The EOS 2D/3D X-ray imaging system: a cost-effectiveness analysis quantifying the health benefits from reduced radiation exposure

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Record Status
This is a critical abstract of an economic evaluation that meets the criteria for inclusion on NHS EED. Each abstract contains a brief summary of the methods, the results and conclusions followed by a detailed critical assessment on the reliability of the study and the conclusions drawn.

CRD summary
The study evaluated the cost-effectiveness of the EOS imaging system for diagnosing and monitoring orthopaedic conditions. The authors concluded that unless EOS image quality and nature generated additional health benefits, throughpunt determined cost-effectiveness. A lack of available evidence limited the evaluation. The authors conclusions were reasonable based on available single indication evidence but considerable uncertainty remains and further research is advisable.

Type of economic evaluation
Cost-utility analysis

Study objective
To evaluate the cost-effectiveness of the EOS two-dimensional or three-dimensional (2D or 3D) X-ray imaging system for diagnosing and monitoring of orthopaedic conditions.

Interventions
EOS is a biplane X-ray imaging system with the ability to scan in 2D/3D or create biplane images while a patient is upright in a weight-bearing position. It can take full body images without digital or manual image stitching, take simultaneous posteroanterior and lateral images, and produce 3D spinal reconstructions. The comparator was standard x-ray (computed radiography and digital radiography) which represented standard practice in the UK NHS.

Location/setting
UK/Outpatient

Methods
Analytical approach:
A lifetime decision analytical model was developed to quantify the long-term outcomes associated with the different imaging technologies. The primary benefit of EOS is to provide radiographic imaging at relatively low-dose radiation. Therefore, the model considered long-term costs and consequences associated with radiation exposure. Orthopaedic indications were evaluated (scoliosis, congenital kyphosis, ankylosing spondylitis, Scheuermann's disease and other deforming dorsopathies and congenital deformities of the hips and lower limbs). The analysis was undertaken from the perspective of the UK NHS.

Effectiveness data:
A systematic review of the effectiveness of EOS compared to standard X-ray modalities was undertaken; full details of the systematic review were published elsewhere (see Other Publications of Related Interest). The systematic review found no differences in patients health outcomes in terms of either lower radiation dose or health benefits derived from image quality.

The authors used the ratio of entrance surface radiation dose (radiation absorbed by the skin) for EOS compared to computed radiography to modify effective radiation doses (radiation absorbed by the body) for computed radiography and generate an effective radiation dose reduction for EOS. The dose reduction was assumed based on synthesis of two published papers identified in the review. Effective radiation doses for different imaging technologies (computed radiography and digital radiography) were derived from the UK Health Protection Agency. Radiation dose was
translated into cancer risk using published risk data from the UK Health Protection Agency.

**Monetary benefit and utility valuations:**
In the absence of cancer models for all types of cancer, a weighted average of QALYs (quality-adjusted life years) for four cancers (breast, colorectal, prostate and lung) was used to provide an estimate of QALYs associated with all cancer. This weighting was based on incidence of radiation-induced cancer reported by type of cancer.

**Measure of benefit:**
The primary measure of benefit was QALYs gained from cancer risk reduction. Benefits were discounted at 3.5% annually.

**Cost data:**
All costs were reported in UK pounds sterling (£). Costs included the price of the scanning unit (derived from the manufacturer for EOS and derived from expert advice for computed radiography and digital radiography) and set-up and recurring costs. Recurring costs included maintenance and other recurring costs (cassettes for computed radiography; software upgrades for digital radiography). Set-up and recurring costs were annuitised over 10 years at a rate of 3.5% per annum. Two throughput assumptions were tested: one where throughput was assumed at 30 per working day and another that assumed 48 patients per working day. As with QALYS, a weighted average of four cancers was used to provide a cost associated with all cancers. Costs were discounted at 3.5% annually.

**Analysis of uncertainty:**
Due to high levels of uncertainty, numerous scenario and threshold analyses were undertaken. Scenario analyses: changed age assumptions for onset of radiation-induced cancer diagnosis from 60 to 40 years for breast cancer, 72 to 55 years for lung cancer and 74 to 55 years for colorectal and prostate cancer (lower than the general population); used the highest dose reduction ratio of entrance surface dose for EOS compared to standard X-ray; used lifetime risk estimates for radiation-induced cancer reported in an alternative published source; reduced the radiation dose of digital radiography to two-thirds that of computed radiography; and compared EOS to digital radiography (computed radiography was base-case). Threshold analysis was conducted to determine the throughput necessary or the additional QALYs necessary to make EOS cost-effective.

**Results**
Base-case results and sensitivity analyses were presented in tables with benefits, costs and ICERs (incremental cost-effectiveness ratios) reported for each indication. In the base-case analysis, computed radiography was the primary comparator; digital radiography was more expensive and not more effective so it was excluded.

Across the range of indications computed radiography resulted in a maximum health loss of 0.001 QALYs (in deforming dorsopathies in non-adult) and EOS was associated with a maximum health loss of 0.00015 in the same indication. This resulted in a improvement in health gained from using EOS of up to 0.000869 QALYs.

Two different throughput scenarios were evaluated: in scenario one throughput for both computed radiography and EOS was assumed to be 30 patients per working day; and in scenario two throughput for EOS was assumed to be 48 per working day and throughput for computed radiography remained at 30. For scenario one, the increase in costs for EOS was between £10.66 and £224.47 per patient depending on indication. For scenario two, the increase in costs for EOS was between £5.19 and £111.47 per patient depending on indication. For both throughput scenarios, all EOS ICERs were greater than conventional thresholds of £20,000 to £30,000 per QALY.

Sensitivity analyses generally showed that throughput would have to increase and/or health gains from EOS would have to be significantly higher for EOS to be considered cost-effective.

**Authors’ conclusions**
The authors concluded that cost-effectiveness will be determined by throughput unless EOS can generate additional health benefits from the nature and quality of the image.

**CRD commentary**

Interventions:
The interventions were generally clearly reported and appeared appropriate.

Effectiveness/benefits:
A systematic review was conducted appropriately and revealed no evidence of health benefit to patients so the decision model focused on increased cancer risk related to exposure to radiation. The reduction in radiation dose to the body was measured via entrance surface dose. Two studies identified as part of the review were used to derive an estimate. It was unclear how synthesis of these studies was conducted. Wide uncertainty estimates were appropriate around this estimate but this was not clearly reflected in sensitivity analyses. The induced risks for cancers were not reported and the mechanism for transformation of radiation dose to cancer risk was not entirely clear. QALY losses due to cancer were derived from published modelling studies for the different types of cancers but it was unclear how or why these models were selected. A full report is available and further details may be presented there.

The scope of the analysis was restricted to orthopaedic conditions that require radiographic monitoring over time. It was not clear whether EOS may have additional uses outside of load-bearing scans in these conditions. The scope of the analysis may not fully capture the benefits and risks of employing the technologies.

Costs:
Costs were derived by soliciting the manufacturer for EOS and by consulting expert advice and hospital records for computed radiography and digital radiography and patient throughput estimates. The assumptions were clearly presented but it was not clear whether the assumptions of identical or greater throughput for EOS were justified. Given that all throughput, resource use and cost data were based on expert opinion, wide uncertainty intervals should have been assumed around for application in a probabilistic sensitivity analysis.

Throughput was assumed based on expert opinion. It was not clear whether throughput was driven by limitations in demand or limited capacity. Where capacity drives throughput, a quicker scanning technology will have more favourable throughput. A better understanding of how throughput was determined would aid decision making.

It was not clear whether throughput data were specifically for the indications listed or whether these included all potential indications for the technologies.

Analysis and results:
The study gave detailed reporting of methods and results for all base-case and sensitivity analyses for every condition individually. However, EOS and computed radiography would not be used for only one of the indications so a more comprehensive approach to modelling a throughput of a more mixed population of indications may have been appropriate.

The model was driven largely by throughput assumptions and data assumptions that were often derived from elicitation. Several scenario analyses were presented but it was unclear whether the uncertainty around these assumptions was fully characterised. The authors acknowledged that these assumptions were based on was poor data without standard deviations. This complicates probabilistic analysis of uncertainty but does not prevent analysis. A probabilistic analysis that incorporated broad uncertainty in assumptions would provide potentially valuable information for decision making and could have been undertaken.

Concluding remarks:
A lack of available evidence limited the evaluation. The authors’ conclusions were reasonable based on available single-indication evidence but considerable uncertainty remains and further research is advisable.

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