

NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE

Diagnostics consultation document The EOS 2D/3D X-ray imaging system

Note that this document is not NICE's final guidance on this technology. The recommendations in section 1 may change after consultation.

1 Provisional recommendations

- 1.1 The evidence indicated insufficient patient benefit in terms of radiation dose reduction and increased throughput to justify its cost. No evidence was identified on patient benefits from the EOS system's imaging features including 3D imaging and weight bearing whole body imaging and simultaneous 2 view imaging. The EOS 2D/3D X-ray imaging system is therefore not recommended for routine use in the NHS.
- 1.2 The EOS 2D/3D X-ray imaging system is recommended for use in research settings to collect evidence about potentially important clinical benefits associated with 3D imaging, simultaneous posteroanterior (PA) and lateral imaging, and whole body imaging in a single image.

2 The technology

- 2.1 The EOS 2D/3D X-ray imaging system from EOS Imaging (formerly Biospace Med) is a novel device that takes 2D X-ray images similar to those derived by conventional means but can also make 3D reconstructions for some bony body parts. It differs from

conventional film, computed, and digital radiography systems in several respects. First, it uses slot-scan technology (that is, scanning a line at a time rather than taking the entire image at the same instant) to vertically scan all or part of the body in a weight-bearing position. Second, it takes simultaneous images in two planes (PA and lateral). Third, by using computer models, it can construct 3D surface images from the simultaneous two-plane images. Additional details are provided in section 4.

3 Clinical need and practice

The conditions

3.1 The EOS 2D/3D X-ray imaging system can be used for many types of radiological examinations, but is likely to offer particular benefits for weight-bearing imaging, full body imaging, and simultaneous PA and lateral imaging or where reduce radiation dose is important.

3.2 The experts agreed that the most important applications of this technology for inclusion in the scope 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 (notably hip and knee replacement planning)).

3.3 The indications included in the scope can be divided into those affecting children and adolescents and those affecting adults.

Indications in children and adolescents included:

- spinal deformity, principally scoliosis but also including other conditions such as Scheuermann's disease
- leg length discrepancy and alignment.

Indications in adults included:

- spinal deformity, including degenerative scoliosis, progressive kyphosis and osteoporotic fractures

- loss of sagittal and coronal balance, including issues relating to the hips and knees for which full body or full leg length images are currently requested.

3.4 The management of scoliosis and other spinal deformities involves repeated imaging, which leads to increased radiation exposure, a particular concern for children and adolescents. Leg length discrepancy and leg alignment problems in children and adolescents are often assessed and monitored with multiple images that may require stitching together (that is, aligning and combining).

3.5 For adults, the principal spinal deformities are those associated with degenerative diseases that lead to arthritic changes, kyphosis or scoliosis. In some cases, problems resulting from adolescent scoliosis may appear with other symptoms in adulthood. Full leg and hip or full body radiographs may be used to diagnose and manage degenerative conditions of the hips and knees, and may also be used to plan joint replacement.

3.6 During the initial phase of this assessment, the External Assessment Group (EAG) identified no evidence for some of the conditions that were initially included in the scope and, therefore, did not include these conditions in the Diagnostics Assessment Report (DAR – see appendix C). These conditions included lordosis, acquired kyphosis, neurofibromatosis, osteoporotic fracture and issues relating to hip and knee replacement for which full body or full leg length images are currently requested. According to clinical experts, lordosis is very rare on its own and is almost always associated with scoliosis. Therefore the inclusion of scoliosis should encompass patients with lordosis secondary to scoliosis. Acquired kyphosis and neurofibromatosis were excluded because of high variability in patient groups and the relatively small numbers of patients needing surgery. Osteoporotic fracture was not

considered because clinical experts advised that it is only rarely associated with spinal deformity.

The diagnostic and care pathways

- 3.7 The management of spinal deformity primarily involves monitoring at intervals to assess disease progression and guide treatment decisions. Progression is measured in terms of the degree of spinal curvature, which is typically monitored using serial X-rays in the upright weight-bearing position. The frequency of monitoring depends on the age of the patient, their rate of growth and the nature of the curvature. The frequency 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 2 years. Patients are also monitored using X-rays in the weight-bearing position before surgery, for up to 2 years after surgery or up to the age of 20 years. Patients with congenital deformities of the lower limbs, hips or spine are likely to undergo surgery at a younger age than patients with scoliosis, kyphosis or other deforming dorsopathies. Therefore, X-ray monitoring for congenital deformities usually continues for a shorter period.
- 3.8 Imaging in the weight-bearing position is important for evaluating deformities of the spine because of 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 in an upright position for initial examination or for screening. Imaging in a non-weight-bearing position can lead to misinterpretation of images and misdiagnosis. Full body images also provide information about the position of the pelvis and legs and so help to avoid misinterpretation of the degree of spinal curvature.

4 The diagnostic tests

The referred technology: EOS 2D/3D X-ray imaging system

- 4.1 EOS 2D/3D X-ray imaging system is a biplane system that uses slot-scanning technology to produce an image of comparable or better quality with less irradiation than standard imaging techniques. The EOS system allows imaging 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 'stitching' of multiple images. The system takes approximately 20 seconds for an adult full body scan and 4–6 seconds to scan just the spine, depending on the patient's height. As for all spine radiographs, the patient is asked to remain still, with their arms folded at 45°, and to hold their breath during the scan.
- 4.2 The EOS system takes PA and lateral images simultaneously, using a c-shaped imaging device. The digital image is available immediately on a 2D workstation. A 3D image can be reconstructed on the separate sterEOS workstation using the PA and lateral images and a statistical 3D spine model, generated from data from multiple patients 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 EOS system takes up a similar amount of space and uses a similar amount of power as other computed or digital X-ray suites.
- 4.3 The acquisition cost of the EOS system in the UK is approximately £400,000, with a current annual maintenance cost of approximately £32,000. The maintenance contract covers all parts except X-ray tubes, which require replacement every 3–5 years at a cost of approximately £25,000 (including fitting). In addition to the cost of purchasing and maintaining the equipment, there may be some building costs if existing rooms complying with radiation legislation

requirements are not available. The EOS system requires the same room planning and shielding as a general X-ray room and the same radiation protection protocols apply. The EOS system is not currently in general use in the NHS, although it has been used in research settings.

The comparator: conventional radiography

- 4.4 Currently available imaging technologies that can be used in an upright weight-bearing position include X-ray film, computed radiography and digital radiography, although X-ray film has been replaced by computed radiography and digital radiography in standard UK practice. X-ray film, computed radiography and digital radiography can only take images from one angle at a time; simultaneous PA and lateral images, and 3D reconstruction are not possible. When a full body image is required, these conventional X-ray imaging technologies need adjustment for distortion or stitching of multiple images.
- 4.5 The acquisition cost of a computed radiography system is approximately £95,000, with an annual maintenance cost of approximately £10,000. Cassettes for computed radiography need replacing every 3–5 years at a cost of £150–200. The acquisition cost of a digital radiography system is between approximately £105,000 and £230,000, with an annual maintenance cost of approximately £18,000. Upgrading software to improve the functionality and performance of digital radiography costs approximately £2000 which were assumed to occur every 4 years.

5 Outcomes

The Diagnostics Advisory Committee (appendix B) considered a review of the evidence by the External Assessment Group (EAG, appendix C).

How outcomes were assessed

- 5.1 The assessment consisted of a systematic review of clinical effectiveness data for the EOS system for the conditions described in the scope followed by modelling to assess final patient outcomes and cost effectiveness when evidence was found. Because no studies followed patients to final outcomes, modelling was necessary to assess clinical effectiveness as well as cost effectiveness. Descriptions of the systematic review process are contained in chapter 4 of the DAR. The only relevant data uncovered dealt with image quality and radiation dose reduction.
- 5.2 Three studies of image quality were found – two comparing the EOS system with X-ray film (Kalifa et al. 1998; Le Bras et al. unpublished data) and one comparing it with computed radiography (Deschênes et al. 2010). All found images from the EOS system to be comparable or better than the comparator in most cases. These studies also reported radiation dose reductions with ratios of means ranging from 2.9 to 18.8 depending on the study and body part imaged. No direct comparisons with digital radiography were found, but similar dose reductions were assumed in the base-case models. A separate scenario assuming that digital radiography used two-thirds the radiation dose of computed radiography was also modelled.
- 5.3 Additional reviews were conducted to establish the impact of radiation dose reduction. Two different approaches to modelling cancer risk, identified in these reviews, were included in the assessment. These included data from a personal communication

from the Health Protection Agency and data from the BIER VII phase 2 report.

Test accuracy intermediate outcomes

- 5.4 No data were found to specifically compare the diagnostic accuracy of the EOS system with that of conventional radiological examinations beyond the three studies (described above) which showed comparable or better images. No evidence for sensitivity and specificity of the EOS system for any specific condition was uncovered.

Clinical outcomes

- 5.5 The only clinical outcomes assessed came from modelling and were restricted to the impact of radiation dose reduction. Although direct evidence was available showing significant dose reductions with the EOS system, modelling was needed to link dose reduction to reduced cancer occurrence. The base-case analysis used computed radiography as the comparator because it is cheaper than digital radiography and has equivalent radiation doses. Extensive modelling of the impact of radiation dose on future cancer was performed. The basic structure of the model is shown in appendix A. The modelling explored only the most prevalent forms of cancer, namely breast, lung, colorectal and prostate. In the base case, incremental quality-adjusted life years (QALYs) from cancer reduction as a result of radiation dose reduction varied by indication from about 0.0001 to 0.0009.

Cost and cost effectiveness

- 5.6 The EOS system costs 3-4 times as much as computed radiography machines and 2–3 times as much as digital radiography machines.
- 5.7 The cost-effectiveness analysis was performed using cancer reduction as the primary measure of benefit. The impact of

throughput on cost effectiveness was modelled using three different assumptions about the throughput of the EOS system. 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 throughput as computed radiography, 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 explore the impact on cost effectiveness of full use of the machine. If a machine that was fully used imaging the indicated conditions had been found to be cost effective, then further analysis would have been needed to determine whether a machine partially used for the indicated conditions and also used 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 system can take simultaneous PA and lateral images.

5.8 The base-case analysis showed the incremental cost-effectiveness ratio (ICER) to range from approximately £148,000 to over £15,000,000 per QALY gained depending on the indicated use. The width of this range is primarily because 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 per QALY gained (TA2) and from £47,000 to £351,000 per QALY gained (TA3).

5.9 Additional scenarios modelled included:

- earlier age for cancer diagnosis (55 years vs. the average age of diagnosis in the population for the cancers modelled)
- reduced discount rate for both costs and benefits (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 [BIER VII phase 2] vs. newer models from the Health Protection Agency)
- comparison with digital radiography (with digital radiography assumed to have a dose rate of two-thirds that of computed radiography).

5.10 None of these scenarios reduced the ICER to less than £30,000 using the throughput assumptions TA1 and TA2. The earlier age for cancer diagnosis or the alternative risk data reduced the ICER to less than £30,000 for scoliosis and Scheuermann's disease in adolescents for throughput assumption TA3.

5.11 Threshold analysis was performed to determine what level of additional benefits from imaging improvements would be required to reach levels that might normally be considered cost effective 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. Threshold analyses of QALY gains required to reach an ICER of £20,000 under the six additional scenarios listed above varied from less than 0.001 to over 700 depending on the scenario, the condition, and the throughput assumptions.

6 Considerations

- 6.1 The Diagnostics Advisory Committee was informed that the evidence suggests that the EOS system creates images with significant radiation dose reductions compared with other modalities. However, there was uncertainty about the overall impact of that benefit. The External Assessment Group explored one scenario in which cancers were averted at the same time as similar cancers not caused by radiation dose and one scenario in which cancer occurred at the earlier age of 55. The Committee understood that any cancers induced by radiation may occur even earlier, and averting these would result in increased QALYs. The Committee also heard that some rare conditions, such as congenital scoliosis, arising from complex genetic syndromes might make people more susceptible to radiation damage. However, because the numbers would be small this would not significantly affect the total QALYs gained from radiation dose reduction.
- 6.2 The Committee noted that the EOS system may provide throughput improvements because it takes simultaneous images in two planes, but no evidence was available to quantify these improvements.
- 6.3 The Committee noted that for the EOS system to be cost effective, benefits relating to the nature of the image need to translate into health benefits for patients. For example, the full body weight-bearing image generated by the EOS system should provide more accurate information, which might translate into an improved management strategy, and consequently into a health benefit.
- 6.4 On the basis of clinical advice, the Committee considered that significant benefits may accrue from imaging improvements and that better clinical decisions might be made as a result. The improvements include 3D imaging, simultaneous posteroanterior (PA) and lateral imaging, and whole body imaging in a single

image. Health outcome benefits could result from better decisions about surgery, in particular planning hip and knee replacements for which knowledge of the position of the pelvis can be important, and possibly managing rare skeletal conditions in children. Other health outcome benefits are possible. No evidence was available for the use of the EOS system for these purposes. Thus, the Committee considered further research into these benefits to be necessary and that use of the machine in a research setting to develop estimates of these benefits was warranted.

- 6.5 The Committee was unclear about the magnitude of any benefits of 3D imaging. No data were found to substantiate these benefits although clinical specialists advised the Committee that such benefits may exist. For example, curvature in multiple planes may more accurately predict worsening of scoliosis than simply measuring the Cobb angle.
- 6.6 The Committee did not consider that the EOS system would be a cost-effective use of NHS resources given the cost of the system and the magnitude of the benefits associated with radiation dose reduction and possible throughput improvements. Depending on how large these benefits prove to be, the level of benefit from imaging improvement needed to achieve cost effectiveness could be large because the EOS system is approximately four times the cost of conventional computed radiology.
- 6.7 The Committee noted that the conditions examined are not common enough to allow an EOS system to be fully utilised in most settings. Even adding the conditions not examined because of lack of evidence would not be likely to provide sufficient numbers for many of the machines that would be needed by the NHS. The EOS system can be used for purposes not included in the scope and there is limited evidence showing that despite reduced resolution compared with conventional systems the image quality is

comparable. The Committee considered that those people having imaging with the EOS system for purposes not considered in the scope might gain from the reduced radiation dose and the system might gain from throughput improvements, but the Committee considered it unlikely that for these uses there would be any benefits from imaging improvements. This would reduce the likelihood that the EOS system would represent a cost-effective use of NHS resources.

7 Implementation

- 7.1 NICE intends to develop tools, in association with relevant stakeholders, to help organisations put this guidance into practice.

8 Proposed recommendations for further research

- 8.1 Research is needed to establish whether there are health outcome benefits associated with imaging improvements with the use of the EOS system. Examples of such benefits might include reduced back pain or postural difficulties in people with scoliosis, or longer lasting and less painful joint replacements. Although research is appropriate for all the indications included in the scope, research into the use of the EOS system for planning hip and knee replacement is likely to be most useful. Joint replacement operations are more common than the other indications and changes in image quality are thought to be most likely to provide benefit to patients in this context.
- 8.2 Additional modelling is needed to confirm the benefit arising from radiation dose reduction. Additional work is needed to assess when the radiation-induced cancers actually occur and the impact of that timing on QALY levels.

8.3 Research is needed to determine whether and for which conditions, the 3D features of the EOS system provide benefit for treatment planning or diagnosis.

9 Equalities

No specific equality issues were identified during scoping or during the assessment or Committee meetings.

10 Related NICE guidance

There is no related NICE guidance.

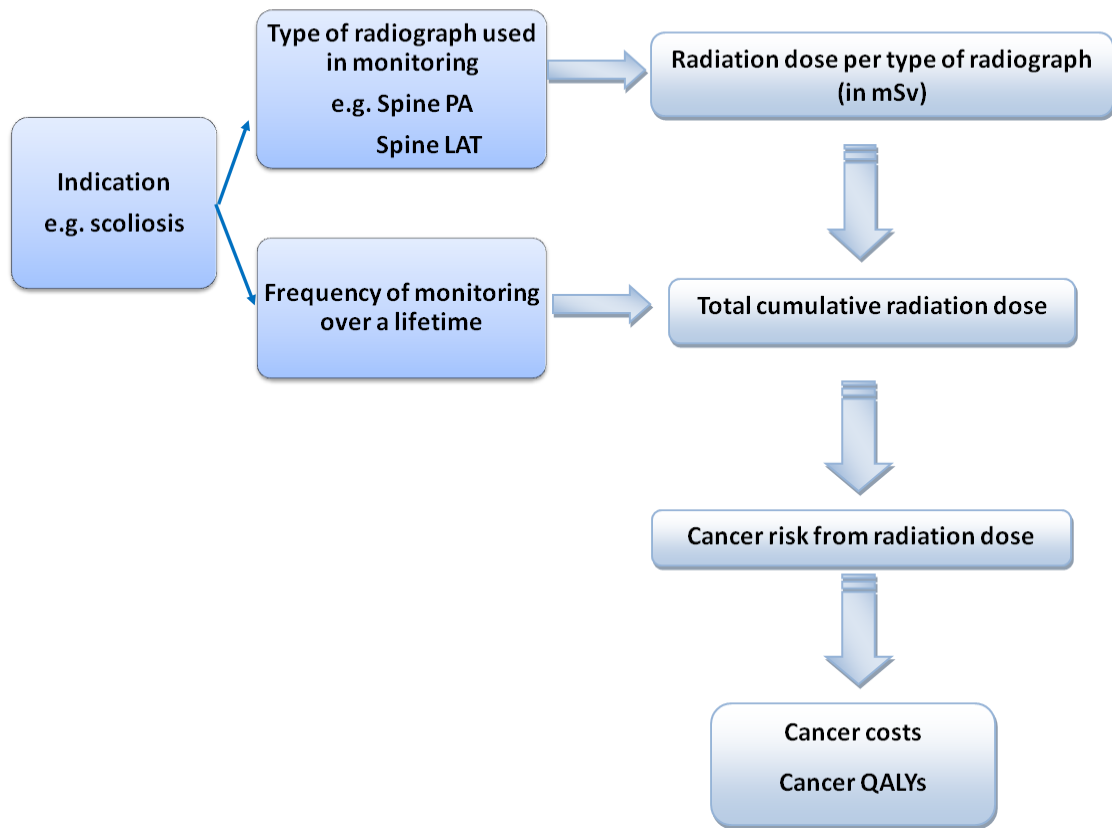
11 Review

No specific time for review has been set, but NICE will monitor improvements in the evidence base for the EOS system to determine when a review would be appropriate.

Adrian Newland
Chair, Diagnostics Advisory Committee

May 2011

Appendix A Schematic representation of the modelling approach



Appendix B: Diagnostics Advisory Committee members and NICE project team

A *Advisory Committee members*

The Diagnostics Advisory Committee is an independent Committee consisting of 22 standing members and additional specialist members. A list of the Committee members who participated in this assessment appears below.

Standing Committee members

Dr Trevor Cole

Consultant Clinical Geneticist, Birmingham Women's Hospital Foundation Trust

Dr Paul O Collinson

Consultant Chemical Pathologist, St George's Hospital

Professor Ian Cree

Director of Efficacy and Mechanisms Programme, NIHR Evaluation, Trials and Studies Coordinating Centre, University of Southampton

Dr Erika Denton

National Clinical Director for Imaging, Department of Health

Dr Simon Fleming

Consultant in Clinical Biochemistry and Metabolic Medicine, Royal Cornwall Hospital

Professor Elizabeth (Lisa) Hall

Professor of Analytical Biotechnology, Institute of Biotechnology, Department of Chemical Engineering and Biotechnology, University of Cambridge

Professor Chris Hyde

Professor of Public Health and Clinical Epidemiology, Peninsula College of Medicine and Dentistry

Professor Noor Kalsheker

Professor of Clinical Chemistry, Molecular Medical Sciences, University of Nottingham

Dr Mark Kroese

Consultant in Public Health Medicine, Peterborough Primary Care Trust and UK Genetic Testing Network

Professor Dietrich Mack

Professor of Medical Microbiology and Infectious Disease, School of Medicine, Swansea University

Professor Adrian Newland (Chair)

Consultant Haematologist, Barts and the London NHS Trust

Dr Richard Nicholas

Consultant Neurologist, Heatherwood and Wexham Park Hospital, Imperial Healthcare Trust

Ms Margaret Ogden

Lay member

Dr Diego Ossa

Global Head, Health Economic and Outcomes Research, Novartis Molecular Diagnostics

Mr Stuart Saw

Director of Finance and Procurement, Tower Hamlets Primary Care Trust

Dr Nick Summerton

General Practitioner, East Yorkshire

Dr Steve Thomas

Senior Lecturer and Consultant Radiologist, University of Sheffield

Mr Paul Weinberger

Managing Director, Diasolve Ltd, Pewsley, Wiltshire

National Institute for Health and Clinical Excellence

Mr Christopher Wiltsher

Lay member

Specialist Committee members

Dr Stephanie Clark

Chair, Scoliosis Association (UK)

Dr Peter Dangerfield

Director of Year 1 MBChB, Liverpool University

Professor Jeremy Fairbank

Professor of Spinal Surgery and Consultant Orthopaedic Surgeon, Nuffield Orthopaedic Centre, Oxford

Dr David Grier

Consultant Paediatric Radiologist, Bristol Royal Hospital for Children

Mr Eric Hughes

Diagnostics Manager, RJA Orthopaedic Hospital, Oswestry

Dr James Rankine

Consultant Musculoskeletal Radiologist, Leeds General Infirmary

B NICE project team

Each diagnostics assessment is assigned to a team consisting of one Technical Analyst (who acts as the topic lead), a Technical Adviser and a Project Manager.

Dr Hanan Bell

Topic Lead and Technical Adviser

Mr Jackson Lynn

Project Manager

Appendix C: Sources of evidence considered by the Committee

- A. The diagnostics assessment report for this assessment was prepared by the External Assessment Group (EAG): Centre for Reviews and Dissemination/Centre for Health Economics at the University of York.
- McKenna C, Wade R, Faria R, Yang H et al. (March 2011). EOS 2D/3D X-ray Imaging System. York: NHS Centre for Reviews and Dissemination and Centre for Health Economics, University of York.
- B. The following organisations accepted the invitation to participate in this assessment as stakeholders. They were invited to attend the scoping workshop and to comment on the diagnostics assessment report and the diagnostics consultation document (this document).
- I Manufacturers/sponsors:
- EOS Imaging (previously known as BioSpace Med)
 - GE Healthcare
- II Professional/specialist and patient/carer groups:
- Scoliosis Association UK
 - Limbless Association
 - British Institute of Radiology
 - Royal College of Paediatrics and Child Health
 - Society and the College of Radiographers
 - UK National Screening Committee
 - Royal Orthopaedic Hospital NHS Foundation Trust
 - Health Economics Research Group