NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE

DIAGNOSTICS ASSESSMENT PROGRAMME

Evidence overview

EOS 2D/3D X-ray imaging system

This overview summarises the key issues for the Diagnostics Assessment Committee's consideration. It includes a brief description of the topic, a description of the analytical structure and model, a discussion of the analytical difficulties, and a brief summary of the results. It is not a complete summary of the diagnostics assessment report (DAR), and it is assumed that the reader is familiar with that document. This overview contains sections from the original scope and the DAR, as well as referring to specific sections of that reportDAR.

1 Background

1.1 Introduction

The EOS 2D/3D X-ray imaging system was referred by the Medical Technologies Advisory Committee (MTAC) for recommendations on its use for imaging in the vertical weight-bearing position. The product was expected to be particularly useful for conditions in which the weight-bearing position was important, namely orthopaedic conditions of the spine and lower limbs. The potential additional benefits of the product were that it took simultaneous PA and lateral images that could be combined to create 3D reconstructions of bony structures, it provided faster imaging, and it required a significantly lower radiation dose than imaging systems in current use. The EOS system is significantly more expensive than current computed radiography (CR) and digital radiography (DR) imaging systems and has a lower resolution.

1.2 The condition(s)

As described in the scope, the EOS system can be used for many types of radiological examinations. However, it has particular benefits when a reduced radiation dose, weight-bearing imaging, full body imaging, or simultaneous PA and lateral imaging are important. It also produces 3D surface images, but clinical experts did not consider this a particularly important feature at present.

The clinical experts agreed that the most important uses for consideration were the management of spinal deformities and lower limb problems (such as leg length discrepancy, leg alignment and conditions that affect the hip and knee).

The indications included in the scope were been divided into those affecting children and adolescents and those affecting adults.

- In children and adolescents:
    - spinal deformity, principally scoliosis but also other conditions such as Scheuermann's disease
    - leg length discrepancy and leg alignment.
- In adults:
    - spinal deformity, including degenerative scoliosis, progressive kyphosis and osteoporotic fractures
    - loss of sagittal and coronal balance, including issues relating to hip and knee for which full body or full leg length images are currently requested.

For children and adolescents, the most important spinal deformity for this evaluation is scoliosis because of the need for repeated imaging and the impact of radiation dose. However, other spinal deformities may also be considered. Leg length discrepancy and leg alignment issues in children and adolescents are also included in the scope because their diagnosis requires the stitching together of multiple images.

For adults, the principal spinal deformities are related to degenerative diseases leading to arthritic changes, kyphosis or scoliosis. In some cases, problems resulting from adolescent scoliosis may also appear in adulthood. In adults hip and knee imaging may be needed for replacement planning and other degenerative changes that require full leg and hip or full body radiographs.

During the assessment phase, the external assessment gGroup (EAG) withdrew some of the conditions that were initially included in the scope. These included lordosis, acquired kyphosis, neurofibromatosis, osteoporotic fracture and issues relating to hip and knee replacement where full body or full leg length images are currently requested. Lordosis was not considered

because it is very rare on its own and according to the clinical experts is associated with scoliosis. Therefore the inclusion of scoliosis should encompass people with lordosis secondary to scoliosis. Acquired kyphosis and neurofibromatosis were excluded because of the large variation in patient groups and the relatively small numbers needing surgery. Osteoporotic fracture was not considered because it is usually not associated with spinal deformity.

Additional descriptions of the conditions can be found on pages 27–30 of the DAR.

1.3 Diagnostic and care pathways

The management of spinal deformity primarily involves monitoring at intervals to assess disease progression and to guide treatment decisions. Progression is measured in terms of the degree of spinal curvature, which is typically monitored using serial upright weight-bearing X-rays. The frequency of monitoring depends on age, the rate of growth at the time and the nature of the spinal curvature. The pattern of monitoring for kyphosis and other deforming dorsopathies is broadly similar to that for scoliosis, which tends to range from every 4 months to almost every 2 years. People are also monitored using weight-bearing X-rays before and after surgery, for up to 2 years or up to the age of 20 years. People with congenital deformities of the lower limbs, hips or spine are likely to have surgery at a younger age than people with scoliosis, kyphosis or other deforming dorsopathies. Therefore, the duration of the X-ray monitoring is shorter.

A weight-bearing image is important for evaluating deformities of the spine due to the effect of gravity. The American College of Radiology Practice Guideline for the Performance of Radiography for Scoliosis in Children recommends PA and lateral radiography of the spine obtained in an upright position for initial or screening examination. Non-weight-bearing images are open to misinterpretation and misdiagnosis. Full body images can also help prevent misinterpretation of the spinal curvature by providing information about the position of the pelvis and legs.

2 The technology

The EOS device is a biplane X-ray imaging system manufactured by EOS imaging (formerly Biospace Med, Paris). It uses slot-scanning technology to produce a high-quality image with less irradiation than standard imaging techniques. EOS allows the acquisition of images while the patient is in an

upright weight-bearing (or seated or squatting) position, and can image the full length of the body (up to 175 cm), removing the need for digital stitching. Imaging takes approximately 20 seconds for an adult full body scan and 4–6 seconds to scan the spine, depending on the person's height.

The EOS system takes PA and lateral images simultaneously, and the digital image is available immediately on a 2D workstation. A 3D image can be reconstructed on a separate workstation using the PA and lateral images and a statistical 3D spine model, generated from a database of images from people with scoliosis. The reconstruction of a 3D image takes 5–10 minutes for each part of the skeleton (for example, the spine or femur).

The acquisition cost of the EOS system in the UK is about £400,000, with an annual maintenance cost of £32,000 plus X-ray tube replacement every 3–5 years at a cost of £25,000. The EOS system needs the same room planning and shielding as a general X-ray room and the same radiation protection protocols apply. EOS is not currently in use in the NHS.

The comparator technology is upright conventional imaging using either film, computed or digital radiography. These systems cannot take simultaneous PA and lateral images and images need to be stitched together to cover larger areas of the body. Also because the X-ray source doesn't move, as it does with EOS, there is some distortion in the images.

3 The evidence

3.1 Test accuracy

The assessment team identified two studies of the EOS and one of a predecessor technology using the same or similar sensors. The studies showed equivalent or better image quality with EOS as compared with film (two studies) and computed radiography (one study). Detailed studies of accuracy and the impact on treatment decisions were not found.

3.2 Clinical outcomes

Clinical outcomes other than the effects of radiation dose were not directly analysed by the external assessment group because of a lack of data. Although the original protocol allowed for expert elicitation to be performed to estimate changes in outcome associated with imaging improvements for the various conditions, time and resource constraints prevented this from occurring. No estimates of patient benefit from improved imaging were given,

but the cost-effectiveness analysis included some modelling of what those benefits would need to be in order for EOS to be cost effective.

The clinical outcome examined was the effect of a reduced radiation dose with the EOS compared with CR and DR. Because is cheaper than DR and has equivalent dose levels, DR was considered dominated and the analysis was based on CR. Extensive modelling of the impact of radiation on future cancer was performed. This modelling was restricted to the most prevalent forms of cancer, namely breast, lung, colorectal and prostate. Incremental quality-adjusted life years (QALYs) from cancer reduction in the base case varied by indication from about 0.0001 to 0.0009 (see DAR table 4.19).

3.3 Costs and cost effectiveness

The EOS machine is 3-4 times the cost of CR or DR machines (see DAR page 90). This makes achieving cost-effectiveness difficult since there must either be significant operational savings or significant patient benefits to counterbalance the additional costs.

The analysis was performed using two primary measures of benefit: throughput and benefits associated with cancer reduction. The cancer reduction benefits have been discussed above. The issue of throughput was modelled using three different assumptions about the throughput of the EOS machine. The base-case throughput assumption (TA1) was based on using a single machine for the entire country and limiting use to only the number of cases of the studied conditions that actually exist in the country with no other use of the machine. Additional throughput assumptions were based on full use of the machine for the indicated uses at the same number as CR, namely 30 cases per day (TA2) or at a higher throughput, specifically, 48 cases per day (TA3). Because there are not enough cases of the indicated conditions to make full use of the machine, these last two assumptions were used to see if the machine could be cost-effective if in full use. If that were the case, then further analysis would be needed to see whether including the use of the the machine for other conditions could still be cost-effective. Thirty cases per day was the assumed rate of utilisation of the comparator. One reason the higher throughput of 48 cases per day may be justified is that the EOS can take simultaneous PA and lateral images.

The base-case analysis showed the incremental cost-effectiveness ratio (ICER) to range from approximately £148,000 to over £15,000,000 depending on the indicated use (see DAR table 4.19). The width of this range is driven primarily by the fact that the base case limits the use of the machine to the

estimated number of cases of the studied conditions. For the throughput assumptions that are not limited by number of cases, the ICERs range from about £97,000 to £700,000 (TA2) and £47,000–£351,000 (TA3) (see DAR table 4.20). These are all still much higher than the usual cost–effectiveness thresholds of £20K-£30K.

Additional scenarios were run to model (see DAR Table 4.18):

- reduced age for cancer diagnosis (55 years vs. population norm)
- reduced discount rate (0% vs. 3.5%)
- further reductions in radiation dose (3 times the reduction of base case)
- probabilistic modelling of QALYs gained from cancer reduction
- increased cancer risk from radiation (using 1999 US data vs. newer models from personal communications from the Health Protection Agency)
- Reduced radiation dose from DR to 2/3 of CR and comparing to DR.

None of these scenarios reduced the ICER to less than £30,000 with throughput assumptions TA1 and TA2. The earlier age for cancer diagnosis or the alternative risk data did reduce the ICER to less than £30,000 for scoliosis and Scheuermann's disease in adolescents for throughput assumption TA3 (see DAR page 108 and tables 4.22 and 4.26).

Threshold analysis was performed to determine what level of additional benefits from imaging improvements would be required to reach cost-effectiveness for each of the three throughput assumptions. This showed that additional QALYs required for cost-effectiveness ranged from 0.0002 to 0.435, depending on the throughput assumptions and the condition being imaged (see DAR section 4.7.1). Threshold analyses of QALY gains required to reach an ICER of £20,000 under the six scenarios listed above varied from less than 0.001 to over 700 hundred depending on the scenario, the condition, and the throughput assumptions (see DAR tables 4.22 to 4.27 and pages 112–117).

4 Issues for consideration

1. The base case (with throughput assumption TA1) was limited by the use of the technology for people with the conditions studied and was further limited because many of the indications set out in the scope

were omitted. However, the base case assumed that only one machine would be used and this reduced the overall costs. Limiting the use of the technology is probably unwarranted because everyone imaged would likely receive some benefit from a reduced radiation dose and the system is apparently suitable for a variety of imaging needs beyond those modelled. Two other cases were also modelled: one which assumed that the EOS had the same throughput as CR (TA2) and one that assumed increased throughput (TA3). Because the EOS system takes PA and lateral images simultaneously, it might have greater throughput than CR although the level of throughput increase is unknown.

2. The analysis was based on future cancer reduction from reduction in radiation dose. Because of lack of evidence, the impact of any imaging improvements was only covered by a threshold analysis. The number of QALYs from imaging improvement, on average, needed to reach cost-effectiveness can be small depending on the throughput assumptions. For the TA2 assumptions, the amount needed ranged from less than 0.001 to about 0.01 (see DAR page 107); this was less for TA3. Although these numbers are large compared with the QALYs achieved by reducing the radiation dose, they are possible if there is actual clinical benefit from improved imaging. It is unclear whether such clinical benefits exist.

3. In the base case, the modelling of cancer reductions from reducing the radiation dose assumed that radiation-induced cancers occur at the same age as the cancer occurs in the general population. For those receiving radiation at young ages, this assumption may be unrealistic because it would involve cancers emerging more than 50 years after the radiation dose. A scenario was modelled with many cancers occurring at age 55 (scenario 1). In this case, some ICERs actually fell into the possibly cost-effective range under the TA3 assumption, even with no improvements in imaging quality (see AR page 108 and table 4.22). It is not known whether 55 is the correct age or whether a younger or older age should be used.

4. Only a few common cancers were included. Although these probably would produce most of the QALYs that would be associated with reducing the radiation dose, there may have been greater benefits from including other cancers.

5. Because the benefits from cancer reductions occur late in life, discounting greatly reduces the benefits for young people. For older people, benefits are also reduced by competing mortality risks before the development of a cancer. The effect of discounting for younger patients was estimated in scenario 2 (see DAR table 4.23) by assuming no discounting. Again for TA3 throughput assumptions, the ICERs were below £30,000 for most conditions. NICE methods generally specify that discounting be used, however.

6. The benefits for people with indications other than those examined in the diagnostics assessment report would need to be estimated if it was felt that the EOS system would be cost-effective under throughput assumption TA2 or TA3. In that case, the system could not be used exclusively for people with the studied indications. Unless there were very large additional benefits accruing from improved imaging of people with the studied indications, all patients imaged by the EOS would need similar levels of benefit from either imaging improvements or radiation dose reduction for the overall system to be cost-effective. The dose reduction effects might be achievable if the dose reductions apply to other conditions because radiation dose effects are usually linear. Improvements in imaging are less likely.

5 Summary

There is considerable uncertainty about the impact of the EOS 2D/3D X-ray imaging system on patient outcomes based on the currently available evidence. There is evidence that there would be some benefit from reduced radiation Dose. Under most of the scenarios and assumptions modelled by the external assessment group, the EOS system, at its current price, did not appear to be cost-effective. However, under some sets of plausible assumptions, the system may be cost-effective. Much of the uncertainty centres around any benefits that accrue from possibly faster throughput and from improved imaging.

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March 2011

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March 2011