to 2015 provided the platform to validate the efficacy of the technique, with a proliferation of research following to drive service changes, access and funding in the local context. Supporting research concluded that patients treated with a large vessel occlusion MT combined with tPA was more cost effective than IV tPA alone. Kabore et al.<sup>12</sup> found MT to have improved patient outcomes, lower treatment costs and reduced burden on the health service due to improved patient outcomes.

### Cost-utility analysis

A CUA aims to determine the cost required to change a generic measure of health, the quality-adjusted life year (QALY). A QALY is used to measure both quantity and QoL. Perfect health is given a utility value of 1, and death a utility value of zero, with utility values measured using validated survey tools (such as the EQ-5D standardised instrument, developed by the EuroQol Group<sup>13</sup>). With the assumption that maximising health outcomes with limited resources is the aim of the health decision-maker, and that individuals may move from various health states between perfect health and death, the QALY places a value on the health states. It should also be appreciated that individuals may value levels of health states differently, for example a healthy individual may not place as much value on a small incremental increase in QoL compared to one who is living with a chronic disease that is decreasing their QoL. Therefore, preferences need to be accounted for in weighting QALYs (further detail around which is beyond the scope of this commentary).

As with the CEA, CUA determines the ICER. The utilisation of the QALY generic measure enables the

comparison of different medical services for different patient populations. This is useful for hospital and health policy makers in deciding upon funding priorities. For example, where they are deciding between interventions for cancer patients and cardiac patients. There are, however, some considerations with the use of QALYs, including sensitivities to individual health/conditions, preferences for individuals or groups, and equity.

### Medical Imaging CUA Example

An example of a recent CUA in medical imaging was conducted by Arora *et al.* on the EXTEND-IA trial.<sup>14</sup> This study showed that MT for acute large-vessel ischemic stroke saves one life for every fourteen thrombectomies performed, reduces disability, and is cost-effective when compared with intravenous thrombolysis (IV-tPA) alone. Although the cost of MT was higher than that of IV-tPA initially, it led to savings downstream in the stroke care pathway due to better outcomes and reduced length of stay and rehabilitation costs.

### Radiation Therapy CUA Example

Vanneste *et al.*<sup>15</sup> evaluated the use of spacers to separate the prostate and rectal wall and thus reduce rectal toxicity in men undergoing prostate cancer radiotherapy. A patient cohort with a spacer was compared to a cohort without, finding an increase in QALY in those with a spacer. In calculating the ICER, the authors concluded that the spacer was cost effective in reducing rectal toxicity, and thus a reduction in health care costs associated with the toxicities at a cost of €55,880 per QALY gained which was below the local willingness to pay threshold of €80,000.

### Cost-benefit analysis

CBA seeks to assign a monetary cost to all outcomes (health and non-health) of a medical service and is designed for the unique situation where evidence for a budget expansion, as opposed to reallocation, is desired.<sup>5</sup> The outcome of CBA can be described as a cost-benefit ratio of the net benefit and net costs associated with the intervention, providing an understanding on return of investment. Alternatively, the difference in net cost and net benefit values can be summed when comparing two interventions with the outcome describing whether the intervention is cost-saving or not.

To perform a CBA the cost of the intervention and the cost of the health outcomes of interest need to be calculated. Where the costs of providing an intervention are usually straight-forward to determine, assigning a cost

to the health outcomes is more challenging and is one of the limitations of this approach. In some cases, the health outcome cost can be based on market value, or a hypothetical willingness to pay threshold that is elicited via direct stated preferences of patients.<sup>16</sup> Due to methodological difficulties in acquiring consistent and accurate values of health outcome cost, as well as a resistance to place a monetary value on health outcomes,<sup>16</sup> studies and publications applying CBA are uncommon in the health care setting.

This was no truer than in the medical radiation literature where it was difficult to find a study that applied CBA. One rare example was the evaluation of ultrasound-guided surgery for palpable breast cancer.<sup>17</sup> In this CBA the costs of performing ultrasound-guided surgery were compared against the costs of the standard palpation-guided surgery. Benefits were described as the reduction of additional procedures, such as re-excision or radiotherapy boosts, required by patients who had positive margins following the surgical procedure and these were based on market values. The results of this analysis showed that the sum of differences in cost and benefits favoured the ultrasound-guided approach with a cost saving of €154.<sup>18</sup>

### Incorporating Health Economics into Medical Radiation Research

Clinical application of these analytical methods is influenced by the question being asked and the study resources available. CEA and CUA are the types of economic evaluations more likely to be conducted in the context of healthcare since they assess different patient outcomes and healthcare costs between the intervention and comparator. While there may be a desire to capture all possible patient outcomes and associated costs, these are time and resource intensive tasks that may not be feasible in all health care settings. Rather, evaluating what data is initially available will help direct the health economic methodology. In this final section we briefly look at some practical considerations before initiating a health economic evaluation.

### Prospective data

As with a majority of research methodologies, the most robust health economics data is that which is collected prospectively. It is therefore recommended that in the research study protocol development, the expertise of a health economist is drawn upon to ensure adequate protocol design and data collection. Considerations of common types of cost data are summarised in Table 3. Mitera *et al.*<sup>19</sup> also provides an example of their cost break-down in their CEA.

### Capturing outcome data robustly

It is advisable to collect patient-specific data from baseline (demographic, disease characteristics, health-related QoL), particularly if not routinely collected in the patient’s diagnostic or treatment journey. Additionally, patient and societal costs such as out-of-pocket expenses around travel and loss of income associated with health should be considered. Appropriate approvals including ethics, governance, and consent or consent-waivers must be followed as per National Health and Medical Research Council guidelines<sup>20</sup> and local jurisdiction requirements.

### Retrospective data avenues

Retrospective health economics analyses may be possible and appropriate for certain research questions, particularly those relying on hospital clinical coding, Medicare Benefits Schedule (MBS), and/or Pharmaceutical Benefits Scheme (PBS) data. Data linkage

**Table 3.** Common cost data examples.

Broad Data Category	Data examples
Treatment / test or illness specific costs	<ul style="list-style-type: none"> <li>• Medicare Benefits Schedule (MBS) coding</li> <li>• Pharmaceutical Benefits Scheme (PBS) coding</li> <li>• Hospital clinical coding</li> <li>• Private/public setting</li> </ul>
Labour & Staffing resources (costs and time)	<ul style="list-style-type: none"> <li>• Radiographers/Radiation Therapists</li> <li>• Radiologists/Oncologists</li> <li>• Other staff (e.g. medical physicists, nursing, administration)</li> <li>• Training time requirements for new medical techniques</li> </ul>
Consumables costs	<ul style="list-style-type: none"> <li>• Linen</li> <li>• Sheath covers</li> <li>• Ultrasound gel</li> <li>• Fiducial markers</li> <li>• Thermoplastic masks</li> <li>• Wound care/dressings</li> <li>• Personal protective equipment</li> </ul>
Hardware/Machinery and Physical Space costs	<ul style="list-style-type: none"> <li>• New technology/equipment purchase and installation</li> <li>• Ongoing servicing and maintenance costs</li> <li>• Clinic/exam room builds</li> <li>• Procedure room fit outs and/or remodelling</li> <li>• Lifetime of equipment</li> </ul>
Patient and Societal costs	<ul style="list-style-type: none"> <li>• Travel</li> <li>• Loss of work/income</li> <li>• Carer loss of work/income</li> </ul>

projects may strengthen the retrospective data, such as the CancerCostMod project, which brings together cancer diagnosis details in Queensland with Queensland Health Admitted Patient Data Collection, Emergency Department Information System, Medicare Benefits Schedule, and Pharmaceutical Benefits Scheme.<sup>21</sup> When feasible, qualitative or survey methods may ascertain approximate costs, however this can be particularly prone to recall bias.

### Perspectives

Another important consideration is the perspective taken in any health economics analysis. The needs and priorities will differ depending upon the perspective in consideration (Table 1). For example, an individual may value reduced number of oncology follow up appointments in person compared to telehealth appointments, as this reduces the amount of travel costs associated in attending these appointments. The healthcare decision maker may however only be concerned in these associated travel costs if they are paying a subsidy. Multiple perspectives may be considered in an analysis (Table 1); however, it is important that perspective/s are clearly defined in the development of the analysis.

### Additional Resources

Again, we recommend the researchers engage with health economists early in the project and study protocol development when considering a health economics analysis. The Australian Health Economics Society maintains a list of health economics research centres within Australia.<sup>22</sup> Increasingly, health economics research centres are offering workshops and courses for the clinician. Additionally, we suggest ‘Methods for the Economic Evaluation of Health Care Programmes’ by Drummond et al.<sup>5</sup> as a good resource.

### Conclusion

As the medical radiation field continues to be a rapidly developing and technologically driven profession, health economics analysis is of great importance to ultimately lead to improved access for patients to cost-effective medical techniques. We therefore urge all medical radiation professionals to consider incorporating health economics into future research protocol development. Including health economics analysis within our field will ensure we continue to optimise patient care and outcomes in both medical imaging and radiation oncology with the limited resources of the healthcare system.

## Acknowledgements

Scott and Amy acknowledge the support and encouragement of Dr Cathy Hargrave and the Queensland Health State-wide Radiation Therapy Research Leadership Group. Vanessa acknowledges the input and support of Dr John Clouston and Ms Marita Prior, PhD.

## References

- Smith PC. Measuring Value for Money in Healthcare: Concepts and Tools. The Health Foundation, London, 2009.
- Duchesne GM, Grand M, Kron T, et al. Trans Tasman Radiation Oncology Group: Development of the Assessment of New Radiation Oncology Technology and Treatments (ANROTAT) Framework. *J Med Imaging Radiat Oncol* 2015; **59**: 363–70.
- Lievens Y, Dunscombe P, Defourny N, Gasparotto C, Borrás JM, Grau C. HERO (Health Economics in Radiation Oncology): a pan-European project on radiotherapy resources and needs. *Clin Oncol (R Coll Radiol)* 2015; **27**: 115–24.
- Committee MSA. Technical Guidelines for preparing assessment reports for the Medical Services Advisory Committee – Medical Service Type: Therapeutic. In: Australian Government DoH, ed. 2.0 ed: Australian Government; 2016.
- Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. Methods for the Economic Evaluation of Health Care Programmes, 4th edn. Oxford University Press, Oxford, 2005.
- Webb A. Handbook of Intensive Care Organization and Management, 1st edn. Imperial College Press, London, 2016.
- Dakin H, Wordsworth S. Cost-minimisation analysis versus cost-effectiveness analysis, revisited. *Health Econ* 2013; **22**: 22–34.
- Gill S, Younie S, Rolfo A, et al. Cost minimisation analysis: Kilovoltage imaging with automated repositioning versus electronic portal imaging in image-guided radiotherapy for prostate cancer. *Clin Oncol* 2012; **24**: e93–9.
- Council NHMR. How to Compare the Costs and Benefits: Evaluation of the Economic Evidence. Biotext, Canberra, ACT, Australia, 2001.
- Brouwer W, van Baal P, van Exel J, Versteegh M. When is it too expensive? Cost-effectiveness thresholds and health care decision-making. *Eur J Health Econ* 2019; **20**: 175–80.
- Ruggeri M, Basile M, Zini A, Mangiafico S, Clemente Agostoni E, Lobotesis K. Cost-effectiveness analysis of mechanical thrombectomy with stent retriever in the treatment of acute ischemic stroke in Italy. *J Med Econ* 2018; 902–11.
- Kabore N, Marnat G, Rouanet F, et al. Cost-effectiveness analysis of mechanical thrombectomy plus tissue-type plasminogen activator compared with tissue-type plasminogen activator alone for acute ischemic stroke in France. *Rev Neurol (Paris)* 2019; **175**: 252–60.
- Herdman M, Gudex C, Lloyd A, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual Life Res* 2011; **20**: 1727–36.
- Arora N, Makino K, Tilden D, Lobotesis K, Mitchell P, Gillespie J. Cost-effectiveness of mechanical thrombectomy for acute ischemic stroke: an Australian payer perspective. *J Med Econ* 2018; **21**: 799–809.
- Vanneste BG, Pijls-Johannesma M, Van De Voorde L, et al. Spacers in radiotherapy treatment of prostate cancer: is reduction of toxicity cost-effective? *Radiother Oncol* 2015; **114**: 276–81.
- Frew E. Applied Methods of Cost-benefit Analysis in Health Care. Oxford University Press, Oxford, 2010.
- Haloua MH, Krekel NMA, Coupé VMH, et al. Ultrasound-guided surgery for palpable breast cancer is cost-saving: Results of a cost-benefit analysis. *Breast* 2013; **22**: 238–43.
- Goodman DA, Zonfrillo RM, Chiou PD, Ebersson IC, Cruz IA. The cost and utility of postreduction radiographs after closed reduction of pediatric wrist and forearm fractures. *J Pediatr Orthop* 2019; **39**: e8–11.
- Mitera G, Swaminath A, Rudoler D, et al. Cost-effectiveness analysis comparing conventional versus stereotactic body radiotherapy for surgically ineligible stage I non-small-cell lung cancer. *J Oncol Pract* 2014; **10**: e130–6.
- National Health and Medical Research Council. Australian Code for the Responsible Conduct of Research, 2007.
- Callander E, Topp SM, Larkins S, Sabesan S, Bates N. Quantifying Queensland patients with cancer health service usage and costs: study protocol. *BMJ Open* 2017; **7**: e014030.
- Australian Health Economics Society, 2018 [cited 16 August 2019]. Available from: <https://www.ahes.org.au/>.